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ENVIRONMENTAL REMEDIATION AT DA NANG AIRPORT

Environmental Assessment

in Compliance with 22 CFR 216

June 2010

Environmental Remediation at Da Nang Airport

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Technical analysis for this report was prepared under USAID Task Order #1, EDH-I-00-08-00023-00 by CDM International, Inc.

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ACRONYMS AND ABBREVIATIONS

10-80 Division	10-80 Division of the Ministry of Health
ADB	Asian Development Bank
ADS	Automated Directives System
Airport	Da Nang Airport
ATSDR	United States Agency for Toxic Substances and Disease Registry
BEM	BEM Systems, Inc.
BEO	Bureau Environmental Officer
bgl	below ground level
BOD	biological oxygen demand
°C	degrees Celsius
CAAV	Civil Aviation Agency of Vietnam
CDM	CDM International, Inc.
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act of 1980
CFR	United States Code of Federal Regulations
CH_4	methane
CO_2	carbon dioxide
CO_{2e}	carbon dioxide equivalent
COD	chemical oxygen demand
COPC	contaminant of potential concern
cm	centimeter
d	day
DOD	United States Department of Defense
DQO	data quality objective
EA	environmental assessment
EIA	environmental impact assessment
EMMP	environmental mitigation and monitoring plan
ESS	environmental scoping statement
°F	degrees Fahrenheit
FAA	United States Foreign Assistance Act
FAR	United States Federal Acquisition Regulation
FDA	United States Food and Drug Administration
FS	feasibility study
g	gram
GAC	granular activated carbon
GCL	geosynthetic clay liner
GCMS	gas chromatography – mass spectrometry
GHG	greenhouse gas
GSO	General Statistics Office
GVN	Government of Vietnam

ha	hectare
Hatfield	Hatfield Consultants
HDPE	high-density polyethylene
HMU	Hanoi Medical University
hr	hour
JAC	Joint Advisory Committee
IEE	Initial Environmental Examination
IOM	Institute of Medicine
IPTD	in-pile thermal desorption
ISTD	in-situ thermal desorption
kg bw	kilogram body weight
km	kilometer
km^2	square kilometer
kwh	kilowatt hour
LLDPE	linear low-density polyethylene
m	meter
m^2	square meter
m^3	cubic meter
MAC	Middle Airports Corporation
MCL	maximum contaminant level
MDL	method detection limit
MLA	former Mixing and Loading Area
mm	millimeter
MOD	Ministry of Defense
MoNRE	Ministry of Natural Resources and Environment
MOU	Memorandum of Understanding
N_2O	nitrous oxide
NGO	non-governmental organization
NIP	National Implementation Plan
O&M	operation and maintenance
Office 33	Office of the National Steering Committee 33
OSHA	Occupational Health and Safety Administration
PAH	polycyclic aromatic hydrocarbon
PCB	polychlorinated biphenyl
PCDD	polychlorinated dibenzo-p-dioxin
PCDF	polychlorinated dibenzofuran
pg	picogram
PIRA	former Pacer Ivy Re-Drumming Area
PISA	former Pacer Ivy Storage Area
PPE	personal protective equipment
ppm	parts per million
ppt	parts per trillion
PRG	Preliminary Remediation Goal

the Project	Environmental Remediation at Da Nang Airport: Assessments and Engineering Designs and Plans for Dioxin Contamination
RCRA	Resource Conservation and Recovery Act
RI	remedial investigation
ROD	Record of Decision
SA	former Storage Area
SAP	sampling and analysis plan
SARA	Superfund Amendments and Reauthorization Act of 1986
SS	suspended solids
t	ton (metric)
TCDD	tetrachlorodibenzo-p-dioxin
TCVN	Vietnam National Standard
TEQ	toxicity equivalent
TOC	total organic carbon
UNDP	United Nations Development Programme
U.S.	United States
USAID	United States Agency for International Development
U.S.C.	United States Code
USDA	United States Department of Agriculture
USEPA	United States Environmental Protection Agency
USG	United States Government
UXO	unexploded ordnance
VAST	Vietnam Academy of Science Technology
VAT	value added tax
VOC	volatile organic compound
VRTC	Vietnam-Russia Tropical Centre
WHO	World Health Organization
yr	year

Section 1. Introduction

1.1. USAID Environmental Health and Remediation Program

The airports at Da Nang, Bien Hoa, and Phu Cat have been referred to as dioxin "hotspots" due to high dioxin concentrations remaining decades after large volumes of Agent Orange and other defoliants were handled at these sites. The Government of Vietnam (GVN) has requested assistance from the United States (U.S.) to remediate dioxin-contaminated soil and sediment at Da Nang, and from the United Nations Development Program (UNDP) at Bien Hoa.

In 2007, the U.S. Congress appropriated $3 million to carry out Agent Orange/dioxin health and remediation activities in Vietnam. The U.S. Congress has since appropriated an additional $3 million for each year in 2009 and 2010. Approximately one-third of the total $9 million has been programmed to support health and social services to people with disabilities of the Greater Da Nang area. The remaining two-thirds have been programmed for environmental remediation for Da Nang Airport (Airport). Within the U.S. Government (USG), the U.S. Agency for International Development (USAID) was designated as the lead agency to implement assistance programs in Vietnam, in cooperation with the U.S. Department of State, the U.S. Department of Health and Human Services, the U.S. Department of Defense (DOD), and the U.S. Environmental Protection Agency (USEPA). Assistance to Vietnam is part of a multilateral effort requiring the closest possible cooperation and coordination with international agencies, other donors, non-governmental organizations (NGOs), and public and private foundations.

In 2008, USAID launched its environmental health and remediation program. It awarded a cooperative agreement to East Meets West Foundation to provide health, rehabilitation, and education services for people with disabilities of Da Nang. Vietnam Assistance to the Handicapped was granted an award to provide capacity building in rehabilitation medicine and to provide health, rehabilitation and social services in three Da Nang Districts. Save the Children was awarded a cooperative agreement to provide training and livelihood development support to people with disabilities of Da Nang. These activities started in October 2008 and will continue through September 2011.

In October 2008, USAID awarded a contract to CDM International, Inc. (CDM) to carry out the project, "Environmental Remediation at Da Nang Airport: Assessments and Engineering Designs and Plans for Dioxin Contamination" (the Project). Under this contract, CDM is to prepare an environmental assessment (EA) for dioxin remediation at the Airport. CDM will develop engineering designs for the remedial technology alternative selected through the EA process and develop a remediation workplan for design implementation. This workplan will detail the process steps associated with the remediation activity and identify specific engineering controls and protective measures. This will inform the final Environmental Management and Monitoring Plan (EMMP) which will be included as part of bid documents for the procurement of goods and services for remedial action. In conjunction with development of the remediation workplan, CDM will conduct a gender assessment that examines functional labor categories associated with each step of the remediation process to determine whether gender-specific measures are necessary. The gender assessment will also determine project beneficiaries, by gender, to track longer term project benefits. Using engineering designs, the remediation workplan, and gender assessment as the point of departure, CDM will prepare a Health and Safety Plan, Health and Safety Training Plan, and a Sampling and Analysis and Monitoring Plan to be implemented during the remedial action phase.

1.2. Coordination with Other USG Agencies and Donors on Environmental Remediation in Vietnam

Since 2000, USG agencies have engaged with their Vietnamese counterparts to work on the complex Agent Orange/dioxin issue, notably through the bilateral Joint Advisory Committee (JAC) on Agent Orange/dioxin that was created to coordinate collaborative research on this issue. The JAC, co-chaired by the USEPA and the GVN's Ministry of Natural Resources and Environment (MoNRE), has met four times since its inception. USEPA has supported joint research on dioxin analysis and workshops on methodologies for dioxin screening, remediation, and site characterization. Elements of this work included a pre-feasibility study (FS) for dioxin remediation at the Airport and design and implementation of a 6-month treatability study for bioremediation treatment of dioxin with funding from the Ford Foundation.

In 1999, the Prime Minister of Vietnam issued Decision 33, which established the National Steering Committee 33 and assigned it responsibility for coordination of dioxin-related matters and for development of short-, medium-, and long-term dioxin implementation and research plans. The MoNRE Minister chairs the National Steering Committee, and its multi-sectoral membership includes participants from the Academy of Science and Technology, the Ministry of Defense (MOD), the Ministry of Foreign Affairs, the Ministry of Health, the Ministry of Planning and Investment, the Ministry of Finance, the Ministry of Science and Technology, the Ministry of Justice, the Ministry of Labor, and the Office of Government. The Office of the National Steering Committee 33 (Office 33) was established under MoNRE as the implementing arm of the National Steering Committee 33. Office 33 is the implementation counterpart of USAID on dioxin-related activities. In December 2009, USAID and MoNRE, through Office 33, entered into a Memorandum of Understanding (MOU) regarding implementation of USAID's Environmental Health and Remediation Program. The MOU established the partnership framework for program implementation. Preparation of the EA is one activity that is being implemented under the MOU.

In addition to USG agencies, NGOs such as the Ford Foundation and the Bill and Melinda Gates Foundation have played important roles in dioxin remediation efforts over the past several years. The Ford Foundation has been instrumental in the identification of dioxin hotspots in Vietnam The Ford Foundation also provided financial support for detailed assessments of dioxin contamination at the Airport and surrounding area in 2006 and 2009. In 2008, in conjunction with the USG, it financed interim mitigation measures to help reduce potential exposure of residents and workers at the Airport, which included: a ban on fishing and agricultural activities, construction of a barrier wall along the northern boundary of the Airport, temporary capping of the former Mixing and Loading Area (MLA), and construction of a sediment filtration system upstream of Sen Lake. The Bill and Melinda Gates Foundation and

Atlantic Philanthropies are presently financing a $6 million environmental laboratory that, when completed, will provide Vietnam with high-resolution dioxin analysis capability.

UNDP has been another significant contributor on this issue. UNDP and Office 33 co-sponsored a workshop in February 2009 to build consensus among the GVN and donors on a national-level approach for dioxin remediation. Conference participants concluded that dioxin concentrations at the three former airbases of Da Nang, Bien Hoa, and Phu Cat were present in levels high enough to warrant significant investments in remediation. Participants agreed to a short-term goal of dioxin containment to eliminate the possibility of human exposure and a longer-term goal of dioxin destruction. They also agreed to share lessons learned as information evolves on remediation processes at the key dioxin hotspot sites of Da Nang, Bien Hoa, and Phu Cat. UNDP also conducted soil and sediment sampling investigations at Bien Hoa and Phu Cat in 2008, which provided important information for dioxin characterization at these sites.[1]

In August 2009, the United Nation's Global Environment Facility approved the $5 million "Vietnam Environmental Remediation of Dioxin Contaminated Hotspots" project. UNDP and Office 33 are co-implementers of the project. The purpose of the project is to further delineate hotspot areas in Bien Hoa, to evaluate appropriate treatment technologies for dioxin destruction, and to build capacity of Vietnamese counterparts to develop an environmental remediation plan for Bien Hoa. UNDP's program for Bien Hoa is following a similar track to that which USAID has adopted at Da Nang: to conduct an environmental impact assessment and develop designs for the best approach to remove dioxin from hotspots in these areas. UNDP's program also provides for an overarching umbrella framework that facilitates donor coordination among those working on environmental remediation of dioxin in Vietnam.

[1] VRTC/Hatfield 2009.

Section 2. Purpose

2.1. Purpose and Need for the Proposed Action

The Da Nang Airport is located within Da Nang City within a densely populated urban area. Three of the municipality's seven districts are adjacent to the Airport: Thanh Khe, Hai Chau, and Cam Le Districts, which have a combined population of approximately 436,000. The Airport facility is used by both the MOD and the Civil Aviation Agency of Vietnam (CAAV). It is an international airport, with flights arriving from and departing to cities such as Bangkok, Vientiane, Hong Kong, Phnom Penh, and Taipei. The GVN plans to expand the Airport facilities and runways, and construction has already commenced in some areas.

2, 3, 7, 8-tetrachlorodibenzo-p-dioxin (dioxin) is a toxic chemical which is associated with a range of health effects.[2] Studies conducted to date show that dioxin concentrations within hotspot areas of the Airport substantially exceed international standards and Vietnamese standards for dioxin. [3] Uncontrolled access to contaminated areas of the Airport and transport of contaminated soils and sediments resulted in human exposures primarily through agricultural activities and fish consumption. Although the human exposure pathway was largely interrupted as a result of 2008 interim containment measures, these measures are not permanent. Therefore, the GVN has requested U.S. assistance with environmental remediation at this site.

To eliminate further human and wildlife exposure to dioxin at this site, the GVN initially proposed that, as the next step toward remediation at the Airport, contaminated soil and sediment be removed and contained at a secure landfill to be constructed at the southern end of the base. A containment program would involve removal of dioxin from a wetland ecosystem located in close proximity to residential areas, and construction of a secure onsite landfill further from residential areas at the southern end of the airport. However, the EA has identified an environmentally safer, more effective alternative, which has been selected as the preferred project alternative.

2.2. Threshold Determination

On May 26, 2009, the Asia Bureau Environmental Officer (BEO) approved the Initial Environmental Examination (IEE) for "Environmental Remediation at Da Nang Airport." This approval included a positive Threshold Determination that pertains to engineering design and remedial action activities, because such activities may pose a significant risk to the environment. CDM has been awarded a contract to prepare assessments and engineering designs and plans for dioxin remediation at the Airport. Therefore, an EA must be completed and approved by the Asia BEO before these USAID-financed activities can proceed.

The purpose of this EA is to fulfill requirements for environmental remediation at the Airport in accordance with Title 22 U.S. Code [U.S.C.] of Federal Regulations [CFR] Chapter 216 (22 CFR 216.6[a]) which states:

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[2] ATSDR 1998.
[3] Hatfield/Office 33 2007 and Hatfield/Office 33 2009.

> "The purpose of the Environmental Assessment is to provide Agency and host country decision makers with a full discussion of significant environmental effects of a proposed action. It includes alternatives which would avoid or minimize adverse effects or enhance the quality of the environment so that the expected benefits of development objectives can be weighed against any adverse impacts upon the human environment or any irreversible or irretrievable commitment of resources."

This EA provides the basis for selection of the preferred project alternative and includes an EMMP for the significant impacts that are identified through the EA process. Furthermore, design documents, remediation work plan, health and safety plan, and a health and safety training plan will be developed for the preferred alternative. If additional potentially significant impacts on the environment are identified during the design process, the EA will be amended to reflect these. Furthermore, EMMPs will be developed for each implementing mechanism identified for the remedial action phase, based on the remediation workplan(s), health and safety plan(s), health and safety training plan(s), and sampling and analysis monitoring plans that are to be prepared under the engineering planning and design activity. These EMMPs will be included with each procurement action related to this EA.

Vietnamese environmental law and its environmental compliance regulations also require an Environmental Impact Assessment (EIA) for dioxin remediation activities. While USAID's EA process requires consideration of project alternatives, the GVN EIA procedures are based on a single project proposal, and require submission of feasibility analyses, designs, and cost estimates. Therefore, the USAID EA represents a first step in the GVN EIA process. After approval of the EA, the EIA will be prepared and submitted to the GVN along with preliminary designs, plans, specifications, and cost estimates.

2.3. Environmental Scoping Statement

In support of the EA, an Environmental Scoping Statement (ESS) was prepared for the Project in compliance with 22 CFR 216, which USAID's Asia BEO approved in February 2010. Scoping sessions were held with stakeholders as part of this process in October 2009 which identified the need to explore a range of viable alternatives for dioxin containment at the Airport. They also help to identify the environmental issues that the EA must address. As a result of field visits and scoping sessions, the ESS identified the following environmental issues to be addressed in the EA:

- Human health risks associated with cleanup of unexploded ordnance and munitions
- Surface water hydrology
- Surface water quality
- Groundwater
- Air quality and indirect effects on human health

- Greenhouse gases
- Terrestrial ecosystems and biodiversity
- Wetlands, aquatic ecosystems, and aquatic biodiversity
- Noise
- Natural or depletable resources

2.4. Stakeholder Engagement and Host Government Consultations

During the eight month period (October 2009-May 2010) that the EA was under development, USAID and it contractors held 14 meetings/site visits/workshops to discuss various aspects of the EA process and technical matters. A list of these is provided below.

- Initial Field Visit to Da Nang Airport – October 14, 2009 (Da, Nang)
- Workshop to Reconcile USAID's Environmental Compliance Procedures with GVN's Environmental Impact Procedures – October 15, 2009 (Hanoi)
- Workshop to Discuss Bioremediation Technology – December 9, 2009 (Hanoi)
- Presentation of Da Nang Environmental Sampling Plan to USEPA – December 10, 2009 (Hanoi)
- Field Visit to Dioxin Sites of Da Nang Airport – December 14, 2009 (Da Nang)
- Workshop Discussion with Da Nang Stakeholders – December 15, 2009 (Da Nang)
- Assessment and Engineering Planning and Design Workplan Presentation (including discussion of how the EA process is necessary for designs and plans to proceed) – December 16, 2009 (Hanoi)
- Presentation of Initial EA findings to USAID, USEPA, and U.S. State Department – January 5, 2010 (Washington, DC)
- EA Progress Report Workshop – January 29, 2010 (Hanoi)
- Draft EA Presentation to USAID, USEPA, and U.S. State Department – February 26, 2010 (Hanoi)
- Draft EA Presentation to Hanoi Stakeholders – March 16, 2010 (Hanoi)
- Draft EA Presentation to Da Nang Stakeholders – March 18, 2010 (Da Nang)

- Technical Workshop on In-Situ Thermal Desorption/In-Pile Thermal Desorption (ISTD/IPTD) – May 18, 2010 (Hanoi)
- Field Visit and Technical Workshop on ISTD/IPTD and 2010 Sampling Results (including estimates of extent of contamination) – May 20, 2010 (Da Nang)

Hanoi stakeholders participating in workshops and meetings during this period included the Science Advisory Panel of National Committee 33, Office 33, MoNRE Department of Pollution Management, MoNRE Department of Environmental Impact Assessments and Appraisal, and MoNRE Department of Hazardous Waste Management. MOD representation included Agency for Science, Technology and Environment, Vietnam-Russia Tropical Centre (VRTC), ADCC Company Air Force Command, High Command of Chemical Arms, High Command of Engineers Arms, Air Force and Air Defense Services, and Strategy Department. The CAAV was also represented. Stakeholders from the Da Nang area included representatives from the Army Corp 372 (Da Nang Airbase), the Middle Airports Corporation (MAC), and Da Nang Power Company. Representatives from the People's Committee of Hai Chau District, the People's Committee of Thanh Khe District and the People's Committee of Cam Le District also participated. As a result of these meetings, close coordination on technical matters was achieved. Furthermore, the meetings resulted in significant information sharing that enabled a much more concise assessment than might not have otherwise been the case. The ongoing exchange enabled the high level of consensus reached on the results and findings of the EA. In addition to the ongoing exchange with host government counterparts, USAID/Vietnam regularly consulted with USG stakeholders, including the U.S. Embassy, U.S. State Department, USAID/Washington, and USEPA.

2.5. Legal and Regulatory Considerations

2.5.1. VIETNAM

The GVN's proposed action for dioxin remediation at Da Nang Airport was to remove dioxin contaminated soil and sediment and dispose of it in a secure onsite landfill. The GVN has established a national cleanup standard for dioxin of 1,000 parts per trillion (ppt) toxicity equivalent (TEQ) in soil and 150 ppt TEQ in sediment.[4] The EA adopts GVN's national dioxin standards in determining the extent and depth of contamination to be addressed and in determining the treatment level than must be attained to achieve a final remedy.

2.5.2. UNITED STATES

Dioxin remediation is particularly complex due to the stringent cleanup goals (normally measured in the ppt range) that are required for protection of public health and the environment. The 1984 Hazardous and Solid Waste Amendments to the Resource Conservation and Recovery Act (RCRA) banned land disposal of dioxin contaminated waste.[5] Consequently, if dioxin is to be contained it must be in a secure landfill designed, constructed, and permitted in accordance with 40 CFR 264 Hazardous Waste Disposal Regulations.

[4] TCVN 8183: 2009.

[5] 40 CFR 260-280.

The Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) as amended by the Superfund Amendments and Reauthorization Act of 1986 (SARA),[6] is the U.S. federal law designed to cleanup abandoned hazardous waste sites and is commonly known as Superfund. CERCLA, as amended by SARA, directs USEPA to select a permanent remedy or treatment whenever possible for Superfund hazardous waste sites.[7] Containing waste in a secure onsite landfill is the least preferred alternative, and is generally only considered when a destruction remedy is determined to be infeasible, for example, due to community objections to the selected treatment option or due to funding limitations.[8]

The 2007 Annual Status Report for Treatment Technologies for Site Clean Ups[9] states that from 1982 to 2005, approximately 3,000 Records of Decision (RODs) and ROD Amendments were signed to select the remedies for Superfund hazardous waste sites. Of those, 56% selected treatment remedies (some [16%] included a containment component of the remedy), 17% selected containment remedies with no treatment, 12% selected other remedies including long term monitoring and/or institutional controls (e.g., land use restrictions), and the remaining 15% determined no further action was required. The report does not provide information on which of the sites address dioxin contamination, the volume of contaminated material, or the cost of the remedies. However, it provides a benchmark to relate the remedies under evaluation for the Airport to remedies selected for Superfund hazardous waste sites in the U.S. USEPA's Annual Status Report Remediation Database lists 19 dioxin/furan contaminated sites for which remediation of soil is operational or has been completed under the Superfund program[10]. As shown in Table 1, incineration was the selected remedy for 13 of the 19 dioxin/furan sites (10 offsite and 3 onsite). Solidification/stabilization was applied at two sites, ex situ thermal desorption was applied at two sites, in situ thermally enhanced recovery was applied at one site, and bioventing was applied at one site. Overall, incineration is one of the most common ex situ treatment technologies for all hazardous waste sites; however, in recent years the number of RODs that include incineration have declined. For example, 29% of ex situ treatment remedies between 1982 and 2002 included incineration, but this percentage declined to 6% during the period from 2002 to 2005.[11]

According to USEPA, "remediation technologies for the cleanup of dioxin-contaminated soils and sediments are still being developed, and many of the accepted techniques rely on thermal destruction, though physical, chemical, and biological technologies show promise."[12] Dioxin site cleanups in the U.S. have historically been shown to be technically complex with remediation activities for a single site taking at least 10 years from site discovery through final remedial action.

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[6] 42 U.S.C. 9601 et seq.
[7] Section 121[b] of SARA.
[8] USEPA 2007.
[9] USEPA 2007.
[10] USEPA Office of Solid Waste and Emergency Response Office of Innovative Technologies Annual Status Report Remediation Database: http://cfpub.epa.gov/asr/.

[11] USEPA 2007.
[12] USEPA Office of Solid Waste and Emergency Response Office of Technology Innovation: http://www.clu-in.org/contaminantfocus/default.focus/sec/Dioxins/cat/Overview/.

TABLE 1. DIOXIN CONTAMINATED SITES IN THE UNITED STATES FOR WHICH REMEDIAL ACTION WAS COMPLETED UNDER THE SUPERFUND PROGRAM[1]

	Site Name	ROD Date	Technology	State
1	Woodbury Chemical	1985	Incineration (offsite)	Colorado
2	Baird & McGuire	1986	Incineration (onsite)	Massachusetts
3	Minker/Stout/Romaine Creek	1988	Incineration (offsite)	Missouri
4	Selma Pressure Treating	1988	Solidification/Stabilization	California
5	Syntex Facility	1988	Incineration (offsite)	Missouri
6	Times Beach Site	1988	Incineration (onsite)	Missouri
7	Jacksonville Municipal Landfill	1990	Incineration (offsite)	Arkansas
8	Pristine, Inc.	1990	Thermal Desorption (ex situ)	Ohio
9	Rogers Road Municipal Landfill	1990	Incineration (offsite)	Arkansas
10	Shenandoah Stables	1990	Incineration (offsite)	Missouri
11	Vertac, Inc.	1990	Incineration (onsite)	Arkansas
12	Eastern Diversified Metals	1991	Incineration (offsite)	Pennsylvania
13	Ellisville Site	1991	Incineration (offsite)	Missouri
14	Koppers Co., Inc. (Morrisville Plant)	1992	Incineration (offsite)	North Carolina
15	Southern California Edison, Visalia Pole Yard	1994	Bioventing	California
16	Arkwood Inc.	1995	Incineration (offsite)	Arkansas
17	Standard Steel and Metal Salvage Yard (United States Department of Transportation)	1996	Solidification/Stabilization	Alaska
18	Coleman-Evans Wood Preserving	1997	Thermal Desorption (ex situ)	Florida
19	Wyckoff/Eagle Harbor	2000	Thermally Enhanced Recovery (in situ)	Washington

Notes:
1 – USEPA Office of Solid Waste and Emergency Response Office of Innovative Technologies Annual Status Report Remediation Database: http://cfpub.epa.gov/asr/search.cfm. Database search criteria: Contaminant – "dioxins and furans"; Media – "soil (ex situ)" and "soil (in situ)"; Status – "operational" and "completed".

Table 2 provides site profile characteristics of selected dioxin sites in the U.S. and Vietnam. The U.S. sites listed here include Times Beach (Missouri), Baird and McGuire (Massachusetts), Vertac (Arkansas), and the Dow Chemical site (Michigan). The sites in Vietnam include Bien Hoa, Da Nang, and Phu Cat airbases. Site contamination of the U.S. and Vietnam sites are similar, volume of contaminated material and cleanup goals. Lessons learned from dioxin site cleanups in the U.S. will provide a valuable contribution to dioxin remediation at Da Nang.

TABLE 2. CHARACTERISTICS OF SELECTED DIOXIN CONTAMINATED SITES IN THE UNITED STATES AND VIETNAM

Site	Source	Maximum Dioxin Concentr-ation (ppt)	Clean Up Goal	Material	Volume (Tons)	Treatment Technology	Cost (U.S. Dollars)	RI/FS	ROD	Remedial Action End Date
Times Beach (Missouri)[1]	Hexachlorophene Production Waste Oil used for road dust control throughout Missouri	1,800,000	1,000 ppt for surface soils in residential settings; 10 ppt for soils above a depth of 1 foot; 20,000 ppt in commercial and industrial settings	Soil and Debris	265,000	On Site Rotary Kiln Incineration	110,000,000	1984	1995	1997
Baird and McGuire (Holbrook, Massachusetts)[1]	Land Disposal of chemical production wastes	270,000	None (Technology Based)	Soil and Sediment	214,000	On Site Rotary Kiln Incineration	133,000,000	1986	1986	1996
Vertac (Jackson, Arkansas)[1]	Herbicide Production	400,000	1 in a million lifetime risk of cancer for a 70 year exposure	Waste and Soil	10,831	On Site Rotary Kiln Incineration	31,700,000	1978	1990	1994
Dow Chemical Site: Tittabawasee and Saginaw Rivers (Midland, Michigan)[2]	Chemical Production Wastewater Discharge into surface water	1,600,000	90 ppt	Soil and Sediment	83,000					
Da Nang Airport (Vietnam)	Herbicide Use	365,000	1000 ppt soil/150 ppt sediment	Soil and Sediment	93,000 (estimate)					
Bien Hoa Airbase (Vietnam)[3]	Herbicide Use	409,818	1000 ppt soil/150 ppt sediment	Soil and Sediment	150,000 (estimate)	Landfill and bioremediation				
Phu Cat (Vietnam)[3]	Herbicide Use	238,000	1000 ppt soil/150 ppt sediment	Soil and Sediment	3,450 (estimate)					

Notes:
1 – USEPA Office Technology Innovation. 2005. EPA-542-R-05-006. http://www.clu-in.org/pops.
2 – USEPA Region 5 Cleanup Sites. http://www.epa.gov/region5/sites/dowchemical/.
3 – UNDP 2009a.

To ensure that the environmental remediation activities for the Airport are consistent with best standards and practice, USAID will, to the extent feasible, follow processes and approaches used for dioxin site remediation in the U.S. The assessment, design, and remedy implementation process USAID is following for the Airport is similar to the Superfund process, which begins with site discovery and preliminary investigation (similar to the results achieved through the Ford Foundation investigations conducted between 2006 and 2009).[13] This is followed by a Remedial Investigation (RI), which determines the nature and extent of contamination and the risk to public health and the environment. USAID conducted sampling in 2010 to build upon data collected in previous investigations and refine estimates of extent of contamination and volume of contaminated materials requiring treatment. Under Superfund, a FS is then conducted to evaluate remedial alternatives. Similarly, this EA provides an evaluation of four remedial alternatives for the Airport. In the Superfund program, USEPA issues a ROD to identify the cleanup goals and selected remedy for the site; a Remedial Design is then developed for the selected remedial alternative, and finally, a Remedial Action is conducted to implement the design and to cleanup the contamination. Following approval of this EA, which provides the evaluation and selection of the Airport remedial action, USAID will prepare engineering designs and specifications and develop a remediation workplan to support remedial action implementation.

2.5.3. CONSIDERATION OF REQUIREMENTS OF BOTH COUNTRIES

In preparing the EA, USAID considered the site context and the legal and regulatory context of both countries. The following laws and regulations were identified as having potential applicability either to the EA, or to the remediation of dioxin contamination at the Airport; this list is not comprehensive.

<u>Laws and Regulations</u>

- U.S. Foreign Assistance Act (FAA) Section 117 and 22 CFR 216, Automated Directive System (ADS) 201.5 and 204 – Environmental Compliance
- FAA 611(a)(1) – Adequate Planning
- U.S. Brooks Act and U.S. Federal Acquisition Regulation (FAR) Part 36--Engineering Integrity
- USAID ADS 201.3.9.3--Gender Considerations
- Vietnamese Construction Regulation Standard Article 3.3
- Viet Nam Labor Code, Article 113 of Chapter X – Gender Restrictions on Employment at Hazardous Waste Sites
- Vietnam National Law on Environmental Protection: No. 52/2005/QH11
- Vietnam National Standard (TCVN) 8183: 2009--Dioxin Standard for Soil and Sediment

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[13] Hatfield/Office 33 2007 and Hatfield/Office 33 2009.

- Vietnam Law on Gender Equality Article 13, Section 1, 3a
- Vietnam Law on Construction No. 16-2003-QH11.
- Vietnam Decree No 68/2005/ND-CP dated 20/5/2005 and Government Circular No. 12/2006/TT-BCN guiding the implementation of the Decree stipulate that unsafe chemicals must be treated appropriately.
- Vietnam Announcement No 69/2002 of the Political Bureau directs the Government to strengthen international cooperation in preventing and overcoming consequences of the use of toxic chemicals in the War.
- Vietnam Decision 155/1999/QD-TTg of the Prime Minister of the Government on promulgating regulation of hazardous waste management.
- Vietnam Decision No 64/2003/QD-TTg of the Prime Minister of the Government approving the plan for thoroughly handling establishments which cause serious environmental pollution.
- Vietnam Decision No. 67/2004/QD-TTg dated 27 April 2004 of the Prime Minister regarding the approval of the Action Plan for the Period of 2004-2010 in Overcoming Consequences of Toxic Chemicals
- Vietnam Decision of the Prime Minister No 184/2006/QD-TTg (8/2006) approving the National Implementation Plan (NIP) of the Stockholm Convention on Persistent Organic Pollutants.[14]

Guidance

- U.S. Hazardous Waste Clean Up Process
- U.S. Occupational Health and Safety Administration(OSHA) Standards—29 CFR 1910—for health and safety (monitoring activity)
- 40 CFR 264 Hazardous Waste Disposal Regulations
- USEPA. Draft Recommended Interim Preliminary remediation Goals for Dioxin in Soil at CERCLA and RCRA Sites. December 30, 2009.
- Vietnam Circular No. 05/2008/TT-BTNM--Guide to Strategic Environmental Assessment, Environmental Impact Assessment, and Environmental Protection Commitment
- Vietnam Decree No. 21/2008/ND-CP-- Amending and Supplementing a Number of Articles of Government Decree No. 80/2006/ND-CP, Detail and Guide to the Implementation of a Number of Articles of the Law on Environmental Protection

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[14] UNDP 2009a.

- Vietnam Decree No. 80/2006/ND-CP--Detail and Guide to the Implementation of a Number of Articles of the Law on Environmental Protection
- Vietnam Decision No. 60/2002/QD BKHCNMT, guidance for the design of hazardous waste landfills.[15]

[15] UNDP 2009a.

Section 3. Summary

3.1. Project Area

The Da Nang City population is approximately 825,000, consisting of 401,235 males and 420,943 females, with an average population density of about 640 persons/ square kilometer (km^2). Hai Chau, Thanh Khe and Cam Le Districts are located adjacent to the airport. Hai Chau District includes 13 wards, and its population of 196,842 is the largest of the three districts. It has a population density of 92 people/ hectare (ha). Thanh Khe District, located between the airport property and Da Nang Bay, includes 10 wards. It has a population of 169,268, with a population density of 181/people/ha. Cam Le District includes 6 wards. It has a population of 70,052, with a population density of 21 people/ha.[16]

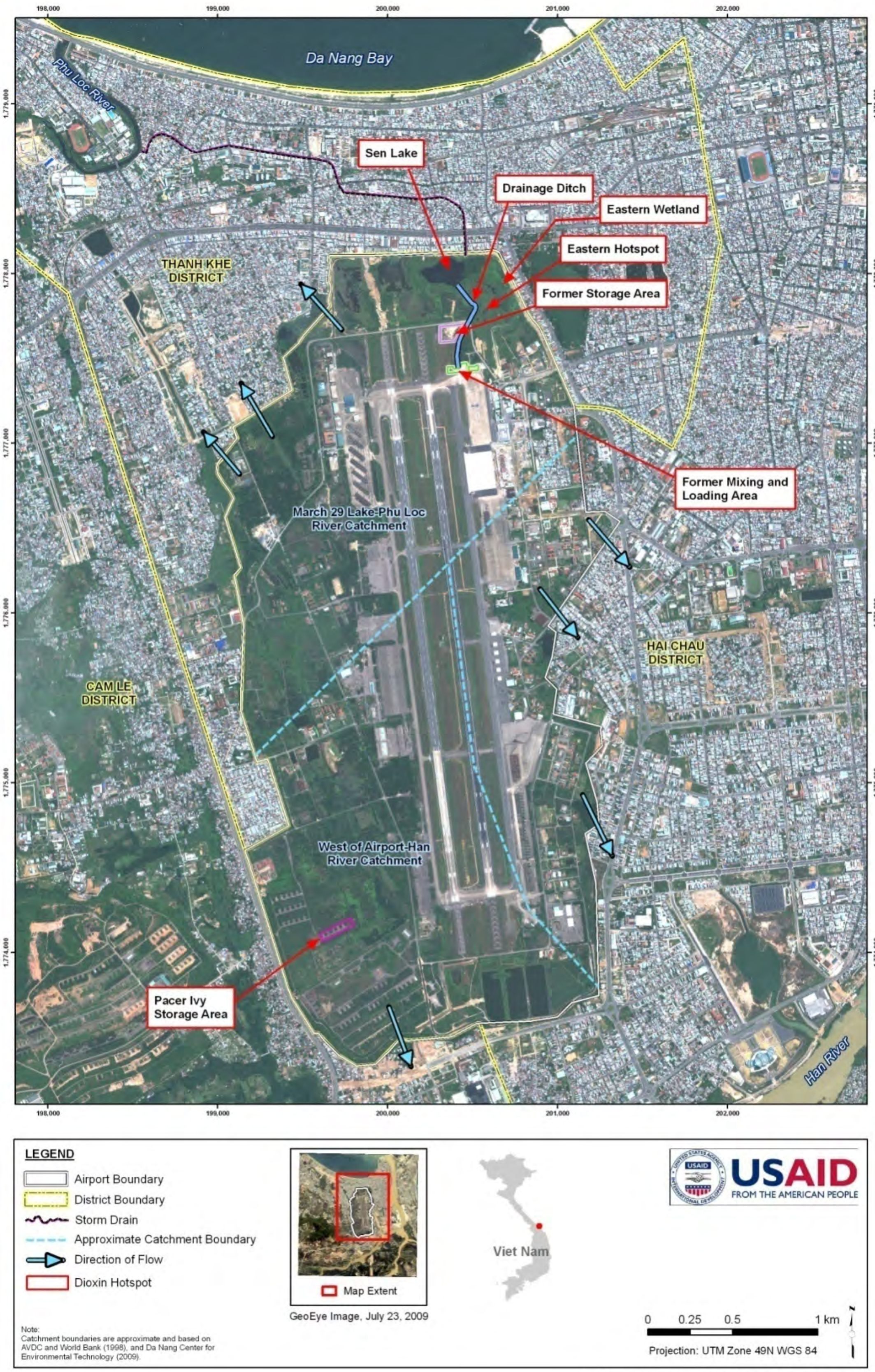
The Airport property is located within Da Nang City and is used by both MOD and the CAAV. It has a total area of 820 ha, of which 150 ha are allocated to civil aviation, and the remaining 670 ha are under the jurisdiction of the MOD. It is an international airport, with flights arriving from and departing to cities such as Bangkok, Vientiane, Hong Kong, Phnom Penh, and Taipei. The GVN plans to expand the Airport and requires dioxin removal from the northern area of the Airport to allow for extension of the runway and expanded taxiways.[17]

Dioxin hotspots identified at the Airport are primarily located in the northern portion of the Airport property (Figure 1) and include the:

- 2 ha MLA;
- 1.6 ha former Storage Area (SA);
- 3.5 ha Drainage Ditch consisting of 0.9 ha of sediments in the main drainage ditch, associated minor drainage ditches, and the drainage outlet from Sen Lake to the Da Nang storm drain, as well as the 2.6 ha area of contaminated soils on either side of the main drainage ditch;
- 0.8 ha area east of the Drainage Ditch (Eastern Hotspot);
- Sen Lake and the Eastern Wetland, two hotspots with a combined area of 8.5 ha; and
- 0.3 ha dioxin hotspot located in an isolated area of the southern portion of the Airport property at the former Pacer Ivy Storage Area (PISA).

[16] 2008 population figures taken from General Statistics Office online database.
[17] Da Nang Centre for Environmental Technology 2009.

FIGURE 1. DIOXIN HOTSPOTS IDENTIFIED AT DA NANG AIRPORT



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Studies conducted to date show that dioxin concentrations within hotspot areas of the Airport substantially exceed international Vietnamese standards for dioxin.[18,] It is clear that dioxin has entered the aquatic and human food chain, and that levels in the human population are above World Health Organization (WHO) standards.[19] Interim mitigation measures (a ban on fishing and agricultural activities, construction of a barrier wall along the northern boundary of the Airport, temporary capping of the MLA, and construction of a sediment filtration system upstream of Sen Lake) implemented in 2007 with financial assistance from the Ford Foundation and the USG helped to reduce dioxin exposure to the local population, although it is recognized that these measures only provide a temporary solution to the problem.

Dioxin is a toxic chemical associated with a range of health effects.[20] 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) is the most toxic form of dioxin, and was the main congener present in the Agent Orange mixture. In the main hotspot areas of the Airport, TCDD comprises greater than 90% of the TEQ, indicating Agent Orange as the source of contamination. Other dioxin congeners are expressed in terms of 2,3,7,8-TCDD TEQ. The GVN has established a national cleanup standard for dioxin in soil in hotspot areas of 1,000 ppt TEQ in soil and 150 ppt TEQ in sediment.[21]

Using the GVN dioxin cleanup goals for soil and sediment, the remediation effort will need to address an estimated volume of 61,700 cubic meters (m^3) of contaminated material in the six hotspots at the Airport. Table 3 provides the estimated excavation volume (m^3) and footprint (square meters [m^2]) for each hotspot.

TABLE 3. DIOXIN HOTSPOTS AT DA NANG AIRPORT—VOLUME AND AREA OF CONTAMINATED MATERIAL[1]

Hotspot	Volume (m^3)	Area (m^2)
Mixing and Loading Area	19,500	19,600
Storage Area	8,900	16,200
Drainage Ditch[2]	8,500	35,600
Eastern Hotspot	500	7,700
Sen Lake and Eastern Wetland	22,800	85,400
Pacer Ivy Storage Area	1,400	3,200
Total	61,600	167,700

Notes:
1 – These estimates were derived from data collected during previous studies conducted between 2007 and 2009 by Hatfield/Office 33, the estimates of dioxin contamination provided in Allen and Fong (2009), as well as results from additional samples collected in January 2010 (see Appendix A1) by USAID. Appendix A2 presents the methodology used to calculate the excavation volumes.
2 – The Drainage Ditch hotspot consists of 9,200 $m^2$of contaminated sediments and 26,400 m^2 of contaminated soils, requiring an excavation of 3,300 m^3 of sediments and 5,200 m^3 of soils.

[18] MOD 1997 [unpublished data], Xenobiotic Detection Systems 2006, Hatfield/Office 33 2007, and Hatfield/Office 33 2009.
[19] Hatfield/Office 33 2007 and Hatfield/Office 33 2009.
[20]ATSDR 1998.
[21] TCVN 8183: 2009.

3.2. Alternatives

A number of technologies and/or management strategies have potential applicability for treatment of dioxin contamination in soil and sediments. A screening process was used to identify the most viable technology options to consider as alternatives based on environmental impact, effectiveness, feasibility, and cost. Previous studies have been performed to review technologies potentially applicable to dioxins associated with Agent Orange in Vietnam.[22] The technologies that received unfavorable assessments in these reports were not considered further in this EA. The highest scoring technologies presented in the UNDP report were considered for evaluation under this EA. The BEM Systems, Inc. (BEM) (2007) report appeared to give significantly greater weight to the cost criterion than to demonstrated effectiveness; both are given equal weight in the current screening process. If a technology/strategy was determined to be effective for containment, it was retained for further consideration even if it is not considered effective for treatment. Table 4 summarizes the technologies that were considered and findings of the screening process.

TABLE 4. SCREENING OF POTENTIALLY APPLICABLE TECHNOLOGIES/ STRATEGIES FOR DIOXIN REMEDIATION AT DA NANG AIRPORT

Technology/Strategy	Retained?	Criteria Not Met
No Action	Yes[1]	Effectiveness – will not meet cleanup objectives
Incineration	No	Effectiveness – shown to generate significant concentrations of dioxins in off-gas; this can be mitigated through off-gas treatment. Implementability – public perception could be a significant problem given the potential for dioxin air emissions.
Base-Catalyzed Decomposition	No	Implementability/Cost – large quantity of byproduct generated that would require a large landfill in addition to the treatment process.
Ball Milling with Active Landfill	No	Effectiveness – neither ball milling nor a biologically active landfill have been demonstrated at large scales to treat dioxins to below project cleanup objectives. Implementability/Cost – this approach requires full-scale implementation of both technologies.
In-Situ/In-Pile Thermal Desorption Destruction (ISTD/IPTD)	Yes	
Geo-Melt™ Process	No	Effectiveness – has never been applied full-scale for dioxin treatment
Passive Landfill	Yes[2]	
Active Landfill	Yes[3]	Effectiveness – has never been applied full-scale for dioxin treatment; has never been demonstrated to treat dioxins below project cleanup objectives (1,000 ppt soil; 150 ppt sediment).

Notes:
1 – Retained as a baseline although it fails the effectiveness criterion.
2 – Expected to be effective for containment, but not for long-term treatment.
3 – Expected to be effective for containment, but not demonstrated for treatment.

[22] UNDP 2009 and BEM 2007.

Based on the screening analysis discussed above and an assessment of the site conditions at the Airport during the scoping process, USAID selected four remedial alternatives for consideration under this EA. These include: 1) No Action; 2) Passive Landfill Containment; 3) Active Landfill (Bioremediation); and 4) ISTD/IPTD Destruction. These are discussed briefly below.

3.2.1. No Action

Under the No Action alternative, the contaminated soil and sediment would be left in place, and no mitigation measures would be implemented. This alternative is required to be included under 22 CFR 216 and serves as a baseline for comparison to the other alternatives. No Action is not considered an appropriate alternative because concentrations of dioxin substantially exceed the Vietnamese National Standard for dioxin in soil and sediment[23] and USEPA's proposed preliminary remediation goals (PRGs) for dioxin in soil[24]. Furthermore, the Airport expansion is planned to take place within hotspot areas which eliminate the option of leaving the contaminated soil and sediment in place.

3.2.2. Passive Landfill

The Passive Landfill alternative was the originally proposed action. This alternative would involve construction of a secure onsite landfill on the Airport premises and removal, dewatering, transport, and deposition of contaminated material into the landfill. This approach would provide a means to securely contain dioxin for the lifetime of the landfill (assumed to be 50 years), and is an approved option for containing dioxin at contaminated sites in the U.S. This would require construction of a large aboveground landfill, equivalent to approximately four football fields in area and 1.5 stories high. Operation and maintenance (O&M) and environmental monitoring and management would be required for a minimum of 50 years. At the end of this period, it is expected that dioxin levels of contaminated material in the landfill would remain significantly above GVN cleanup standards. Construction of a new landfill or dioxin destruction would be necessary at that time, with an additional significant cost.

3.2.3. Active Landfill (Bioremediation)

An active landfill would provide the same containment benefit as the Passive Landfill alternative. Under this alternative, however, additives would be mixed with contaminated material to facilitate growth of bacteria that might destroy dioxin. These "bulking agents" would add up to 40% to the volume of material to be contained in the landfill, resulting in a much larger landfill (more than five football fields in area and 1.5 stories high). Bioremediation has not been applied full scale for dioxin destruction; therefore, the design parameters for a large landfill to facilitate the bioremediation process are uncertain. As a result, it is difficult to predict whether the Active Landfill alternative would result in dioxin destruction to meet cleanup goals. How long this process might take is also unknown, and as a result, it is difficult to determine the need for long-term O&M and environmental monitoring and management.

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[23] TCVN 8183: 2009.
[24] USEPA 2009a.

3.2.4. In Situ/In Pile Thermal Desorption

ISTD/IPTD was selected as the preferred project alternative in this EA. ISTD/IPTD is an innovative dioxin destruction technology that was developed by Royal Dutch Shell.[25] This is the only alternative of the three technology options considered for the EA that has been proven to destroy dioxin to levels that meet both soil and sediment GVN national dioxin standards.[26]

Under this alternative, the contaminated material would be excavated and placed into two or three stockpiles near the contaminated areas. The stockpiles would then be heated to 335 degrees Celsius (°C) to destroy 95% of the dioxins. The remaining dioxin would be drawn through an air treatment system for removal, resulting in air emissions that are below regulatory limits. This technology has been applied successfully at a similarly-sized dioxin site in Alhambra, California for which the California Department of Toxic Substances Control granted unrestricted land use status after treatment.[27] The Government of Japan conducted a carefully controlled pilot test of ISTD/IPTD that led to the technology being approved for dioxin destruction in Japan.[28]

3.3. EA Evaluation and Results

The EA included preparing conceptual designs corresponding to 10% of the final design for each alternative and used the following criteria to select the preferred alternative for the Airport: 1) effectiveness of the alternatives to achieve cleanup goals and be ultimately a final remedy for dioxin cleanup; 2) implementability of each alternative at the Airport; 3) potential environmental impacts of each alternative; and, 4) cost of the alternatives. Tables 5, 6, 7, and 8 provide the results of evaluating these criteria, respectively.

3.3.1. Effectiveness Evaluation

The EA evaluated each alternative based on its ability to meet dioxin remediation goals, either through containment or through destruction. Both the Passive and Active Landfill alternatives were found to be effective for containment. Although the Passive Landfill alternative provides a 50-year remedial solution, it will not provide for full dioxin destruction over the long term. The effectiveness of the Active Landfill alternative for destruction of dioxin to meet treatment goals is unknown. The ISTD/IPTD alternative would not require construction of a landfill and would not include long-term containment. Rather, the ISTD/IPTD alternative would bring dioxin concentrations in treated soils and sediments to below cleanup goals. A summary of the results of the effectiveness evaluation is provided in Table 5.

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[25] http://newsite.terratherm.com/about/history.htm.
[26] ENSR 2000, Baker and La Chance 2003, Baker et al. 2007 and Heron et al. 2010.
[27] Baker et al. 2007.
[28] Heron et al. 2010.

TABLE 5. COMPARISON OF EFFECTIVENESS EVALUATION OF THE REMEDIAL ALTERNATIVES

PASSIVE LANDFILL	ACTIVE LANDFILL	ISTD/IPTD
Effective for containment: Proven containment strategy; hazardous waste landfills have been used successfully for decades worldwide; 50-year solution. **Ineffective for treatment:** Dioxins would be expected to persist for many decades and would require eventual treatment.	**Effective for containment:** Proven containment strategy; hazardous waste landfills have been used successfully for decades worldwide. **Unknown effectiveness for treatment:** Review of the scientific literature on microbial degradation of chlorinated dioxins[1] shows some degradation of 2, 3, 7; 8-TCDD, but no studies demonstrate degradation below either GVN cleanup goals. Initial results from USEPA and Vietnam Academy of Science Technology (VAST) pilot study[2] show approximately 50% dioxin degradation after 120 days; however, it remains unclear whether cleanup goals can be met and scalability of the pilot study to full-scale application is uncertain.	**Effective for treatment (no long-term containment required):** Several well-documented case studies[3] have shown that ISTD/IPTD can treat 2, 3, 7, 8-TCDD to concentrations below GVN cleanup standards. Concentrations of dioxins in exhaust gas in previous case studies were orders of magnitude below regulatory limits. • Over 95% of dioxins will be destroyed in situ. • If design calculations show that granular activated carbon (GAC) would not meet emissions standards for exhaust gas, then a thermal oxidizer would be considered. • Dispersion between the stack and property boundaries or locations of other receptors would be considered in this analysis as well.

Notes:

1 – Field and Sierra-Alvarez 2008.

2 – Allen and Fong 2009 and Allen 2010.

3 – ENSR 2000, Baker and La Chance 2003, Baker et al. 2007, and Heron et al. 2010.

3.3.2. IMPLEMENTABILITY EVALUATION

All of the remedial alternatives can be implemented at the Airport. Table 6 presents a summary of the challenges of implementing each alternative.

TABLE 6. COMPARISON OF IMPLEMENTABILITY EVALUATION OF THE REMEDIAL ALTERNATIVES

PASSIVE LANDFILL	ACTIVE LANDFILL	ISTD/IPTD
Landfill siting: an ideal site does not exist on Airport property. **Haul route:** long haul route and high number of truckloads required. **Fill material:** Significant amount of fill material (~140,000 m^3) required for landfill construction, operation, and closure. **Long-term O&M:** 50 years after construction.	**Landfill siting:** an ideal site does not exist on Airport property. **Haul route:** long haul route and high number of truckloads required. **Fill material:** Significant amount of fill material (~200,000 m^3) required for landfill construction, operation, and closure. **Electrical use:** estimated ~33,000 kilowatt hours (kwh)/year (yr) required for nutrient distribution system operation (10 years). **Bioremediation design uncertainty:** • Target mechanism: aerobic, aerobic cometabolic, anaerobic, or combination? • Design basis for full scale: distribution of microbes and nutrients/substrates, bioavailability of TCDD, longevity of nutrients/substrates relative to persistence of TCDD, and ability to maintain desired geochemical conditions **Long-term O&M:** assumed to be 10 years after construction, but may be more if degradation does not occur.	**Electrical use:** estimated 21,000,000 kwh for 6 months of continuous treatment time per pile (two piles total). **Mobilization:** some equipment and technical expertise will have to come from overseas. **Air monitoring:** must ensure emissions do not exceed regulatory limits; GAC and/or thermal oxidizer would be used. **Geotechnical properties of soil post-treatment:** limited quantitative data available, but one study indicated no significant effect.[1] Conservative design assumptions made to stockpile soil and revegetate it post-treatment rather than to use it as structural fill.

Notes:
1 – Heron et al. 2009.

3.3.3. Environmental Consequences

The overall potential environmental impact of all three remedial alternatives is substantial. The remedial action requires the excavation, transport, and deposition of dioxin-contaminated soil from the hotspots into a landfill or stockpile. The wetland ecosystem (Sen Lake) must be drained and dredged to remove contaminated sediments. Impacts to wetlands and terrestrial and aquatic biota are unavoidable over the short term, in order to eliminate the possibility of future dioxin exposure to humans and the environment. Detailed assessments of the potential environmental impacts associated with each alternative were conducted for this EA and are summarized below and in Table 7.

The Passive Landfill alternative would require hauling approximately 7,500 truckloads of contaminated soil and sediment. In addition, approximately 10,000 truckloads of clean fill would need to be brought in from offsite, an action in and of itself that could require a GVN EIA if all the clean fill material were to be obtained from a single new source. The total distance of material that would be hauled is approximately 369,000 kilometers (km). The most significant potential environmental impacts of the Passive Landfill alternative include risks from unexploded ordnance (UXO), munitions bunker decommissioning at the landfill site, potential impacts on surface water quality, contaminated fugitive dust/sediment exposure to workers and area residents, noise impacts, impacts to natural resources due to the large size of the landfill footprint, and potential environmental impacts associated with long-term operation of the landfill. The potential environmental impact of the Passive Landfill was found to be lower than the No Action and Active Landfill alternatives, but significantly greater than the ISTD/IPTD alternative.

The Active Landfill alternative would require hauling approximately 7,500 truckloads of contaminated soil and sediment. In addition, approximately 17,000 truckloads of clean fill and bulking agent would need to be brought in from offsite, an action in and of itself that could require a GVN EIA if all the clean fill material were to be obtained from a single new source. Potential environmental impacts of the Active Landfill alternative are incrementally greater than those of the Passive Landfill due to the need for a larger temporary storage and dewatering area, and the need for a larger landfill footprint to accommodate the up to 40% increase in total volume of material. Greater contact with contaminated material would be necessary to mix it with bulking agents to facilitate the biological reaction process. As a result, the potential environmental impacts associated with UXO, munitions bunker decommissioning at the landfill site, potential impacts on surface water quality, contaminated fugitive dust/sediment exposure to workers and area residents, noise impacts, and impacts to natural resources are greater than those of the Passive Landfill and significantly greater than those of the ISTD/IPTD alternative.

The ISTD/IPTD alternative does not require large storage and dewatering operations, upgrade of the haul routing, long hauling distance, UXO clearance and munitions bunker decommissioning at the landfill site, construction of the landfill, and deposition of contaminated material into the landfill. The hauling distance is roughly half of that required of the Passive and Active Landfill alternatives, and the need for clean fill for construction and operation is less than half of that needed for the Active Landfill alternative and 60% less than that of the Passive Landfill alternative. The potential environmental impacts to surface water quality due to contaminated wastewater discharges are less than 10% of those estimated for the Passive Landfill alternative and less than 20% of those estimated for the Active Landfill alternative. Following ISTD/IPTD treatment, it is likely that soils could be used as fill for a variety of purposes, but geotechnical testing would need to be performed before using the soils as structural fill. As no long-term O&M and environmental monitoring concerns exist after treatment with the ISTD/IPTD alternative, there are no potential long-term impacts; in contrast to the two landfill alternatives. This alternative was assessed as having a lower overall potential environmental impact than any of the other alternatives that were assessed.

The assessment results were used to rank the alternatives to identify the environmentally-preferred alternative which is the alternative with the lowest overall potential environmental impact. The results of the environmental impact analysis of the four alternatives are summarized in Table 7. For each assessment criterion, the three alternatives (excluding No Action) are ranked depending on their relative potential environmental impacts. A score of "1" indicates the highest relative potential environmental impact and a score of "3" indicates the lowest potential environmental impact. Lower cumulative scores are associated with the greatest potential environmental impact among the evaluated alternatives. It should be noted that no weighting has been given to each of the impact assessment criteria.

TABLE 7. COMPARISON OF POTENTIAL ENVIRONMENTAL IMPACTS OF THE REMEDIAL ALTERNATIVES

Potential Environmental Impact	Assessment Criterion	Remedial Alternative (Environmental Impact Ranking; 1 = Highest Impact Total Score. The Lower the Score, the Higher the Environmental Impact Ranking)		
		Passive Landfill (Total Score = 29)	**Active Landfill (Total Score = 24) Highest Potential Environmental Impact**	**ISTD/IPTD (Total Score = 37) Lowest Potential Environmental Impact**
Potential Environmental and Associated Human Risks Associated with Cleanup of UXO and Munitions	Qualitative Assessment based on land area affected by Project	Significant (2)	Significant (1)	Significant (3)
		Requirements to remediate munitions bunkers and possible other similar facilities in the southwestern part of the Airport property are unknown.		
Potential Impacts on Surface Water Hydrology	Qualitative Assessment	Insignificant (3)	Insignificant (3)	Insignificant (3)
Potential Impacts on Surface Water Quality	Volume of Project-Affected Water Generated and Requiring Treatment before Release	262,242 m^3 (1)	136,597 m^3 (2)	23,603 m^3 (3)
Potential Impacts on Groundwater Resources	Qualitative Assessment	Insignificant (3)	Insignificant (3)	Insignificant (3)
Potential Impacts on Groundwater Quality	Qualitative Assessment	Insignificant (3)	Insignificant (3)	Insignificant (3)
Potential Effects of Extraction, Transport, Containment, and Treatment of Dioxin-Contaminated Material on Air Quality and Human Exposure	Relative Potential Exposure Index for Dioxin	Intermediate (2)	Highest (1)	Lowest (3)
Potential Effects of Emissions of Other contaminants of potential concern (COPCs) and Dust on Air Quality and Human Exposure	Qualitative Assessment	Significant (1)	Significant (1)	Significant (1)

TABLE 7. COMPARISON OF POTENTIAL ENVIRONMENTAL IMPACTS OF THE REMEDIAL ALTERNATIVES

Potential Environmental Impact	**Assessment Criterion**	**Remedial Alternative (Environmental Impact Ranking; 1 = Highest Impact Total Score. The Lower the Score, the Higher the Environmental Impact Ranking)**		
		Passive Landfill (Total Score = 29)	**Active Landfill (Total Score = 24) Highest Potential Environmental Impact**	**ISTD/IPTD (Total Score = 37) Lowest Potential Environmental Impact**
Potential Contribution to Greenhouse Gases	Tons (metric) (t) of carbon dioxide (CO_2) generated by the Project	3,925 t (3)	5,059 t (2)	7,926 t (1)
Potential Effects on Terrestrial Ecosystems and Terrestrial Biodiversity	Qualitative Assessment	Insignificant (1)	Insignificant (1)	Insignificant (1)
Potential Effects on Wetlands, Aquatic Ecosystems, and Aquatic Biodiversity	Qualitative Assessment	Insignificant (1)	Insignificant (1)	Insignificant (1)
Potential Effects on Noise Levels	Total Estimated Duration of Equipment Use	7,340 hours (hrs) (2)	7,790 hrs (1)	3,030 hrs (3)
	Total Distance Driven by Hauling Equipment	369,920 km (2)	580,570 km (1)	230,600 km (3)
Potential Effects on Natural or Depletable Resource Requirements	Amount of clean fill required	138,200 m^3 (2)	201,300 m^3 (1)	84,300 m^3 (3)
Potential Effects on Land Use	Land Area Disturbed	296,050 m^2 (2)	334,950 m^2 (1)	183,100 m^2 (3)
Potential Long-Term Environmental Risks Associated with Operation of the Project	Qualitative Assessment	Significant (1)	Unknown (2)	Insignificant (3)

3.3.4. Cost Evaluation

The EA includes cost estimates for each of the three alternatives based on Superfund guidance. Although such cost estimates are normally associated with a -30%+50% cost range, at this 10% conceptual design phase of the Project, underlying cost assumption for these estimates with respect to contaminated material volumes, local labor, electricity, and value added tax (VAT) have been refined significantly. Therefore, the range may be narrower than -30 + 50%. Cost estimates assume a 2-year implementation period for the three remedial alternatives. Longer implementation timeframes will increase total cost. Table 8 provides a summary of the cost estimates for each alternative.

TABLE 8. COMPARISON OF ESTIMATED COSTS ($ MILLION) OF THE REMEDIAL ALTERNATIVES (COST RANGE -30%+50%)

Component	Passive Landfill	Active Landfill	ISTD/ IPTD	Cost Differentiators Between Alternatives
Disposal	$11.5	$11.5	$8.7	Less excavation, hauling, and site clearing/prep for ISTD/IPTD
Construction	$10.3	$15.5	$24.4	Various
Subtotal (First 2 years)	$21.8	$27.0	$33.1	
Long Term O&M	$3.2	$0.7	$0	Passive Landfill: 50 years Active Landfill: 10 years ISTD/IPTD: none
EMMP Implementation	$10.8	$3.0	$0.6	Passive Landfill: 50 years Active Landfill: 10 years ISTD/IPTD: none
Overall Total	**$35.8**	**$30.7**	**$33.7**	

3.4. Selected Preferred Project Alternative

Table 9 summarizes the results of the alternatives analysis in this EA. The ISTD/IPTD alternative was found to have the highest treatment effectiveness, the highest feasibility, the lowest potential environmental impact, and a cost in the same range as the other alternatives. The Passive Landfill alternative was the most expensive option, ranked third in terms of environmental impact, was possibly feasible in the context of the Airport, and, while effective for containment, does not provide a final remedy. The Active Landfill alternative was associated with the highest environmental impact, while its effectiveness for destroying dioxin to cleanup goals is uncertain. The Active Landfill alternative is possibly feasible in the context of the Airport although it is unclear whether it would provide a final remedy. No action is not considered a viable alternative due to the high levels of dioxin contamination present at the site and because the Airport expansion project will require removal of dioxin from hotspot areas. Based on these results, USAID has selected ISTD/IPTD as the preferred alternative for dioxin remediation at the Airport. As described in Section 2, this alternative was not the originally proposed action for the Airport remediation program.

TABLE 9. SUMMARY OF EA FINDINGS FOR DIOXIN REMEDIATION AT DA NANG AIRPORT

Alternative	Effectiveness (i.e., dioxin ≤ cleanup goals/"final remedy")?	Implementable	Environmental Assessment	Estimated Cost (in Millions) -30%+50%	Implementation Schedule
No Action	No	Yes	Highest overall potential environmental impact	Externalized	NA
Passive Landfill	No	Yes with challenges	Third-highest overall potential environmental impact	$35.8M	2-year construction, and 50 years long term O&M
Active Landfill (Bioremed-iation)	Uncertain	Yes with challenges	Second-highest overall potential environmental impact	$30.7M	2-year construction, and 10 years long term O&M
ISTD/IPTD	Yes	Yes with challenges	Lowest overall potential environmental impact	$33.7M	2-year construction and no long term O&M

Notes:
This table summarizes the results of the alternatives analysis in this EA; it also provides a summary of the implementation schedule for each remedy (additional details regarding schedule are provided in the conceptual designs of each alternative).

3.5. Stakeholder Response

Formal approval of the revised proposed action will occur through an exchange of letters to take place after the EA receives USAID Asia BEO approval and during the GVN approvals process for the EIA.

USAID and GVN participated in two workshops in March 2010 (March 16, 2010 in Hanoi and March 18, 2010 in Da Nang) to review the findings of the Draft EA. The objectives of the workshops were to: present the findings of the EA; obtain stakeholder input into the assumptions used to complete the EA; and, to obtain consensus on the technology option to be selected as the "preferred" alternative for the EA and subsequent EIA. At the completion of the workshops, the following conclusions were reached:

- The No Action alternative cannot be considered as a viable alternative.
- GVN participants indicated their full support and agree on using the best technology for destroying dioxins at the Airport. The ISTD/IPTD alternative has many merits. The ISTD/IPTD alternative costs are in the same range as both of the landfill alternatives and the EA demonstrates that ISTD/IPTD is the preferred alternative. However, GVN specified that they would like the remediation activities to proceed in such a way that

performance of the technology in the Da Nang context is guaranteed prior to full scale implementation.

- The Passive Landfill is an acceptable alternative for dioxin containment and is used in other international contexts. Although the ISTD/IPTD alternative is associated with reduced environmental consequences and is expected to reach GVN cleanup goals (i.e., a final remedy), GVN wants to keep the Passive Landfill alternative as the default alternative if for some reason the ISTD/IPTD alternative cannot be implemented at the Airport.

- The Active Landfill alternative has not been proven effective for dioxin remediation in the U.S. or other international contexts. GVN does not support further discussion of this alternative in the context of the Da Nang remediation effort.

The GVN will need to approve the Project at the Prime Minister's level. This approval will most likely take place as part of the EIA acceptance process.

Section 4. Baseline Information

This section provides general baseline (i.e., current) information about the Airport area, dioxin contamination at the Airport, potential exposure pathways, and gender considerations for the Project. Section 6 (Affected Environment) provides baseline environmental condition information.

4.1. Da Nang Airport and Surrounding Communities

Da Nang City has a population of approximately 825,000 persons as of 2008 (male: 401,235; female: 420,943), with an average population density of about 640 persons/m^2 (Table 10). The Airport property is located within the urban part of Da Nang City and is surrounded by three urban districts: Hai Chau on the northeast and east; Thanh Khe on the northwest and west; and Cam Le on the southwest, south, and southeast (Figure 2). The three districts are densely populated, with most of the land in these districts used for housing, industrial facilities, transportation, and other facilities. With the exception of Cam Le District, few areas near the Airport property are used for agriculture, aquaculture, or forestry. These land uses in Cam Le District are generally to the southwest of, and not immediately adjacent to, the Airport property.

The Airport property is located within Da Nang City and is used by both MOD and the CAAV. It has a total area of 820 ha, of which 150 ha are allocated to civil aviation, and the remaining 670 ha are under the jurisdiction of the MOD. It is an international airport, with flights arriving from and departing to cities such as Bangkok, Vientiane, Hong Kong, Phnom Penh, and Taipei. The GVN plans to expand the Airport and requires dioxin removal from the MLA, the SA, and Sen Lake to allow for extension of the eastern runway to the north and expanded taxiways.[29] There are at least 14 lakes on the Airport property which are still used today for fishing and aquaculture. Fishing activities on Sen Lake have been banned since 2007, but this ban has not been implemented on other lakes. During the 1960s, land use in the Da Nang City area was very different, particularly north of the Airport; large tracts of land were used for rice agriculture, and several of the wetlands in the area could be considered as extensions of the Sen Lake ecosystem.[30]

General information on Da Nang City and the districts of Thanh Khe, Cam Le, and Hai Chau is provided in Table 10. A number of people reside on the western edge of the Airport property, between the western boundary and the active runways. These are primarily military personnel, Airport workers, and their families.

[29] Da Nang Centre for Environmental Technology 2009.
[30] Hatfield/Office 33 2007.

FIGURE 2. DA NANG AIRPORT AND SURROUNDING COMMUNITIES

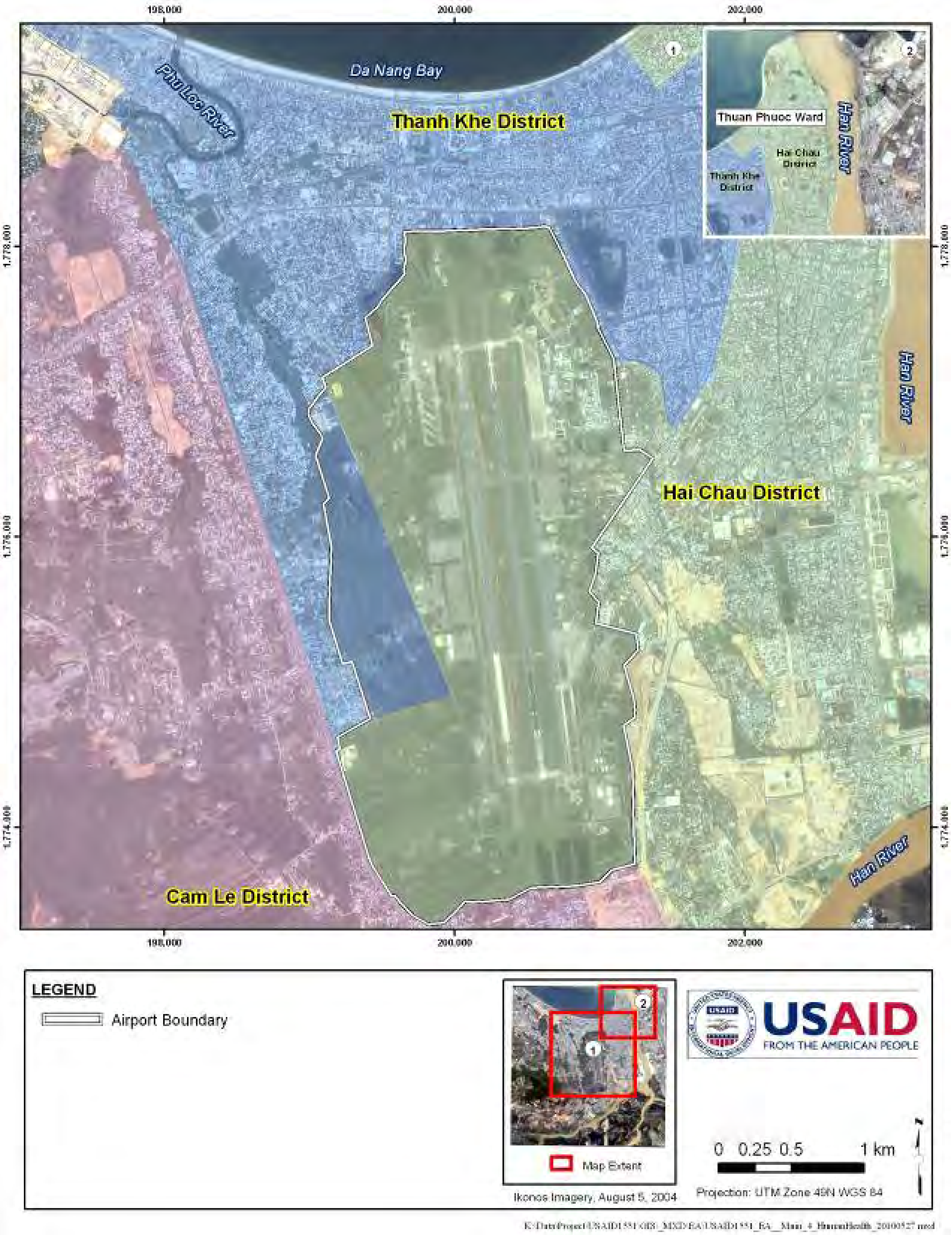

TABLE 10. DA NANG CITY DISTRICTS ADJACENT TO DA NANG AIRPORT[1]

	Hai Chau District	Thanh Khe District	Cam Le District
General			
Area (ha)	2,135	936	3,376
Total Population	196,842	169,268	70,052
Male Population	94,721	83,418	33,993
Female Population	102,121	85,850	36,059
Population Density (persons/ha)	92	181	21
Number of Wards	13	10	6
Land Use (ha, as of 2007)			
Total Agriculture Land	23	18	826
Rice	0	0	536
Other Cultivated Crops[2]	0	10	217
Tree Crops[3]	23	8	73
Aquaculture	0	0	28
Forestry Land[4]	0	0	210
Special Use Land[5]	1,328	388	956
Residential Land	473	454	676
Unused Land	311	76	680

Notes:
1 – Information as of 2008 unless otherwise noted (Da Nang Statistics Office 2008).
2 – Other cultivated crops include beans, groundnut, corn, and other vegetables
3 – Tree crops include coconut, pepper, and cashew.
4 – Forestry land is defined as land used for the cultivation of trees for timber, other building products, or pulp and paper.
5 – Special Use Land includes roads, industrial zones, retail facilities, and canals.

4.2. Dioxin Contamination at Da Nang Airport

The Airport is recognized as a dioxin hotspot due to high 2,3,7,8-TCDD concentrations remaining decades after large volumes of Agent Orange and other herbicides were stored, handled and spilled at this site during Operation Ranch Hand during the Vietnam War.[31] Several studies of dioxin contamination in and around the Airport have been conducted since 1997 (Table 11). This section provides a summary of the key studies conducted at the Airport, and provides details on the amount of contaminated material to be remediated under this Project.

[31] Dwernychuk et al. 2002

TABLE 11. DIOXIN STUDIES UNDERTAKEN BETWEEN 1997 AND 2010 AT DA NANG AIRPORT

Agency (Reference)	Year	Number of Samples	Sample Type	Analytical Technique	Laboratory
MOD[1]	1997-1998	~ 330	Soil and Biological	Gas Chromatography – Mass Spectrometry (GCMS) (low resolution)	Vietnam (some in Russia and Japan)
MOD and Hanoi Medical University (HMU)[2]	2000-2005	200	Biological	GCMS (low resolution)	Vietnam (some in Japan)
VAST, MoNRE, MOD, and USEPA[3]	2005	109/179	Soil and Biological	CALUX	USA
Hatfield/10-80 Division[4]	2005	21	Soil and Sediment	GCMS (high resolution)	Canada (AXYS)
Hatfield/ Office 33[5]	2006-2007	147	Soil, Sediment, Fish, Vegetation, Blood and Breast Milk	GCMS (high resolution)	Canada (AXYS)
Hatfield/ Office 33[6]	2009	127	Soil, Sediment, Fish	GCMS (high resolution)	Canada (AXYS)
		115	Blood and Breast Milk	GCMS (high resolution)	Canada (AXYS)
USAID	2010	71	Soil, Sediment, Surface/Ground water	GCMS (high resolution)	Canada (AXYS)

Notes:
1 – MOD unpublished data.
2 – MOD and HMU unpublished data.
3 –Xenobiotic Detection Systems Inc. 2006.
4 – Hatfield/10-80 Division 2006.
5 – Hatfield/Office 33 2007.
6 – Hatfield/Office 33 2009.

4.2.1. Summary of Previous Studies at Da Nang Airport

Prior to 2005, there was limited information in the scientific literature on dioxin levels in and around the Airport.[32] The earliest recorded dioxin investigations at the Airport were conducted by MOD in 1997[33], and by MOD and HMU between 2000-2005.[34] MOD found high concentrations of dioxin in Sen Lake sediments (measured as TEQs; maximum 12,393.2 ppt) in 1997 from a number of sampling locations. MOD's 1997 previously unpublished data from sampling and analysis of sediment from Sen Lake were made available to the Project team, and are provided in Appendix A1 and in the figures in this report.

[32] Dwernychuk 2005
[33] MOD unpublished data
[34] MOD and HMU unpublished data.

From 2003 to 2005, with funding from the Ford Foundation, Hatfield and the 10-80 Division of the Ministry of Health (10-80 Division) conducted a review of all suspected dioxin hotspots in Vietnam, including Da Nang.[35] The project, entitled "Identification of New Agent Orange/Dioxin Contamination Hotspots in Southern Viet Nam," consisted of two phases: Phase I involved the identification of potentially contaminated sites that may pose a risk to human health; and, Phase II included confirmation of selected Phase I sites through a field sampling program, further refinement of human health risks, and recommendations for future action. A total of 21 soil and sediment samples were analyzed for dioxins and furans outside of the Airport as part of the project. Elevated dioxin levels were recorded in soils and sediments from a number of sites, including a ditch in Hai Chau District immediately east of the Airport, and from a former wetland area in Thanh Khe District. Based on these results, recommendations were made for further assessment on the Airport (as well as the Bien Hoa and Phu Cat airports and other suspected hotspots identified in the study), to determine the extent of contamination and possible exposure of the local population to dioxin[36].

Concurrently, in 2005, under a joint study conducted by VAST, MoNRE, MOD, and USEPA, soil and sediment samples, as well as biological tissues, were collected and analyzed from the Airport (using CALUX)[37].

Data from the studies conducted between 1997 and 2005[38] focused on analysis at the three main hotspot areas at the northern end of the Airport, including soils from the MLA and SA, and sediments from Sen Lake. Significant dioxin contamination (>10,000 ppt TEQ) was found in many of the samples analyzed[39], and these data were instrumental in helping to provide a more detailed understanding of contamination levels in hotspots at the northern end of the Airport. The 2005 data[40] were also included in the estimations of extent of contamination at the Airport presented in this EA, and in calculations of volumes of contaminated soil which need to be treated. These data are presented in Appendix A1 (and in the figures in this report).

Between October 2006 and April 2007, with funding from the Ford Foundation, Office 33 and Hatfield Consultants (Hatfield) undertook the "Da Nang Dioxin Assessment and Mitigation Project. [41] This project investigated the issue of residual dioxin contamination on the Airport property and in the surrounding environment, and developed mitigation measures to help prevent dioxin exposure to local populations. The study focused on the three main hotspots at the north end of the Airport, and included analysis of 147 samples for dioxins, furans and other chemical contaminants in soils, sediments, fish tissues and human blood. Data are presented in Appendix A1 (and in the tables and figures in this report), as well as in the Hatfield/Office 33 2007 report.[42]

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[35] Hatfield/10-80 Division 2006 and Dwernychuk et al. 2006.
[36] Hatfield/10-80 Division 2006 and Dwernychuk et al. 2006.
[37] Xenobiotic Detection Systems Inc. 2006.
[38] MOD unpublished data and Xenobiotic Detection Systems Inc. 2006.
[39] Xenobiotic Detection Systems Inc. 2006.
[40] Xenobiotic Detection Systems Inc. 2006.
[41] Hatfield/Office 33 2007 and Boivin et al. 2007.
[42] Hatfield/Office 33 2007.

The key results of the Hatfield/Office 33[43] sampling program at the Airport in 2006 were as summarized below:

- Significant quantities of TCDD were detected in samples analyzed, with maximum concentrations recorded in soils from the MLA (365,000 ppt).

- Dioxin congener profiles confirmed that the main source of dioxin contamination in the northern area of the Airport was Agent Orange and other dioxin-containing herbicides. TCDD contributed over 90% of the TEQ (TCDD toxic equivalents) in soil and sediment samples collected from the MLA, SA, and Sen Lake.

- The maximum TCDD levels recorded in fish fat samples from Sen Lake was 3,000 ppt, 100 times above acceptable levels for human consumption established by Health Canada. Fish contaminated with dioxins from Sen Lake were being consumed by fishermen (and likely some members of the general public). As a point of reference, the U.S. Food and Drug Administration (FDA) issued a recall of fish with dioxin levels higher than 1 pg/g (1 ppt) TEQ wet weight.[44]

- Dioxin levels recorded in vegetation (i.e., lotus, sweet potato) collected at Sen Lake in 2006 were generally low, although there was potential for human exposure to dioxin through contact with contaminated soil and sediments used for growing these food items on the Airport property.

- Blood dioxin levels recorded (n=55 patients sampled) in some Da Nang residents were the highest reported for Vietnam to date, and exceeded international standards for these chemicals. Individuals working on the Da Nang Airbase at Sen Lake (harvesting fish and lotus, and gardening) had the highest dioxin concentrations in their blood – more than 100 times globally acceptable levels. The highest TCDD level of 1,150 ppt (1,220 ppt TEQ; 94% TCDD) was recorded in a 42-year-old male who had worked on the Airport and consumed fish from the Sen Lakes since 1990. A number of other contaminants, including polychlorinated biphenyls (PCBs), were also recorded in blood samples analyzed. As a point of reference, The U.S. Agency for Toxic Substances and Disease Registry (ATSDR) notes that blood dioxin levels typical of those found in developing countries rarely exceed 10 ppt.[45]

- People most affected by direct exposure to dioxins from the Da Nang hotspot were members of an extended family that fished and harvested lotus from Sen Lake, and gardened along its banks. Given that a number of people had consumed fish and harvested lotus from Sen Lake for decades, and that people living outside the Airport could easily gain access to the site, exact numbers of highly exposed people were unknown. Recommendations were made to verify the number of potentially impacted people.

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[43] Hatfield/Office 33 2007 and Boivin et al. 2007.
[44] USDA Food Safety and Inspection Service 1997.
[45] ATSDR 1998.

In June 2007, a workshop was organized in Hanoi by MOD and the DOD to share information on dioxin contamination in Vietnam, and more specifically, the "Pacer Ivy" mission, which took place in 1971. In logistics operations, the word "Pacer" refers to the movement of material, and the word "Ivy" is a short-form of "Inventory."[46] On April 17, 1970 all uses of Agent Orange were halted in Vietnam and all remaining materials were put into storage. The Pacer Ivy mission was launched on September 15, 1971 to consolidate, re-drum and ship all remaining Agent Orange material in South Vietnam to Johnston Island in the Central Pacific Ocean. New potential dioxin hotspots were identified at the Airport during this June 2007 workshop, in the south-western portion of the Airport, namely the PISA and the former Pacer Ivy Re-Drumming Area (PIRA). These areas had not been previously sampled for dioxin contamination, and concerns were raised regarding the existence of other potential dioxin hotspots on the Airport and in surrounding areas.

Following identification of the PISA and PIRA areas,[47] with funding from the Ford Foundation, Hatfield and Office 33 implemented the project "Comprehensive Assessment of Dioxin Contamination in Da Nang Airport, Viet Nam: Environmental Levels, Human Exposure and Options for Mitigating Impacts"[48] This study consisted of two phases: Phase I focused on sampling and analysis of soils from the PISA and PIRA, and also included monitoring of areas in the north of the Airport that were identified as being highly contaminated in the 2006 study .[49] Although the sampling focus was on the two Pacer Ivy sites, a comprehensive assessment of the entire Airport area (and the city surrounding the perimeter of the Airport) was also conducted in January 2009 in order to determine if there were additional unidentified contaminated sites. Phase II of the study was conducted in April 2009 to determine potential human exposure to dioxins and furans in communities surrounding the Airport. Blood and breast milk were collected from randomly selected participants (from all districts surrounding the Airport), and from individuals who had been tested in 2006 in order to determine any temporal trends in dioxin levels. As part of the Phase II study, additional environmental samples were collected from the PISA to better delineate the extent of contamination based on Phase I results.[50]

A total of 127 environmental (soil, sediment and fish tissue) and 115 human (blood and breast milk) samples were analyzed as part of the 2009 Hatfield/Office 33 Da Nang study. Data are presented in Appendix A1 (and in the tables and figures in this report), as well as in the Hatfield/Office 33 2009 report.[51] Key results are summarized below:

- As recorded in 2006, significant quantities of TCDD were detected in samples analyzed from the north end of the Airport in January 2009. Dioxin levels at this location continued to exceed international standards and guidelines for these toxic chemicals.

- One soil sample in the PISA, and one surface sample adjacent to the PISA in the southern area of the Airport, exceeded Vietnamese standards and guidelines for TCDD

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[46] Young 2007.
[47] Young 2007.
[48] Hatfield/Office 33 2009.
[49] Hatfield/Office 33 2007.
[50] Hatfield/Office 33 2009.
[51] Hatfield/Office 33 2009.

(1,180 and 13,400 picograms [pg]/ gram [g] dry weight, respectively). At the PIRA, all samples exhibited low TCDD levels (1.21 to 79.9 pg/g dry weight). The proportion of TCDD to TEQ concentrations at, and adjacent to, the PISA was generally low which might indicate other possible sources of dioxin contamination.

- All soil and sediment samples analyzed from the west and east of the Airport exhibited low TCDD concentrations (non-detect to 46.1 pg/g dry weight).

- The maximum TCDD concentration recorded in tilapia fish fat from Sen Lake in 2009 was 7,900 ppt (wet weight basis), which greatly exceeded the acceptable level established by the U.S. Department of Agriculture (USDA).[52] In 2006, tilapia fat levels were 3,000 ppt (wet weight basis). Possible explanations for increased dioxin concentrations in Sen Lake tilapia between 2006 and 2009 include higher bioconcentration in larger fish over time, and longer residency periods for fish in the lake. Since cessation of fishing practices at Sen Lake in 2007, average fish sizes (and average age) appear to have increased over time, resulting in increased bioaccumulation in biological tissues.

- Fish samples analyzed from 12 other lakes on the Airport property in 2009 generally exhibited low dioxin levels. Therefore, the key concern is potential for consumption of contaminated fish from Sen Lake, and not from other water bodies on the Airport property.

- Analysis of blood dioxin/furan levels from randomly selected individuals in different communities surrounding the Airport in 2009 confirmed high concentrations in people living north, east and west of the Airport. Highest levels were again found in Sen Lake workers who were re-tested in 2009; their dioxin concentrations were not significantly different from those recorded in 2006. Although contamination levels in people living around the Airport are clearly from a variety of sources, working on the Airport was found to increase blood TEQ and TCDD above background levels.

- The distribution of blood dioxin levels in people from the wards surrounding the Airport (Anh Khe Ward in Thanh Khe District, Khue Trung Ward in Cam Le District, and Thuan Tay Ward in Hai Chau District) showed that working on the Airport was the strongest predictor of elevated dioxin levels in blood. Eating fish from Sen Lake also was deemed a significant risk factor for elevated dioxin in blood.

- TCDD concentrations in human blood from donors of Khue Trung Ward in Cam Le District, which exhibited the lowest TCDD and TEQ levels, were all less than 10 pg/g. The low percentage of TCDD in these TEQ values (none exceeded 40%) also indicated that it is unlikely that those sampled were directly impacted by Agent Orange exposure in soils, sediment, water or food supplies. This was also true for individuals sampled in 2006 from the reference area, Thuan Phuoc Ward in Hai Chau District.

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[52] USDA 1997.

- In contrast, some, but not all, individuals sampled from other wards surrounding the Airport exhibited TCDD concentrations greater than 10 pg/g. These include residents from Anh Khe Ward in Thanh Khe District, Thuan Tay Ward in Hai Chau District, and 2006 donors from Chinh Gian Ward in Hai Chau District. These wards are located on the east, north and west sides of the Airport, within 1 km of the boundary.

- Dioxins and furans were recorded in all breast milk samples analyzed in 2009 (n=14). All breast milk samples analyzed (n=14) exhibited TEQs exceeding the WHO Tolerable Daily Intake standard of 4 pg TEQ/kilogram body weight (kg bw)/day (d). Maximum levels were recorded in a young primaparous female (232 ppt TCDD) who previously consumed fish from Sen Lake.

A total of 410 environmental samples, including 198 soil/sediment, 41 fish/vegetation, and 171 human blood and breast milk samples were collected and analyzed for dioxin and furan concentrations over the course of the Hatfield/10-80 Division[53] and Hatfield/Office 33[54] studies conducted between 2005 and 2009. General conclusions from previous studies cited above, relevant to the estimation of contaminated area, and calculation of volume of contaminated of soils in the current USAID Project, are as follows:

- The northern end of the Airport is a significant dioxin hotspot. Soil and sediment samples from the southern, eastern, and western areas of the Airport exhibit significantly less dioxin contamination than those analyzed from the northern areas. Levels of dioxin contamination in samples analyzed from the southern Airport area near former Pacer Ivy sites were low.

- Concentrations of dioxins and furans in soils in the MLA and SA greatly exceed the GVN standard of 1,000 ppt TEQ.

- Dioxin concentrations in sediments of Sen Lake and north Airport drainage ditches were also markedly higher than the GVN standard of 150 pg/g TEQ.

- The drainage canals leading from the MLA and SA to and Sen Lake are likely the primary mechanism for spreading dioxin contaminated sediment beyond the Airport boundaries.

- Sample analysis suggests that there is minimal dioxin contamination in the southern Airport property near former Pacer Ivy sites.

- Sampling results discussed above have enabled the definition of dioxin hotspots at the Airport. These are primarily located in the northern portion of the Airport property and include the MLA, SA, Drainage Ditch, Sen Lake and the Eastern Wetland. In addition, a small hotspot is located in an isolated area of the southern portion of the Airport property at the PISA.

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[53] Hatfield/10-80 Division 2006.
[54] Hatfield/Office 33 2007 and Hatfield/Office 33 2009.

- The highest concentrations of dioxins in contaminated soils/sediments occur in the top 10-centimeter (cm) layer; some contamination was found at deeper levels (e.g., >30 cm), but only in limited areas in the MLA, SA, and PISA at the Airport.
- Other contaminants contributing to the polychlorinated dibenzo-p-dioxin (PCDD)/polychlorinated dibenzofuran (PCDF) load are also present in the environment and human population, both inside and outside the perimeter of the Airport, including PCBs, organochlorine pesticides, and hydrocarbons.
- Results from the Hatfield/Office 33 study[55] suggested that the interim mitigation measures implemented in 2007 have resulted in a reduction in exposure levels in the human population surrounding the Airport.

4.2.2. January 2010 USAID Sampling at Da Nang Airport

The analytical data collected prior to 2010 provided a detailed understanding of contamination at the Airport; however, additional data were needed to refine the lateral and vertical extent of contaminated material requiring cleanup. Specifically, more information was needed to complete the engineering designs and provide information that will guide decision-making related to site remediation. Therefore, a sampling and analysis plan (SAP) was prepared to obtain additional dioxin contamination information for the site.[56]

The specific data quality objectives (DQOs) of this SAP were as follows:

1. Determine the vertical and lateral extent of dioxin/furan contamination in soil in the MLA, SA, and Drainage Ditch.
2. Determine the vertical and lateral extent of dioxin/furan contamination in sediment of Sen Lake and the Eastern Wetland.
3. Determine chemical concentration baseline conditions for groundwater, surface water, and the proposed landfill site.
4. Determine whether COPCs other than dioxins/furans are present in soils and/or sediments that may affect the remedial design, O&M of the remedy, and/or health and safety aspects of the remedy implementation.
5. Determine whether soil properties of the contaminated soil would affect the remedial design.

Specific sampling and analysis was therefore performed to address each of these DQOs, as described in the SAP. Sampling at the Airport occurred at the MLA, SA, Sen Lake, Eastern Wetland, PISA, the proposed landfill site, and the key surface water and groundwater sites near the perimeter of the Airport. These data are presented in Appendix A1.

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[55] Hatfield/Office 33 2009.
[56] CDM 2010b.

Due to the high costs of analyzing all samples collected, some samples were categorized as Tier I and analyzed following collection, while others samples were set aside for future analysis (Tier II), as needed based on Tier I results. Tier I surface soil and sediment samples were analyzed for dioxins and furans. Soil and sediment core (i.e., subsurface) Tier I samples were also analyzed for particle size analysis and total organic carbon (TOC). Water samples were analyzed for polycyclic aromatic hydrocarbons (PAHs), PCBs, metals, and volatile organic compounds (VOCs). A small subset of surface soil and sediment samples were also analyzed for PAHs, PCBs, metals, and VOCs. Table A1.1 of Appendix A1 details the samples collected, and the number and type of analyses performed, for each type of environmental media.

The data collected satisfied the DQOs for this sampling effort, but also revealed new contaminated areas that will require further delineation either prior to Project implementation or as part of confirmation sampling conducted during Project implementation. The analytical results from the 2010 sampling program indicated that dioxin contamination at the northern end of the Airport is more extensive than indicated by earlier studies. Specifically, the reach of contamination potentially extends further west of the MLA, in an area that is currently under construction for the airport runway expansion. The lateral extent of contamination in the Drainage Ditch was significantly more widespread than originally anticipated, and an additional hotspot (Eastern Hotspot) to the east of the Drainage Ditch and SA was also identified.

Results of the 2010 sampling include the following, as organized by their respective DQO:

<u>DQO #1: Determine the vertical and lateral extent of dioxin/furan contamination in soil in the MLA, SA, and Drainage Ditch.</u>

- The lateral extent of contamination in the MLA was better defined, especially along the eastern and northern boundaries. Sampling along the west and northwest boundaries of the MLA identified additional dioxin contamination, and also areas that will require further sampling and analysis. Further sampling along the southern edge of the MLA was not possible due to the presence of Airport site utilities. Soil samples were also collected and analyzed from three soil cores that were advanced up to depths of 180 cm below ground surface. However, despite their proximity to samples collected in past studies that had indicated high dioxin concentrations in this area, many of these deeper samples did not exhibit contamination above the cleanup goals.

- The lateral extent of contamination at the SA was also better defined following the 2010 sampling program. The boundary of contamination was identified along the northwest corner. Additional contamination was identified along the west border of the SA, and along the south border towards the MLA. As with the MLA, further sampling to the west was not possible due to ongoing site construction activities. Soil samples collected at depths up to 150 cm and analyzed further defined the vertical extent of contamination.

- Samples collected along both sides of the Drainage Ditch (from the MLA and SA to Sen Lake) greatly improved the understanding of contamination extent in these areas. Sampling results identified contaminated areas along the entire extent of the Drainage Ditch, including the area between the MLA and the SA, and also identified a new hotspot (Eastern Hotspot) located between the Drainage Ditch and the Eastern Wetland. Sampling results helped identify the western extent of contamination along the Drainage Ditch north of the SA, but additional site characterization is also needed to verify this.

<u>DQO #2: Determine the vertical and lateral extent of dioxin/furan contamination in sediment of Sen Lake and the Eastern Wetland.</u>

- Sediment samples collected from Sen Lake provided a better understanding of contaminant distribution, both vertically and laterally.

- The samples collected in the Eastern Wetland provided a detailed understanding of contaminant distribution, as very limited data existed in this large area prior to the 2010 program. However, a significant portion of the Eastern Wetland was not accessible by the sampling team, due to the difficult terrain and health and safety considerations.

<u>DQO#3: Determine chemical concentration baseline conditions for groundwater, surface water, and the proposed landfill site.</u>

- Samples of site groundwater and surface water, including some collected from outside the Airport, provided baseline data for water hardness, total metals concentrations, and VOC, PCB, and PAH concentrations. The purpose of these samples was to establish baseline conditions to ensure that remediation activities do not have a detrimental impact on any of these constituents relative to their baseline concentrations.

- VOCs and PCBs were not detected in surface and groundwater samples.

- PAH (e.g., naphthalene, benzo[a]pyrene, benzo[a]anthracene, etc.) concentrations in groundwater were low, ranging from non-detect to 6.16 ppt. For comparison purposes, the USEPA maximum contaminant level (MCL) for public drinking water supplies for <u>total</u> PAHs is 200 ppt, which is well above the total concentration observed in all collected groundwater samples. PAH concentrations in surface water samples ranged from non-detect to 32.7 ppt.

- Groundwater and surface water samples were also analyzed to determine a baseline level for dioxins. Both groundwater samples were non-detect for 2,3,7,8-TCDD (the USEPA MCL for public drinking water supplies for 2,3,7,8-TCDD is 0.03 ppt). The two surface water samples collected from Sen Lake were non-detect for 2,3,7,8-TCDD and the surface water sample collected from the Drainage Ditch had a 2,3,7,8-TCDD concentration of 90.4 ppt.

- Samples collected at the proposed landfill site near the PISA provided additional information regarding dioxins and furan levels in this area.

DQO#4: Determine whether COPCs other than dioxins/furans are present in soils and/or sediments that may affect the remedial design, O&M of the remedy, and/or health and safety aspects of the remedy implementation.

- The data collected during the 2010 survey will help improve the basis for future design and planning related to remedy O&M and health and safety during implementation. The data collected are also helpful to GVN with respect to current and future construction and operations at the Airport.

- Background (i.e., naturally occurring and anthropogenic) levels of metals at the Airport are not known, but for comparison purposes, all metals levels were below USEPA Region 9 industrial PRGs with the exception of arsenic which ranged in concentration in soil and sediment from 6 to 328 parts per million (ppm) (the USEPA Region 9 industrial PRG for arsenic in soil is 1.6 ppm, no PRG is established for sediment).

- Several PAHs were detected with levels ranging from 0.1 to 44.5 ppm in all soil and sediment samples except one sediment sample collected from Sen Lake which had PAH levels ranging from 2.4 to 459 ppm. USEPA Region 9 has not established industrial PRGs for total PAHs. The levels of these COPCs will be considered when preparing the health and safety plans for the remedial action. All of these detections are far below levels that would have an impact on the design of the remedy.

- The concentrations of PCBs and VOCs were below detection limits, with the exception of a minor toluene detection of 0.240 ppm in one of the sediment samples; for comparison purposes, the USEPA Region 9 industrial PRG for toluene in industrial soil is 45,000 ppm. It should be noted that VOCs and other COPCs have previously been detected at the MLA, SA, and along Sen Lake during previous sampling efforts.

DQO#5: Determine whether soil properties of the contaminated soil would affect the remedial design.

- The soil property data collected confirm that the soils and sediments will be compatible with the remedial alternatives under consideration. The high fraction of sands present in the material will be conducive to remediation. The high percent moisture in the sediment can be reduced as needed. It is not expected that the low pHs or organic carbon observed would impact any of the remedial alternatives being considered.

- The estimated extent of contamination based on the 2010 sampling program and data from previous studies is presented in Figure 3.

Samples collected and analyzed in 2010 under the Project provided important new information about the site, as they comprise approximately one-third of the total number of soil and sediment samples analyzed from the northern end of the Airport. Using these 2010 data, and the previously collected data, the amount and extent of contaminated material requiring remediation was calculated with improved levels of accuracy. While conducting excavation, samples will be collected from the excavation limits to verify that all soil/sediment above the cleanup levels has been removed. A field screening method for dioxin analysis does not exist; therefore, all confirmation samples must be shipped to an analytical laboratory and will require a 2-3 week turnaround time for results. Having a reasonably accurate estimate of the amount and extent of dioxin-contaminated material at the Airport at this stage of the Project is critical to ensure that excessive iterations of excavation will not be required, resulting in cost increases and schedule delays.

However, data gaps remain in the following locations at the Airport:

- A small area along the southern edge of the MLA could not be sampled due to the presence of underground utilities.
- The Eastern Wetland could not be sampled as planned due to inaccessibility and health and safety concerns.
- The area west of the MLA and SA could not be sampled because airport officials did not allow the sampling team access due to Airport construction activity.
- The extent of contamination between the MLA and SA is not well understood, because this area was not known to be contaminated prior to these sampling efforts, and therefore few samples were collected and analyzed in this area.
- The extent of contamination north of the Eastern Hotspot between the Drainage Ditch and Sen Lake is not well known because this area was not known to be contaminated prior to these sampling efforts and because this area was not accessible during sampling.
- The depth of contamination in the MLA is not well understood because 2010 samples collected did not exhibit high dioxin concentrations, despite their proximity to areas previously[57] identified as having high concentrations. The 2010 samples do not show contamination below depths of 60 cm, but previously collected samples[58] show contamination well above cleanup goals in the samples collected from as deep as 90 cm below ground surface.
- Additional soil sampling and dioxin analysis will be required to verify depth of contamination at the MLA, and in perimeter areas of the MLA, SA and Sen Lake which have been disturbed by ongoing Airport construction activity.

Despite these uncertainties, estimates of the area and volume of dioxin contamination were determined using the results of all samples analyzed to date. All dioxin and furan data were arranged on a scale site plan and TEQ contours for areas were hand-drawn above the cleanup levels of 150 ppt for sediments and 1,000 ppt for soils. The contours were used to divide the site into discrete sections, each with differing levels of contamination, and the total area of each section was calculated. Appropriate excavation depths were determined for each section, based on TEQ data. Finally, each section's area was multiplied by its respective depth, and the

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[57] Xenobiotic Detection Systems Inc. 2006 and Hatfield/Office 33 2007.
[58] Xenobiotic Detection systems Inc. 2006.

contributions from each area were summed. This methodology is described in more detail in Appendix A2.

As noted above, the 2010 sampling effort expanded Project knowledge regarding the extent and area of contamination at the Airport. Areas that were not known to be contaminated were identified, such as the Eastern Hotspot between the Drainage Ditch and the Eastern Wetland, the area west of the MLA and the SA, the soils adjacent to the Drainage Ditch, and most of the Eastern Wetland. Areas that had previously not been included in excavation estimates, such as the PISA, were also included.

4.2.3. UPDATED SITE AREA PROFILE

Table 12 provides a summary of dioxin concentrations above cleanup goals for samples collected from 1997 through 2010. Although each of the sampling activities had different objectives, collectively, the data provide an overall sense of the extent to which dioxin concentrations of hotspot sites exceed cleanup goals. It is important to note that for purposes of this table, the extent of each hotspot location is as defined in Appendix A2, Figure A2.1; previous reports may have defined the extent of each hotspot differently. Also, the sampling locations are generally biased toward areas of higher concentration in that the sampling events specifically targeted areas suspected to have dioxin impacts. Given this context, 44% of the overall samples collected exceeded GVN's dioxin standards. Sixty-three percent of the samples analyzed from the MLA exceeded GVN standards, 79% of the samples from the Drainage Ditch exceeded standards, 33% of the samples from the SA exceeded standards, and 41% of samples from Sen Lake exceeded standards.

TABLE 12. SUMMARY OF RESULTS OF SAMPLING OF DIOXIN HOTSPOTS OF DA NANG AIRPORT 1997-2010

Media and Location[1]	Number of Samples	Minimum TCDD (as TEQ) Concentration (ppt)	Maximum TCDD (as TEQ) Concentration (ppt)	Number of Samples Exceeding GVN Dioxin Standard	Percentage of Samples Exceeding GVN Dioxin Standard
1997 MOD Sampling Results					
Soil					
Mixing and Loading Area	2	51,248	69,444	2	100%
Storage Area	1	42,576	42,576	1	100%
Pacer Ivy Storage Area	0	n/a	n/a	n/a	n/a
Eastern Hotspot[2]	0	n/a	n/a	n/a	n/a
Sediment					
Drainage Ditch	0	n/a	n/a	n/a	n/a
Sen Lake Complex	25	2.2	12,393	9	36%

TABLE 12. SUMMARY OF RESULTS OF SAMPLING OF DIOXIN HOTSPOTS OF DA NANG AIRPORT 1997-2010

Media and Location[1]	Number of Samples	Minimum TCDD (as TEQ) Concentration (ppt)	Maximum TCDD (as TEQ) Concentration (ppt)	Number of Samples Exceeding GVN Dioxin Standard	Percentage of Samples Exceeding GVN Dioxin Standard
2006 Hatfield Sampling Results					
Soil					
Mixing and Loading Area	9	899	365,000	8	89%
Storage Area[3]	10	24.5	106,000	7	70%
Pacer Ivy Storage Area	0	n/a	n/a	n/a	n/a
Eastern Hotspot[2]	1	1,830	1,830	1	100%
Sediment					
Drainage Ditch[4]	3	4,150	8,580	3	100%
Sen Lake Complex	15	18.9	6,820	7	47%
2009 Hatfield Sampling Results					
Soil					
Mixing and Loading Area	0	n/a	n/a	n/a	n/a
Storage Area	0	n/a	n/a	n/a	n/a
Pacer Ivy Storage Area	19	4.4	20,600	3	16%
Eastern Hotspot[2]	0	n/a	n/a	n/a	n/a
Sediment					
Drainage Ditch[5]	2	4,200	11,700	2	100%
Sen Lake Complex	2	2,740	4,540	2	100%
2010 USAID Sampling Results					
Soil					
Mixing and Loading Area	20	2.57	6,930	4	20%
Storage Area	12	768	41,900	5	42%
Pacer Ivy Storage Area	1	1,260	1,260	1	100%
Eastern Hotspot[2]	1	1,620	1,620	1	100%
Sediment					
Drainage Ditch[6]	9	152	13,100	6	67%
Sen Lake Complex	19	6.96	5,370	5	26%

TABLE 12. SUMMARY OF RESULTS OF SAMPLING OF DIOXIN HOTSPOTS OF DA NANG AIRPORT 1997-2010

Media and Location[1]	Number of Samples	Minimum TCDD (as TEQ) Concentration (ppt)	Maximum TCDD (as TEQ) Concentration (ppt)	Number of Samples Exceeding GVN Dioxin Standard	Percentage of Samples Exceeding GVN Dioxin Standard
			All Samples		
Soil					
Mixing and Loading Area	31	2.57	365,000	14	63%
Storage Area	23	768	106,000	13	33%
Pacer Ivy Storage Area	20	4.4	20,600	4	20%
Eastern Hotspot[2]	2	1,620	1,830	2	100%
Sediment					
Drainage Ditch	14	152	13,100	11	79%
Sen Lake Complex	61	2.2	12,393	23	41%
Overall Total	**151**	**2.2**	**365,000**	**67**	**44%**

Notes:
1 – The extent of each hotspot location is as defined in Appendix A2, Figure A2.1; previous reports may have defined the extent of each hotspot differently.
2 – The Eastern Hotspot is considered to be the area that includes SAP624 and 06VN042.
3 – The Storage Area listed in under the "2006 Hatfield Sampling Results" is considered to be the area that includes soil samples except, 06VN072 (water treatment basin adjacent to the Storage Area) – sediment.
4 – The Drainage Ditch listed in under the "2006 Hatfield Sampling Results" is considered to be the area that includes 06VN047 and 06VN048 (soils next to drainage ditch), 06VN081 (drainage ditch sediment).
5 – The Drainage Ditch listed in under the "2009 Hatfield Sampling Results" is considered to be the area that includes 304A (soils) next to drainage ditch and 302A (drainage ditch sediment).
6 – The Drainage Ditch listed under the "2010 USAID Sampling Results" is considered to be the area that includes seven soil samples (SAP626, SAP628, SAP630, and SAP634 through SAP637) and two sediment samples (SAP527 and SAP528).
n/a – no samples taken.

Table 13 presents a comparison of maximum observed dioxin concentrations in surface and subsurface soil and sediment samples analyzed from the Airport between 2007 and 2010 and GVN cleanup standards. As shown on the table, the maximum depth dioxin (TCDD as TEQ) has been detected at the MLA, SA, PISA, and Sen Lake is 180 cm, 150 cm, 115 cm, and 50 cm, respectively.

TABLE 13. TCDD (AS TEQ) CONCENTRATIONS OF DA NANG AIRPORT SURFACE AND SUBSURFACE SOIL AND SEDIMENT BASED ON HOTSPOT SAMPLING RESULTS 2007- 2010[1]

	Surface[2] Soil/Sediment		Subsurface[2] Soil/Sediment		
Media and Hotspot Location	**Maximum TEQ Surface Concentration and Depth**	**# of Times Maximum Surface Concentration Exceeds GVN Cleanup Standards[3]**	**Maximum TEQ Subsurface Concentration and Depth**	**# of Times Maximum Subsurface Concentration Exceeds GVN Cleanup Standards[3]**	**Maximum Depth TCDD (as TEQ) was Detected and Corresponding TEQ Concentration**
Soil					
Mixing and Loading Area	365,000 ppt (0-10 cm)	365	10,700 ppt (30-60 cm)	11	150-180 cm (21 ppt)
Storage Area	106,000 ppt (0-10 cm)	106	14,100 ppt (60-90 cm)	14	120-150 cm (50-727 ppt)
Pacer Ivy Storage Area	20,600 ppt (0-10 cm)	21	189 ppt (30-60 cm)	1.3	90-115 cm (7 ppt)
Eastern Hotspot	1,830 ppt (0-10 cm)	2	n/a	n/a	n/a
Mixed Soil and Sediment					
Drainage Ditch[4]	13,100 ppt (0-30 cm)	13	n/a	n/a	n/a
Sediment					
Sen Lake and Eastern Wetland	6,820 ppt (0-10 cm)	45	67 ppt (30-50 cm)	0	30-50 cm (15-67 ppt)

Notes:
1 – Data from USAID 2010 sampling and Hatfield/Office 33 2007 and 2009.
2 – Surface is defined as 0-30 cm, subsurface as depths greater than 30 cm.
3 - Soil Cleanup Standard = 1,000 ppt; Sediment Cleanup Standard = 150 ppt (TCVN: 8183 2009).
4 – Drainage ditch is a mix of soil and sediment samples.
n/a – no samples taken at subsurface depths.

Using all of the data collected to date, updated estimates of soil and sediment volumes were calculated. These estimates were derived from data collected during previous studies and results from the January 2010 sampling (Appendices A1 and A2). As a result of the 2010 sampling program and new data, the volume of contaminated material increased 50% above estimates based on previous studies. Table 14 provides the recent estimate of excavation volume (m^3) and footprint (m^2) for each hotspot. Figure 3 provides a map of northern area hotspots in association with drawings of airport expansion plans. There is considerable overlap between airport expansion plans with the western boundary of the MLA, SA and Sen Lake hotspots.[59] It will be necessary for GVN to take action to ensure the integrity of the remedial action program through eliminating potential conflicts with the airport expansion activity.

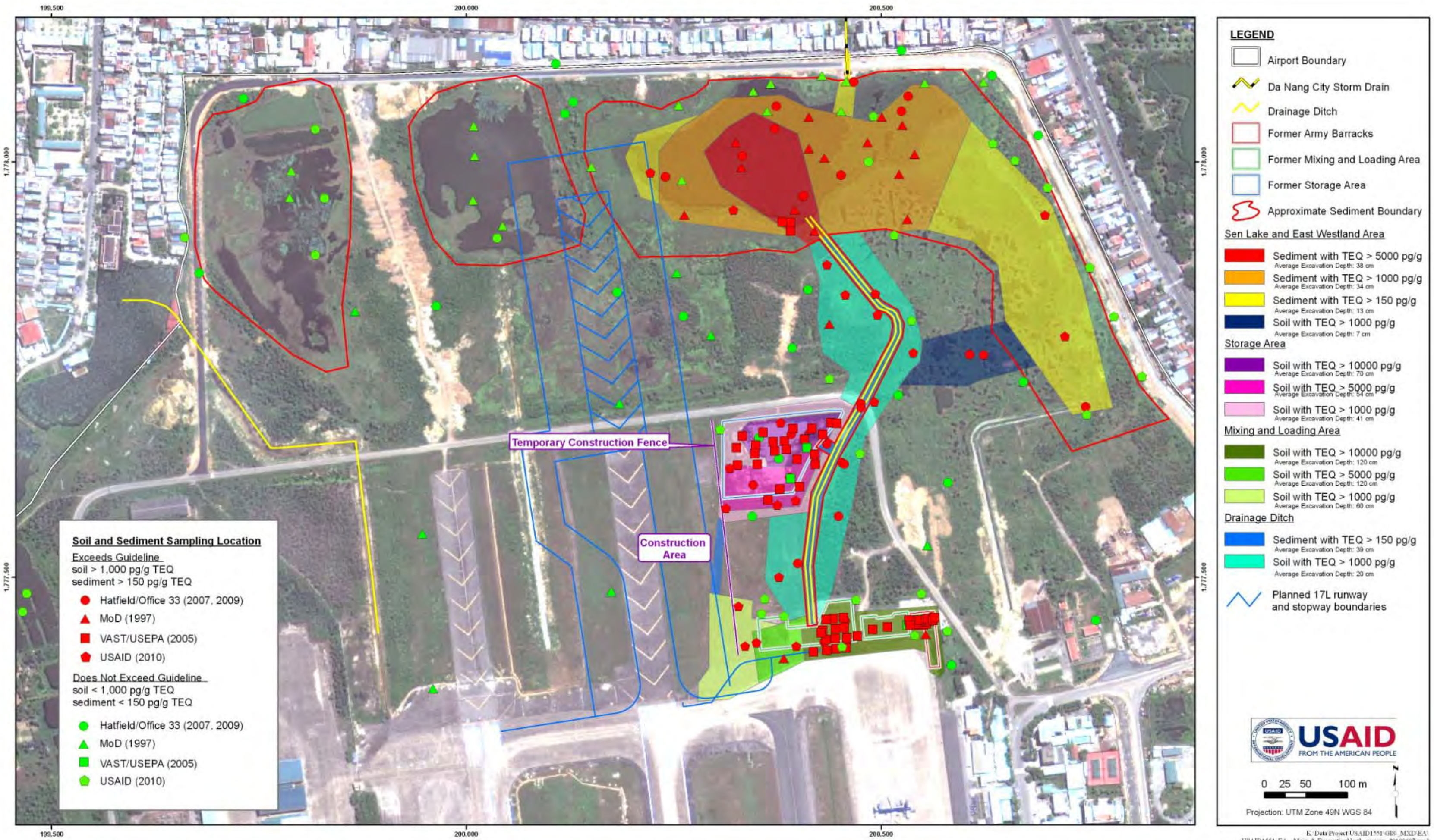
TABLE 14. AREA AND VOLUME ESTIMATES OF CONTAMINATED MATERIAL TO BE REMEDIATED

Hotspot	Estimates based on data from Previous Studies (Previous Estimates)		Estimates based on data from Previous and 2010 Studies (Current Estimates)	
	Area (m^2)	Volume(m^3)	Area (m^2)	Volume (m^3)
Mixing and Loading Area	10000	11000	19600	19500
Storage Area	13400	8500	16200	8900
Drainage Ditch	2900	1500	35600	8500
Eastern Hotspot	0	0	7700	500
Sen Lake and Eastern Wetland	40000	20000	85400	22800
Pacer Ivy Storage Area	0	0	3200	1400
Total	**66300**	**41000**	**167700**	**61600**

Average pre-treatment estimates were calculated for each of the hotspot areas, with average sediment dioxin concentrations estimated at 1,501 ppt, and average soil dioxin concentrations of 5,603 ppt (Table 15). It is important to note that these calculations should not be used to estimate human exposure prior to excavation because they include contaminated and uncontaminated media from a range of depths. Human exposure would most likely occur from surface contamination, where highest dioxin concentrations are found. Average concentrations are important when considering treatment technologies.

[59] Airport Expansion Plans provided by MAC.

FIGURE 3. ESTIMATED AREA TO BE EXCAVATED TO REACH GVN CLEANUP STANDARDS[60] (SOIL: 1000 PPT AND SEDIMENT: 150 PPT) IN RELATIONSHIP TO EXPANSION PLANS FOR THE NORTHERN AREA OF THE AIRPORT[61]



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[60] TCVN 8183: 2009.
[61] Airport Expansion Plans provided by MAC.

TABLE 15. AVERAGE PRE-TREATMENT CONCENTRATIONS OF DA NANG HOTSPOT AREAS

Hotspot	Average Pre-Treatment Concentration (ppt)*
Mixing and Loading Area	7,096
Storage Area	4,240
Drainage Ditch	3,905 (soil) / 2,720 (sediment)
Eastern Hotspot	1,710
Sen Lake and Eastern Wetland (sediments)	1,325
Pacer Ivy Storage Area	1,260

Notes:
These estimates were derived from data collected during previous studies conducted between 2007 and 2009 by Hatfield/Office 33, the estimates of dioxin contamination provided in Allen and Fong (2009), as well as results from additional samples collected in January 2010 (see Appendix A1) by USAID. Appendix A2 presents the methodology used to calculate the pre-treatment concentrations.

4.3. Potential Exposure Pathways

The existing evidence indicates that dioxin from the MLA and SA adheres to soil particles and moves via the Drainage Ditch and via air transport into Sen Lake and nearby areas. Humans are exposed through ingestion of contaminated fish, direct dermal contact with soils and sediments, and likely via inhalation of dust.

There are several potential exposure pathways identified at the Airport:

Localized Transport Pathways – Contaminated surface soil may travel via erosion and surface water runoff into waterways and wind driven dust.

Dietary Exposure/Ingestion – Fish originating from the Airbase were historically consumed by fishermen, their families, and likely some members of the general public. Aquatic animals (i.e., ducks) may also be a source of food exposure along with certain aquatic vegetation, particularly lotus.

Soil Ingestion – People and/or children who come in close and regular contact with contaminated soils derived from the site may ingest small amounts of the soil.

Dermal Absorption – Dermal absorption may occur in situations where certain people contact the soil or sediment during activities such as working onsite, or wading into sediments while fishing, harvesting lotus, etc. Soil or sediment contacting the skin for prolonged periods may result in small amounts of contaminant adhering and absorbing across the skin.

Inhalation of Fugitive Airborne Particulates – Because the surficial soil is contaminated, the finer contaminated particulates may, on occasion, become suspended in the air due to wind erosion or disturbance by vehicle traffic and then inhaled and absorbed across the respiratory pathway.

These pathways and the overall conceptual exposure model of dioxin contamination at the Airport are represented in Figure 4. Exposure pathways are summarized for each potential type of human receptor in Table 16.

TABLE 16. POTENTIALLY AFFECTED RECEPTORS AROUND DA NANG AIRPORT

People Impacted	Exposure Pathway
Workers and extended families	Localized transport pathways, dietary exposure, soil ingestion, dermal absorption, inhalation
Nearby Da Nang residents	Dietary exposure, soil ingestion, dermal absorption, inhalation
Airport passengers	Inhalation

Figure 4 illustrates and summarizes how contaminant sources, exposure pathways, and receptors are linked together to form the potential for health risk associated with dioxin contamination at the Airport.

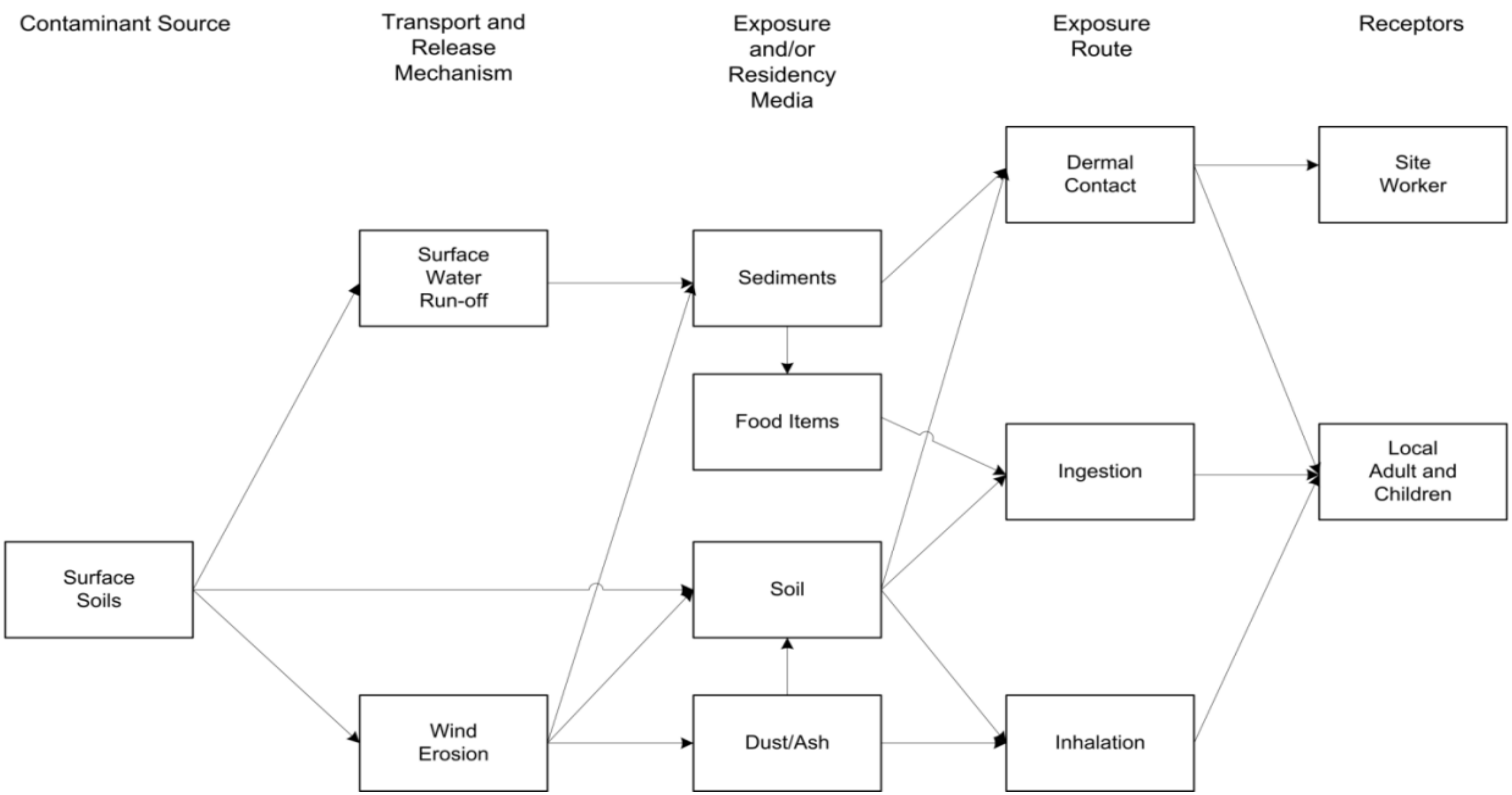
4.4. Gender Considerations

Vietnam has one of the highest economic participation rates in the world. In 2002, 85% of men and 83% of women between the ages of 15 and 60 were engaged in economic activity.[62] Men and women are employed in different sectors of the economy; men are more commonly employed in fishing, mining, construction, transport, and communications. Female-dominated industries include light manufacturing, health, and social work.[63] Within the construction industry, women constitute 12% of the labor force, and make up 26% of the transport and communications sector.[64] Due to their role in the household, women form a greater percentage of the informal labor force. Therefore, it is reasonable to assume that women may have previously or currently work at the Airport or may work at the Airport in the future.

There are provisions under Vietnam's Labor Code that are designed to protect women from hazardous environments. Article 113 of Chapter X[65] states that women may not be hired for "heavy or dangerous jobs which necessitate contact with noxious substances having harmful effects on their reproductive and child-rearing function." Vietnam's Law on Gender Equality also allows specific provisions for protecting the health and safety of women, while still promoting equal opportunities for men and women. Under Article 113, Section 1, 3a, employers must create safe working conditions for women that may have direct contact with noxious substances. Consideration of these restrictions will be a necessary component of designs and plans for an environmental remediation activity to ensure that they are adhered to. Examining gender differences and perceptions toward risk-taking in the workplace will also need to be considered as part of planning for the environmental remediation activity.

[62] World Bank and others 2003.
[63] ADB 2005.
[64] GSO 2003.
[65] Vietnam Labor Code: Article 113 of Chapter X: The labor user is not allowed to use female labor for heavy or dangerous jobs which necessitate contact with noxious substances having harmful effects on the reproductive and child rearing functions of the women laborer

FIGURE 4. CONCEPTUAL EXPOSURE MODEL FOR AFFECTED RECEPTORS AT DA NANG AIRPORT



Section 5. Alternatives Evaluation

5.1. Screening of Potentially Applicable Technologies/Strategies

A number of technologies and/or management strategies have potential applicability for treatment of dioxin contamination in soil and sediments. A screening process was used to identify the most viable technology options to consider as alternatives based on environmental impact, effectiveness, feasibility, and cost. Previous studies have been performed to review technologies potentially applicable to dioxins associated with Agent Orange in Vietnam.[66] The technologies that received unfavorable assessments in these reports were not considered further in this EA. The highest scoring technologies presented in the UNDP report are included.[67] The BEM (2007) report provided more weight to the cost criterion than to demonstrated treatment effectiveness; both are given equal weight in the current screening process. It is also important to note that if a technology/strategy is effective for containment, it can be retained for further consideration even if it is not effective for treatment. Table 17 shows the technologies and strategies considered for screening, as well as whether each was retained for more detailed evaluation. For each technology or strategy that was screened out, the criterion for which it did not meet is identified.

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[66] BEM 2007 and UNDP 2009b.
[67] UNDP 2009b.

TABLE 17. SCREENING OF POTENTIALLY APPLICABLE TECHNOLOGIES/STRATEGIES FOR DIOXIN REMEDIATION AT DA NANG AIRPORT

Technology/Strategy	Retained?	Criteria Not Met
No Action	Yes[1]	Effectiveness – will not meet cleanup objectives
Incineration	No	Effectiveness – shown to generate significant concentrations of dioxins in off-gas; this can be mitigated through off-gas treatment. Implementability – public perception could be a significant problem given the potential for dioxin air emissions.
Base-Catalyzed Decomposition	No	Implementability/Cost – large quantity of byproduct generated that would require a large landfill in addition to the treatment process.
Ball Milling with Active Landfill	No	Effectiveness – neither ball milling nor a biologically active landfill have been demonstrated at large scales to treat dioxins to below GVN cleanup standards. Implementability/Cost – this approach requires full-scale implementation of both technologies.
ISTD/IPTD	Yes	
Geo-Melt™ Process	No	Effectiveness – has never been applied full-scale for dioxin treatment
Passive Landfill	Yes[2]	
Active Landfill	Yes[3]	Effectiveness – has never been applied full-scale for dioxin treatment; has never been demonstrated to treat dioxins below GVN cleanup standards (1,000 ppt soil; 150 ppt sediment).

Notes:
1 – Retained as a baseline although it fails the effectiveness criterion.
2 – Expected to be effective for containment, but not for treatment.
3 – Expected to be effective for containment, but not demonstrated for treatment.

As a result of the screening process, assessment of site conditions, and input and feedback received during scoping sessions, four remedial alternatives were identified for assessment in the EA:

<u>No Action</u> – Under Section 6 of 22 CFR 216, the EA must include the alternative of No Action. The No Action alternative will examine the potential environmental impacts of not addressing dioxin contamination at the Airport. This alternative will establish baseline information and estimate the continuing routes of exposure that could persist over a number of years without action. This alternative will provide a baseline against which other alternatives can be assessed.

<u>Landfill Containment (Passive Landfill)</u> – This alternative would contain dioxin in a secure onsite landfill for 50 years. This was the originally proposed action at initiation of the EA process.

<u>Landfill Containment with Bioremediation (Active Landfill)</u> – This alternative would contain dioxin in a secure onsite landfill, but also include bioremediation as a dioxin destruction technology.

<u>ISTD/IPTD</u> – This alternative would make use of a high heat in situ/in-pile thermal desorption destruction process to treat dioxin. It would not require construction of a secure onsite landfill.

5.2. Evaluation Process of Retained Remedial Alternatives

The four retained alternatives were further evaluated through the consideration of: 1) effectiveness of the alternatives to achieve cleanup goals and ultimately be a final remedy for the Project; 2) implementability of each alternative; 3) the detailed assessment of relative environmental impacts for each alternative; and 4) development of conceptual designs for each alternative (to the extent possible) that served as the basis to evaluate cost. The discussion below provides an overview of each of the four alternatives, their effectiveness, implementability, and cost.

5.2.1. Conceptual Designs and Cost Estimates

Identification and evaluation of potential costs for remedial alternatives is integral to the evaluation process to help determine the best approach to address the contamination issue at the site. The remedial alternative costs presented in this EA were developed in accordance with A Guide to Developing and Documenting Cost Estimates During the Feasibility Study, EPA 540-R-00-002.[68] Although the EA process is distinct from the CERCLA (i.e., Superfund) FS process, the objectives and intent (as well as Project concept development) for this EA are sufficiently similar to the CERCLA process to warrant use of this guidance.

At the alternatives evaluation stage, the design for the remedial alternatives are still conceptual, not detailed, and the cost estimates are considered to be "order-of-magnitude." The cost engineer must make assumptions about the detailed design in order to prepare the cost estimate. As a project progresses, the design becomes more complete and the cost estimate becomes more "definitive," thus increasing the accuracy of the cost estimate.

The remedial alternative cost estimates were developed during the EA primarily for the purpose of comparing Project alternatives during the remedial selection process, not for establishing Project budgets. As a remedial alternative moves from the planning stage into the design and implementation stage, the level of project definition increases, thus allowing for a more accurate cost estimate. An "early" estimate of the remedial alternative's life cycle costs is made during the FS to make a remedy selection decision. The levels of detail employed in making these estimates are conceptual, but are considered appropriate for making choices between alternatives. The information provided in the cost estimate is based on the best available information regarding the anticipated scope of the remedial alternatives. As a project progresses, the design becomes more complete and the cost estimate becomes more "definitive," thus increasing the accuracy of the cost estimate.

Costs for remedial alternatives are expected to have accuracies between -30% to +50% of actual costs, based on the scope presented. However, in this case, cost estimates have been substantially refined to take into account better estimates obtained in this study for volume of material to be treated, labor costs, power costs, and value added taxes. Therefore, the actual cost range of these estimates may be narrower than -30% to +50%, but the true range is difficult to determine. Factors such as increased project duration and phased implementation that might require longer field implementation time and strengthened temporary containment

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[68] USEPA 2000.

measures will increase the cost, although by an undetermined amount. It is important to note that the costs were valued consistently across alternatives, and therefore, estimates allow for reliable comparisons between alternatives.

Flexibility is incorporated into each alternative for the location of Project facilities and the period in which Project implementation will be completed. Assumptions of the Project scope and duration are defined for each alternative to provide cost estimates for the various remedial alternatives. Important assumptions specific to each remedial alternative are summarized in the description of the alternative. Additional assumptions are included in the detailed cost estimate backup, which can be found in Appendix A3.

5.2.2. Effectiveness and Implementability

Each alternative was evaluated based on its effectiveness for containment and treatment. For this EA, strong consideration is given to whether the alternative provides a "final remedy" that would reduce dioxin concentrations to meet GVN standards.

All alternatives were determined to be implementable at the Airport, but each has specific challenges associated with implementation. The implementability challenges are discussed below for each alternative.

5.2.3. Environmental Impact

Detailed assessments of the potential environmental impacts associated with each alternative were conducted and used to rank the alternatives to determine the environmentally preferred alternative.

5.3. Alternatives Evaluation Findings

5.3.1. No Action Alternative

Under Section 6 of 22 CFR 216(c)(3), the EA must include the alternative of No Action. The No Action alternative examines the potential environmental impacts of not addressing dioxin contamination at the Airport. This alternative establishes baseline information and estimates the continuing routes of exposure that could persist over a number of years without action. This alternative provides a baseline against which other alternatives are assessed.

Conceptual Design

Under the No Action alternative, the contaminated soil/sediment would be left in place and no mitigation measures would be implemented.

Effectiveness

The No Action alternative would not effectively reduce dioxin concentrations to meet GVN cleanup standards. As a result, exposure pathways would remain that pose a potential threat to environmental, biological, and human receptors. Without action and given current levels of contamination, existing dioxin pathways would likely persist for several decades or longer. This situation would be unacceptable to the USG and the GVN.

Implementability

The No Action alternative is implementable, as it does not require any action.

Cost

The No Action alternative has no cost associated with implementation or long- term O&M. However, there would be significant externalized costs, such as the costs associated with illness that might result from exposure to dioxin above remediation goals. While these costs cannot be quantified, they are important and could be substantial.

5.3.2. Passive Landfill Alternative

Conceptual Design

The conceptual design of the Passive Landfill was developed from GVN Decision No. 60/2002/QD-BKHCNMT, and similar USEPA regulations,[69] which provide technical guidance for the design of hazardous waste landfills. In general, the Passive Landfill alternative would consist of: excavating contaminated soil from the MLA, SA, Drainage Ditch, Eastern Hotspot, and PISA; excavating contaminated sediments from the Drainage Ditch, Sen Lake, and Eastern Wetland; dewatering the contaminated material; and transporting contaminated material to a constructed landfill located in the southwestern area of the Airport property. Several munitions bunkers are present at this site, and for purposes of the EA, it has been assumed that these bunkers would be removed prior to landfill construction. If removal of the munitions bunkers from the proposed landfill site is not possible, then it will be necessary to consider alternative sites elsewhere on the Airport property.

Figure 5 shows the general location of each of the major components of the Passive Landfill alternative (excavation/hotspot areas, Temporary Storage and Dewatering Area, landfill site, and haul road) in an overall plan view of the Airport. Figure 6 is a conceptual plan view layout of the Passive Landfill alternative, and Figure 7 provides a conceptual cross section of the Passive Landfill alternative to show key components of the landfill.

Mobilization and Project Preparation

Clearing all Project Areas of UXO – All existing UXO within the Project area (excavation areas, Temporary Storage and Dewatering Area, and landfill site) would be detected and cleared prior to the commencement of any Project activities. In addition, the munitions bunkers at the landfill site would be cleared and demolished prior to landfill construction.

Equipment, Facilities, Project Setup – Equipment and vehicles would be procured, two equipment decontamination stations would be constructed (one in the area of the hotspots and another in the landfill area), and the Project work areas would be set up. The set up would include establishing surface water runoff diversions around the main Project work areas to minimize the amount of project-affected water requiring treatment before being returned to existing drainages. It is expected that diverted surface runoff would be conveyed to the natural drainage entering the eastern wetland.

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[69] 40 CFR 264, Subpart N.

FIGURE 5. CONCEPTUAL DESIGN OF REMEDIAL ALTERNATIVES PROPOSED FOR THE DA NANG AIRPORT

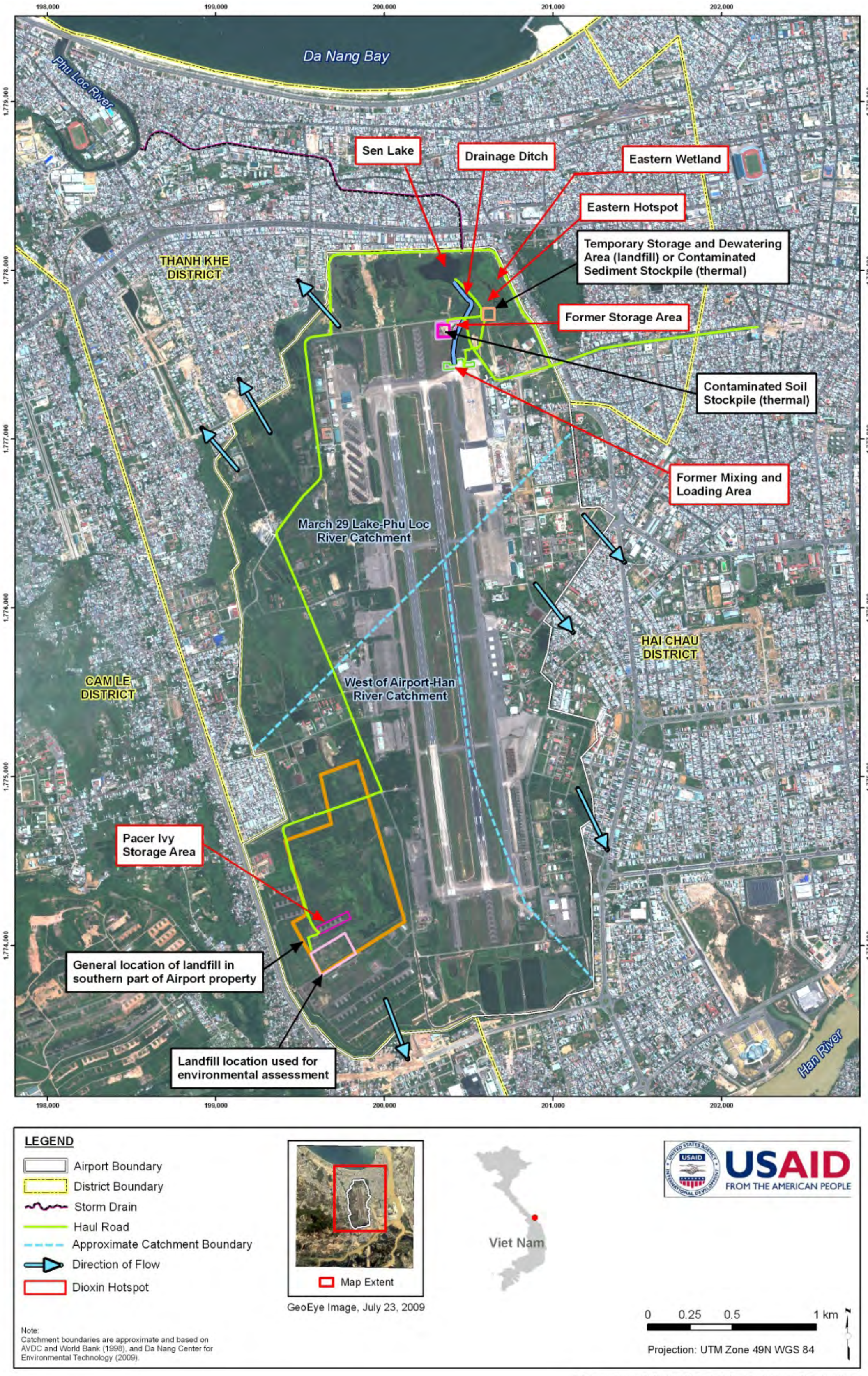
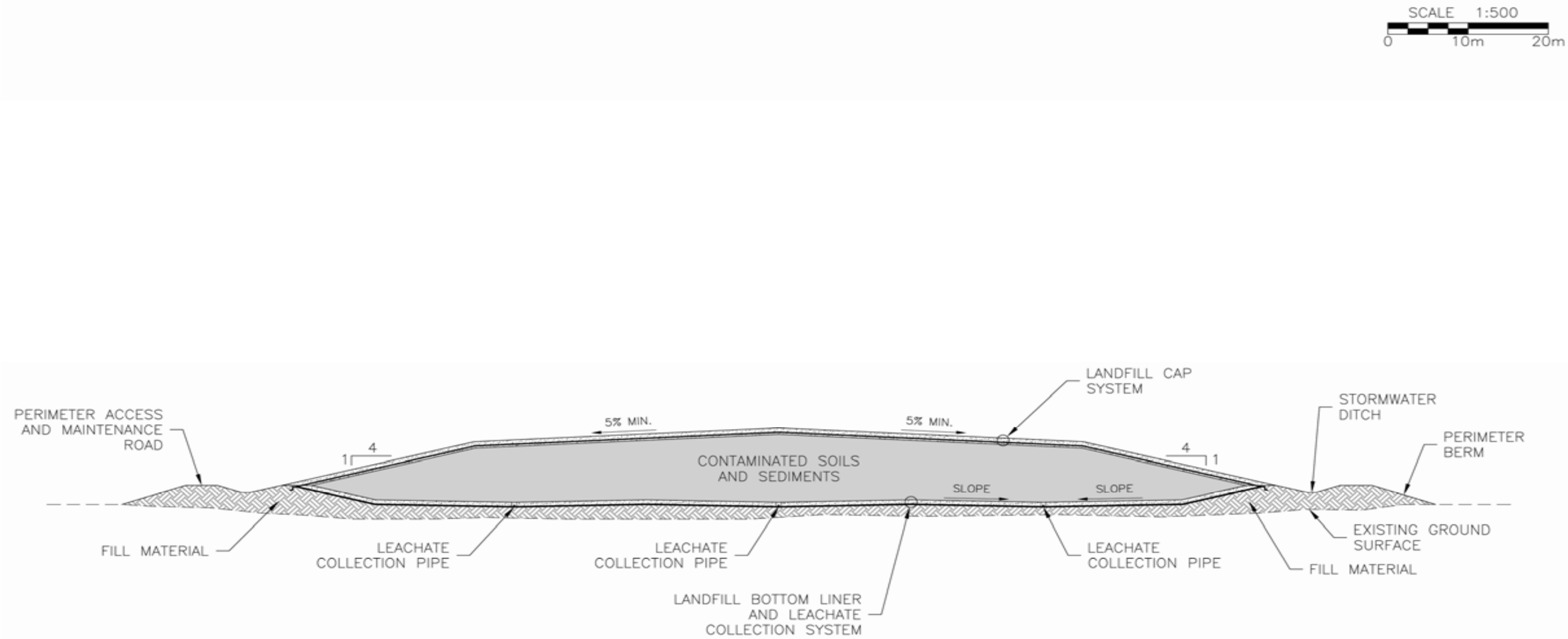


FIGURE 6. CONCEPTUAL LAYOUT OF PASSIVE LANDFILL ALTERNATIVE

FIGURE 7. CONCEPTUAL LANDFILL CROSS-SECTION



Construction of Temporary Storage and Dewatering Area for Contaminated Material – All excavated contaminated material (soil and sediments) would be dewatered in an approximately 2.1 ha temporary storage area. Project-affected water generated from the Temporary Storage and Dewatering Area would be returned to natural drainages when GVN discharge standards are met after treatment.

Haul Road Upgrading and Widening – The 7.4-km haul road from the hotspot area in the northeastern part of the Airport property to the landfill site in the southwestern part would be upgraded and widened to accommodate truck traffic hauling contaminated material from the Temporary Storage and Dewatering Area to the landfill. This would consist of widening the haul road to 10 meters (m) and repaving it.

Excavation of Contaminated Material

Excavation of Contaminated Soils from MLA and Placement into Temporary Storage and Dewatering Area – The MLA area (Photo 1, which can be found in the Photo Section following the text) would first be cleared and grubbed in preparation for excavation. An estimated 19,500 m^3 of contaminated soil from the MLA would then be excavated and transported to the Temporary Storage and Dewatering Area. To minimize the generation of project-affected water from precipitation and groundwater seepage, excavated areas would be filled with clean soil (likely from offsite borrow sources) as soon as practicable after excavation.

Estimates of the locations to be excavated and depths to which excavation would be required are described in Appendix A2. Confirmation sampling will determine the final excavation limits within the MLA.

Excavation of Contaminated Soils and Sediments from SA and Drainage Ditch and Placement into Temporary Storage and Dewatering Area – The SA and Drainage Ditch would first be cleared and grubbed in preparation for excavation (Photo 2, Photo 3, and Photo 4). An estimated 17,400 m^3 of contaminated soil and sediments from the SA and Drainage Ditch would then be excavated and transported to the Temporary Storage and Dewatering Area. As with excavation in the MLA, excavated areas in the SA and Drainage Ditch areas would be filled with clean soil as soon as practicable after excavation so as to minimize the generation of project-affected water from precipitation and groundwater seepage. Water normally conveyed to Sen Lake by the Drainage Ditch would be re-routed to the natural drainage entering the eastern wetland.

Estimates of the locations to be excavated and depths to which excavation would be required are described in Appendix A2. Confirmation sampling will be needed to determine the final excavation limits within the SA and Drainage Ditch.

Excavation of Contaminated Soils from PISA and Placement into Landfill – The PISA would first be cleared and grubbed in preparation for excavation. An estimated 1,400 m^3 of contaminated soil would then be excavated and transported directly to the landfill since the two are in close proximity of one another. To minimize the generation of project-affected water from precipitation and groundwater seepage, excavated areas would be filled with clean soil (likely from offsite borrow sources) as soon as practicable after excavation.

Estimates of the locations to be excavated and depths to which excavation would be required are described in Appendix A2. Confirmation sampling will be needed to determine the final excavation limits within the PISA.

Excavation of Contaminated Soils and Sediments from Eastern Hotspot and Placement into Temporary Storage and Dewatering Area – The Eastern Hotspot would first be cleared and grubbed in preparation for excavation. An estimated 500 m^3 of contaminated soil would then be excavated and transported to the Temporary Storage and Dewatering Area. Excavated areas would be filled with clean soil as soon as practicable after excavation so as to minimize the generation of project-affected water from precipitation and groundwater seepage.

Estimates of the locations to be excavated and depths to which excavation would be required are described in Appendix A2. Confirmation sampling will determine the final excavation limits within the Eastern Hotspot.

Excavation of Contaminated Sediments from Sen Lake and Placement into Temporary Storage and Dewatering Area (Photo 5) – An estimated 22,800 m^3 of contaminated sediments will be excavated from Sen Lake and the associated wetlands. The excavation of contaminated sediments from Sen Lake is expected to proceed as follows:

1. Two inflatable Aqua Dam bladders would be placed in the lake to divide it into three separate areas.
2. Water from one portion of the lake would be pumped into other parts of the lake, taking care to ensure the flow rate of pumped water does not exceed the conveyance capacity of the Sen Lake outlet and culvert.
3. Sediment would be excavated from one of the drained portions of the lake and transported to and placed in the Temporary Storage and Dewatering Area.
4. The process would be repeated with the two remaining parts of the lake. It may be necessary to temporarily divert water entering the Eastern Wetland (and therefore the eastern third of the lake) when the eastern third of the lake is drained and excavated.
5. The inflatable Aqua Dam bladders would be removed and required drainage systems restored after excavation, returning the lake to previous conditions, with contaminated sediments.

The specific portions of Sen Lake to be excavated and the specific depths to which excavation would be required, will depend on final delineation of specific hotspots areas within Sen Lake and the Eastern Wetland.

Landfill Construction

Clean Soil Fill – Approximately 75,000 m^3 of clean fill from offsite borrow sources would be needed to establish a landfill subgrade above flood levels and used for construction, operation, and closure of the landfill. This clean fill would be hauled to the landfill site from borrow pits off the Airport property.

Functional Components – The conceptual design for the Passive Landfill alternative includes three major functional components: 1) the bottom liner system; 2) the leachate collection and removal system; and, 3) the final cap system.

Bottom Liner System

The bottom liner prevents offsite migration of any liquids and leachate from the contaminated soil and sediments in the landfill to the surrounding subsurface. Typically, landfill bottom liners are a combination of several layers, each designed to stop leachate migration and/or allow its extraction. The layers included in this design are as follows, from bottom to top:

- A compacted soil subgrade, constructed from imported fill material, which keeps the bottom of the landfill above historical flood levels.
- A geosynthetic clay liner (GCL), which provides the last barrier for migration of leachate outside the landfill.
- A 60-mil thick high-density polyethylene (HDPE) geomembrane, referred to as the Secondary Liner, which has extremely low permeability and strong chemical resistance.
- A geocomposite layer, where any leaks through the primary geomembrane would be detected and removed by a collection system.
- Another 60-mil thick HDPE geomembrane (the primary liner), which forms the primary barrier to leachate migration.

This conceptual arrangement is typically used to provide the functional redundancy and additional measures of safety desired for hazardous waste landfills. These layers are shown conceptually in the cross-section presented in Figure 7. The inclusion of sufficient fill to elevate the landfill above the flood level is a critical component, as this type of landfill design is not expected to provide the same duration of environmental protection when partially submerged as it will when elevated.

Leachate Collection and Removal System

The primary function of the leachate collection and removal system is to collect and remove leachate before it can permeate the liner layers. In this design, the leachate collection system is located immediately above the bottom liner system and consists of a geocomposite layer overlain by a 60-cm layer of sand. The sand serves as a drainage layer and a protective cover for the liner system. The leachate is collected within pipes wrapped in gravel that are spaced at intervals across the bottom of the landfill. The pipes will convey the leachate to a treatment system, likely consisting of a concrete vault or chamber containing activated carbon, where it is treated prior to discharge.

Final Cap System

This conceptual design is based on the assumption that during placement of the contaminated soil and sediment, a clean soil cover will periodically be placed over the top to limit the area of exposed contaminated media. However, when additional material is ready to be placed, the majority of any soil cover may be removed to maximize the capacity of the landfill for contaminated soils and sediments. Once all the contaminated soil has been hauled to and placed in the landfill, a permanent landfill cap would be constructed to fully encapsulate the landfill.

The landfill cap is designed to prevent liquid from infiltrating the landfill and becoming leachate. The components of the permanent landfill cap design, from bottom to top, are:

- A 30-cm intermediate soil cover over contaminated soil and sediment.
- A GCL layer, as a last barrier to prevent infiltration.
- A 40-mil linear low-density polyethylene (LLDPE) geomembrane, which offers good ultraviolet and chemical resistance and high tensile strength without sacrificing flexibility.
- A geocomposite layer to protect the geomembrane and provide drainage of the overlying soil cover.
- A 60-cm soil cover.
- Grass, which is designed to prevent surface erosion.

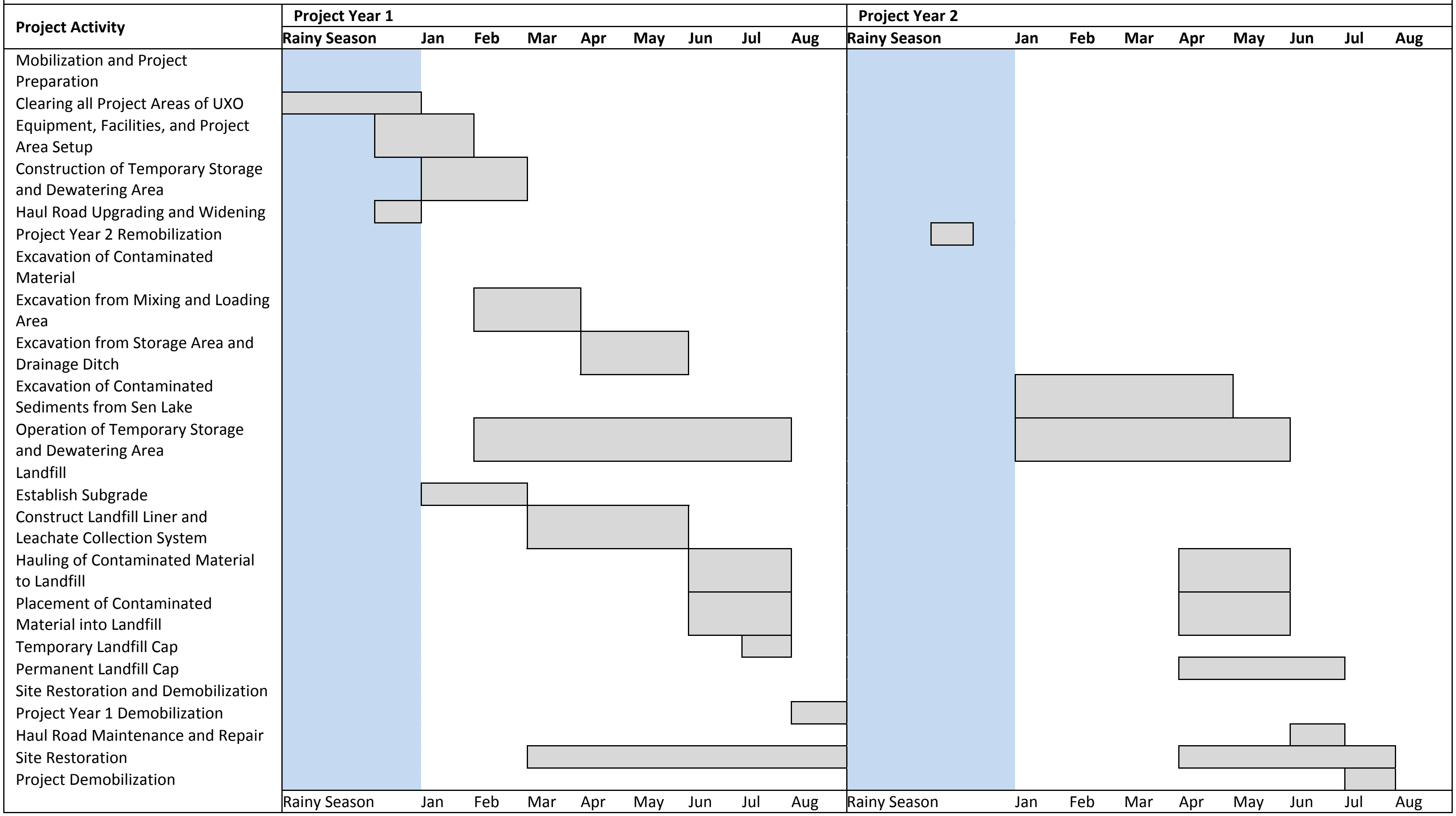
Similar to the bottom liner system, the final cap system is designed to prevent downward migration of water. However, rather than collect the water, the cap is designed to shed the water. The cap will have a minimum slope in all areas of 5% to minimize infiltration. A temporary cap would be used after Year 1 to minimize infiltration during the rainy season. The sides of the landfill will be sloped at 4 horizontal to 1 vertical (4H:1V or 25%) to minimize the required footprint, which is expected to be 110 m by 210 m (excluding support facilities).

Stormwater that drains off the cap will be collected by perimeter ditches and routed to ponds prior to discharge. An access road will encircle the landfill and also provide access to the top of the landfill.

<u>Hauling of Contaminated Material to Landfill</u> – Contaminated material would be hauled along the upgraded 7.4-km haul road from the Temporary Storage and Dewatering Area to the landfill location. Contaminated soils would be hauled in Project Year 1, while contaminated sediments would be hauled in Project Year 2 (see construction and operation schedule in Figure 8). The dredging of Sen Lake and removal of contaminated sediments will occur after the soil excavations to prevent cross-contamination.

<u>Placement of Contaminated Material into Landfill</u> – Contaminated material would be placed within cells in the landfill, with the landfill cells being filled sequentially. Depending on the amount of soil and sediment excavated, it is expected that the height of the landfill will be between 4 and 8 m.

FIGURE 8. INDICATIVE PROJECT SCHEDULE FOR PASSIVE LANDFILL ALTERNATIVE



Site Restoration and Demobilization

Haul Road Maintenance and Repair – Repairs to and maintenance of the haul road would be conducted once all contaminated material has been transported to the landfill, in order to return the road to its pre-Project use of being the major north-south access route for the Airport.

Site Restoration – Site restoration activities would be decided in consultation with the Airport Authority and would generally consist of returning project-affected areas to pre-project or better conditions.

Project Demobilization – All Project equipment and facilities would be removed from the Project area.

Footprint

The area of the total footprint for the Passive Landfill alternative is estimated to be 296,050 m^2, consisting of:

- 167,700 m^2 of area of contaminated soils and sediments to be excavated;
- 21,000 m^2 for the Temporary Storage and Dewatering Area;
- 74,000 m^2 for haul road upgrade and widening; and
- 33,350 m^2 for the landfill footprint.

Construction and Operation Schedule

It is expected that the Passive Landfill alternative would be constructed over a 2-year period. For cost estimation purposes, it is assumed that the Passive Landfill would require long term O&M for 50 years after closure, according to GVN requirements.

The main schedule components for implementation of the Passive Landfill alternative are as follows (Figure 8):

Year 1

- UXO Clearance: September – December (4 months, rainy season)
- Mobilization and Preparation: completed in February (~3 months)
- Soils Excavation: February through May (4 months)
- Landfill Construction: January through May (5 months)
- Site Restoration and Demobilization: March through August (6 months)

Year 2

- Remobilization and Preparation: completed before December (~1 month)

- Sediments Excavation: January through May (5 months)
- Landfill Construction: April through June (3 months)
- Site Restoration and Demobilization: April through July (4 months)

Effectiveness

Effective for containment – Hazardous waste landfills have been used successfully for decades worldwide to contain a variety of contaminants, including dioxins, furans, and other persistent organic pollutants. Design guidance and regulations for such landfills are readily available in the U.S., Vietnam, and in many other countries. This is a proven containment strategy.

Ineffective for treatment – The environmental half-life for chlorinated dioxins without some form of active treatment is generally thought to be measured in decades[70]. The dioxins would be expected to persist for many decades and would require eventual treatment.

Implementability

Landfill Siting Concerns

The Passive Landfill alternative would occupy a footprint of about 100 m by 210 m, or slightly larger than four football fields in size. An ideal site for a hazardous waste landfill of necessary size and without deficiencies or issues does not exist on the Airport property. Shallow groundwater, flooding potential, proximity to adjacent residences and developments, future airport expansion plans, and existing structures (i.e., munitions bunkers) are some of the siting challenges. These issues can be overcome, but with impact to cost.

Three locations at the Airport were evaluated during a site visit on December 14, 2009 as potential landfill sites for the containment of dioxin contaminated soil and sediment. All three locations, described in more detail below, were noted to have deficiencies and issues. Sites 1 and 2 are not deemed suitable due to their inadequate buffers, space restrictions, proximity to water bodies, and potential conflicts with future development. If the munitions bunkers identified in Site 3 can be demolished and removed, it is believed that Site 3 is the most suitable location due to its relative isolation, available buffers from the Airport and surrounding community, and ample space for the landfill and support facilities. If the removal of the bunkers is not possible, then it will be necessary to consider alternative sites elsewhere on the property, such as immediately north of Site 3.

Site 1 – Area East of Sen Lake

The proposed area is located on a narrow strip of land between the airbase perimeter road and Sen Lake. Based on the available future development plans for the Airport for Year 2015 and Year 2025, this area will be developed. As a result, either the development plans will need to be modified to account for the landfill or, if not feasible, the site will need to be eliminated from consideration.

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[70] Field and Sierra-Alvarez 2008.

The site is in close proximity to the airbase perimeter wall (less than 10 to 15 m) and surrounding community and homes (15 to 20 m). The site is long and narrow (approximately 275 m by 50 m). In general, landfill sites that have uniform perimeters (square) are more cost effective. The site may not have sufficient space to accommodate the excavated soils and sediment without expanding into the eastern portion of Sen Lake. This would increase construction costs and also decrease the storage capacity of Sen Lake.

For construction, adequate room to accommodate contractor staging and storage areas does not appear to exist nearby. The more remote these areas are from the landfill construction site, the greater the construction cost will be. The location would abut Sen Lake and, as a result, there would be little to no buffer between the landfill and the lake. This area of the airbase is the lowest and prone to flooding. As it is desirable to construct a landfill above the flood stages, additional fill material will be required to establish the landfill subgrade. Of the three sites, it is the closest to the contaminated soil and sediment areas and would have the shortest haul distance. The haul route for excavated soil and sediment would require interaction with civilian traffic near the airport entrance and also come in close proximity (< 20 m) to homes along the airbase perimeter.

Site 2 – Lake C

The proposed area would be located in Lake C at the north end of the western runway. In order to construct a landfill that is not located in the groundwater, it will be necessary to dewater, demuck, and backfill the lake. This will result in substantially increased construction costs. While constructing a lined landfill below the groundwater level may be feasible, it will be a more complex design and more expensive to construct due to added dewatering requirements, pumping systems, and general construction costs. In addition, O&M costs will be substantially higher due to the required pumping systems throughout the life of the landfill, including post-closure.

The site is in close proximity to the airbase perimeter wall and surrounding community and homes. The site will likely have sufficient space to accommodate the excavated soils and sediments. However, the elimination of Lake C will reduce the water storage capacity of the airbase. This area of the airbase is prone to flooding. As it is desirable to construct a landfill above the flood stages, additional fill material will be required to establish the landfill subgrade.

Height limitations to the landfill will be critical due to the close proximity of Lake C to the end of the runways. In addition, there may also be additional limitations placed on construction, such as equipment heights, hours of operation, etc. In the event that it may be desired to extend the western runway in the future, the landfill cannot encroach upon the eastern portion of Lake C that would be in line with the runway.

Of the three proposed sites, Lake C is the second closest to the contaminated soil and sediment areas. The haul route for excavated soil and sediment would require interaction with civilian traffic near the airport entrance and also come in close proximity (< 20 m) to homes along the airbase perimeter.

<u>Site 3 – Area West of South End of Airport</u>

The site is located in the southwest corner of the airbase, to the west of the runways, and is part of the West of Airport-Han River Catchment.

Of the three potential sites, this site is the most isolated, offers the greatest buffers from the runways and surrounding community/homes, and provides the most space to accommodate the landfill and associated facilities (i.e., stormwater ponds, leachate management, contractor staging and storage areas, etc.). The site currently has approximately 13 ammunition bunkers, at least some of which will require removal and demolition. If removal of the bunkers is not possible, the site does not have sufficient room to accommodate the landfill and will not be suitable. While the site is located on the higher ground of the airbase, there is a depression in the landfill area that appears to hold water during parts of the year. As it is desirable to construct a landfill above the flood stages and groundwater, additional fill material will be required to establish the landfill subgrade.

As the site is located perpendicular to the runway, it might provide an opportunity to obtain a greater landfill height relative to the other two potential landfill locations. However, of the three sites, it is the farthest from the contaminated soil and sediment areas, and would have the longest haul distance. The haul route for excavated soil and sediment would require interaction with civilian traffic near the airport entrance and also come in close proximity to homes along the northern airbase perimeter and buildings on the west side of the airbase.

The potential haul route on the west side of the airbase is bumpy and rough. The road will require improvements to reduce the potential for spillage and/or require limitations on vehicle speed and traffic control.

Haul Route

The relatively long haul route, especially for Site 3, and the number of trucks required for the volume of contaminated material increase both the environmental impact and the cost significantly. Shortening the route may not be feasible due to the requirements of minimizing impacts to airport operations and safety considerations.

Fill Material

A significant amount of fill material (~140,000 m^3) will be required for landfill construction, operation, and closure. The fill material will be used to establish a landfill subgrade above flood-prone areas, and to construct the dewatering area, leachate collection system, operational cover, and the final cover system. This is primarily a cost issue, but also affects the environmental impact.

<u>Cost</u>

At the alternatives evaluation stage, the design for the remedial alternatives are still conceptual, not detailed, and the cost estimates are considered to be "order-of-magnitude." The cost engineer must make assumptions about the detailed design in order to prepare the cost estimate. Costs for remedial alternatives are expected to have accuracies between -30% to +50% of actual costs, based on the scope presented. The accuracy range of –30% to +50%

means that, for an estimate of $100,000, the actual cost of an alternative is expected to be between $70,000 and $150,000. Detailed cost estimate backup is provided in Appendix A3. The total cost estimate for this alternative is $35.8M, comprising construction ($10.28M), excavation and disposal ($11.5M), O&M ($3.26M), and monitoring and mitigation ($10.8M).

The construction cost estimate for this alternative is split into two sections: the "Landfill Passive" estimate includes work that is specific to this alternative and the "Landfill Disposal" estimate includes work that is common to both landfill alternatives, such as excavation of the contaminated soils and sediments. Main elements of the two sections of this cost estimate are listed below. A summary of the overall Passive Landfill alternative cost is provided in Table 18 and detailed backup of the cost estimate is provided in Appendix A3.

The "Landfill Passive" estimate includes the following costs:

Landfill Construction

- Site preparation: clearing and grubbing of the proposed landfill location and UXO clearing and disposal, but not demolition of the munitions bunkers.
- Grading: placement of subgrade fill to bring the landfill above the flood level, and fill for the perimeter berm and longitudinal slope.
- Liner system installation: placement of the bottom liner layers, leachate collection system piping, and the leachate treatment manhole.

Landfill Operation

- Spreading and compaction of contaminated soils and sediments in place at the landfill.
- Installation of the remaining leachate treatment system components.
- Monitoring well network installation.

Landfill Closure – installation of the cap layers.

Indirect Costs – permits, insurance, and bonds; general conditions; overhead; and profit, but not tax, escalation, or contingency (contingency is added later).

The "Landfill Disposal" estimate includes the following costs:

Site Preparation – installation and maintenance of decontamination areas at excavation sites, traffic control, health and safety oversight during all phases of work, clearing and grubbing the sites, construction of soil storage and dewatering areas, and UXO clearing or disposal.

Excavation – excavation of MLA, SA, Drainage Ditch, PISA, Eastern Hotspot, Sen Lake, and Eastern Wetland (using Aqua Dam bladders).

Hauling – from excavation sites and Temporary Storage and Dewatering Areas to landfill location.

TABLE 18. SUMMARY OF COST ESTIMATE FOR PASSIVE LANDFILL ALTERNATIVE

COST ESTIMATE SUMMARY
ENVIRONMENTAL ASSESSMENT OF PROJECT ALTERNATIVES

Project Alternative	**2**
Passive Landfill	
Client:	USAID Vietnam
Site:	Da Nang Airport
Location:	Da Nang, Vietnam
Phase:	Environmental Assessment of Project Alternatives
Level of Project Definition:	10% (Conceptual)
Base Year (Year 0):	2nd Quarter, Fiscal Year 2010 (FY10)
Date:	February 8, 2010

Description: The Passive Landfill Alternative will consist of excavating contaminated soil from the MLA and SA hotspots and contaminated sediments from the drainage ditch and Sen Lake, dewatering the contaminated material and transporting it to a constructed landfill located in the southwestern area of the Airport property.

CONSTRUCTION CAPITAL COSTS: (Assumed to be Incurred During Years 1 and 2)

SPREADSHEET REPORT DESCRIPTION	QTY	UNIT(S)	UNIT COST	TOTAL	NOTES
Landfill Passive	1	LS	$5,578,903	$5,578,903	Includes subgrade fill and preparation, liners, leachate collection system, waste placement, and cover.
SUBTOTAL				$5,578,903	
Contingency (Scope and Bid)	25%			$1,394,726	15% Scope, 10% Bid (Low end of recommended range in EPA 540-R-00-002).
SUBTOTAL				$6,973,629	
Project Management	5%			$348,681	Percentage from Exhibit 5-8 in EPA 540-R-00-002 was used.
Remedial Design	8%			$557,890	Percentage from Exhibit 5-8 in EPA 540-R-00-002 was used.
Construction Management	6%			$418,418	Percentage from Exhibit 5-8 in EPA 540-R-00-002 was used.
Technical Support	15%			$1,046,044	Middle value of the recommended range in EPA 540-R-00-002 was used.
TOTAL				$9,344,662	
TOTAL with VAT (assumed 10%)	10%			$10,279,128	
TOTAL CAPITAL COST				**$10,279,000**	Total capital cost is rounded to the nearest $1,000.
CAPITAL COST PER YEAR (YEARS 1 THROUGH 2)	2	YR	$10,279,000	**$5,139,500**	Annual capital cost over the assumed duration.

CONSTRUCTION CAPITAL COSTS: (Assumed to be Incurred During Years 1 and 2)

SPREADSHEET REPORT DESCRIPTION	QTY	UNIT(S)	UNIT COST	TOTAL	NOTES
Landfill Disposal	1	LS	$6,243,038	$6,243,038	Includes site clearing/preparation, excavation, decontamination, dewatering, hauling, backfilling, site restoration, and UXO screening and clearing of excavation and landfill areas. Excludes demolition of munitions bunkers at landfill site.
SUBTOTAL				$6,243,038	
Contingency (Scope and Bid)	25%			$1,560,760	15% Scope, 10% Bid (Low end of recommended range in EPA 540-R-00-002).
SUBTOTAL				$7,803,798	
Project Management	5%			$390,190	Percentage from Exhibit 5-8 in EPA 540-R-00-002 was used.
Remedial Design	8%			$624,304	Percentage from Exhibit 5-8 in EPA 540-R-00-002 was used.
Construction Management	6%			$468,228	Percentage from Exhibit 5-8 in EPA 540-R-00-002 was used.
Technical Support	15%			$1,170,570	Middle value of the recommended range in EPA 540-R-00-002 was used.
TOTAL				$10,457,090	
TOTAL with VAT (assumed 10%)	10%			$11,502,799	
TOTAL CAPITAL COST				**$11,503,000**	Total capital cost is rounded to the nearest $1,000.
CAPITAL COST PER YEAR (YEARS 1 THROUGH 2)	2	YR	$11,503,000	**$5,751,500**	Annual capital cost over the assumed duration.

Project Alternative	**2**
Passive Landfill	

COST ESTIMATE SUMMARY
ENVIRONMENTAL ASSESSMENT OF PROJECT ALTERNATIVES

Client:	USAID Vietnam
Site:	Da Nang Airport
Location:	Da Nang, Vietnam
Phase:	Environmental Assessment of Project Alternatives
Level of Project Definition:	10% (Conceptual)
Base Year (Year 0):	2nd Quarter, Fiscal Year 2010 (FY10)
Date:	February 8, 2010

Description: The Passive Landfill Alternative will consist of excavating contaminated soil from the MLA and SA hotspots and contaminated sediments from the drainage ditch and Sen Lake, dewatering the contaminated material and transporting it to a constructed landfill located in the southwestern area of the Airport property.

ANNUAL OPERATIONS AND MAINTENANCE (O&M) COSTS-LANDFILL MAINTENANCE (Years 3 through 50)

SPREADSHEET REPORT DESCRIPTION	QTY	UNIT(S)	UNIT COST	TOTAL	NOTES
Passive Landfill O&M	1	LS	$35,466	$35,466	Includes annual landfill O&M; assume 0.3% of landfill construction capital costs.
SUBTOTAL				$35,466	
Contingency (Scope and Bid)	25%			$8,867	15% Scope, 10% Bid (Low end of recommended range in EPA 540-R-00-002).
SUBTOTAL				$44,333	
Project Management	10%			$4,433	Percentage from Exhibit 5-8 in EPA 540-R-00-002 was used.
Construction Management	15%			$6,650	Percentage from Exhibit 5-8 in EPA 540-R-00-002 was used.
Technical Support	15%			$6,650	Middle value of the recommended range in EPA 540-R-00-002 was used.
TOTAL				$62,066	
TOTAL with VAT (assumed 10%)	10%			$68,273	
TOTAL ANNUAL O&M COST				**$68,000**	Total O&M cost is rounded to the nearest $1,000.
TOTAL O&M COST (YEARS 3 THROUGH 50)	48	YR	$68,000	**$3,264,000**	Annual O&M Cost over the assumed duration.

ANNUAL OPERATIONS AND MAINTENANCE (O&M) COSTS-MONITORING (Years 1 through 50)

SPREADSHEET REPORT DESCRIPTION	QTY	UNIT(S)	UNIT COST	TOTAL	NOTES
Environmental Mitigation and Monitoring Plan (EMMP) Implementation	1	LS	$118,220	$118,220	Includes sampling and analysis required by the EMMP; assume 1% of landfill construction capital costs.
SUBTOTAL				$118,220	
Contingency (Scope and Bid)	25%			$29,555	15% Scope, 10% Bid (Low end of recommended range in EPA 540-R-00-002).
SUBTOTAL				$147,775	
Project Management	8%			$11,822	Percentage from Exhibit 5-8 in EPA 540-R-00-002 was used.
Construction Management	10%			$14,778	Percentage from Exhibit 5-8 in EPA 540-R-00-002 was used.
Technical Support	15%			$22,166	Middle value of the recommended range in EPA 540-R-00-002 was used.
TOTAL				$196,541	
TOTAL with VAT (assumed 10%)	10%			$216,195	
TOTAL ANNUAL O&M COST				**$216,000**	Total O&M cost is rounded to the nearest $1,000.
TOTAL O&M COST (YEARS 1 THROUGH 50)	50	YR	$216,000	**$10,800,000**	Annual O&M Cost over the assumed duration.

Notes:
The cost summary and present value analyses provided are based on guidance presented in "A Guide to Developing and Documenting Cost Estimates During the Feasibility Study", EPA 540-R-00-002 (July 2000).
Percentages used for professional/technical services costs are based on guidance from Section 5.0 of "A Guide to Developing and Documenting Cost Estimates During the Feasibility Study", EPA 540-R-00-002 (July 2000).
Costs presented for this alternative are expected to have an accuracy between -30% to +50% of actual costs, based on the scope presented. They are prepared solely to facilitate relative comparisons between alternatives for evaluation purposes. Costs are prepared solely to facilitate relative comparisons between alternatives for evaluation purposes and do not represent annual appropriations or total budgetary expenditures required.

Abbreviations:

EA	Each	O&M	Operations and Maintenance
LS	Lump Sum	QTY	Quantity
NA	Not Applicable	UXO	Unexploded Ordinance

Site Restoration – removal of temporary facilities, restoration of the site, paving the haul road.

Indirect Costs – permits, insurance, and bonds; general conditions; overhead; and profit, but not tax, escalation, or contingency (contingency is added later).

5.3.3. ACTIVE LANDFILL ALTERNATIVE

Conceptual Design

The conceptual design for the Active Landfill was developed from GVN Decision No. 60/2002/QD-BKHCNMT, and similar USEPA documents, including 40 CFR 264, Subpart N, which provide technical guidance for the design of hazardous waste landfills. In general, the Active Landfill alternative would consist of excavating contaminated soil from the MLA, SA, Drainage Ditch, Eastern Hotspot, and PISA and contaminated sediments from the Drainage Ditch, Sen Lake, and Eastern Wetland, dewatering the contaminated material, and transporting it to a constructed landfill located in the southwestern area of the Airport property. The Active Landfill would also include elements intended to stimulate yet to be determined biological processes with the potential to degrade TCDD. Several munitions bunkers are present at this site, and for purposes of the EA, it has been assumed that these bunkers would be removed prior to landfill construction. If removal of the bunkers is not possible, then it will be necessary to consider alternative sites elsewhere on the property.

The general location of each of the major components of the Active Landfill alternative is shown in Figure 9 as a conceptual plan view layout of the Active Landfill alternative. The conceptual Passive Landfill alternative cross section shown in Figure 7 is generally applicable for the Active Landfill alternative to show key components of the landfill.

Mobilization and Project Preparation

Same as Passive Landfill alternative.

Excavation of Contaminated Material

Same as Passive Landfill alternative.

Landfill Construction

The conceptual design of the Active Landfill alternative is similar to the Passive Landfill alternative, and would have many of the same structural components. Key differences between the Active and Passive Landfill designs are described below.

Clean Soil Fill – Because of the additional operational space and the additional volume required for the bulking agents (see below), the Active Landfill alternative would require a larger footprint (115 m by 350 m), compared to the Passive Landfill Alternative. Therefore, approximately 100,000 m^3 of clean fill from offsite borrow sources would be needed to establish a landfill subgrade above flood levels and be used for construction, operation, and closure of the landfill. This clean fill would be hauled to the Project site from borrow pits outside the Airport property.

FIGURE 9. CONCEPTUAL LAYOUT OF ACTIVE LANDFILL ALTERNATIVE

<u>Functional Components</u> – The Active Landfill alternative includes containing contaminated soil and sediments in a landfill and applying bioremediation technology to reduce dioxin concentrations to below the GVN cleanup standards. Conceptually, it is assumed that a bioremediation delivery system would be used to distribute oxygen, substrate, and/or nutrients to the bacteria to facilitate biodegradation. However, an effective pathway for biodegradation of TCDD to below GVN cleanup standards has not been demonstrated, so details of a distribution system are currently speculative. Therefore, the biodegradation system included in this design and cost estimate should be considered a placeholder at best, as it is based on some very preliminary assumptions about the required length of conveyance, pipe sizing, and required equipment. If this alternative were pursued, this portion of the conceptual design would require further revision.

Additional capacity would be required in the Active Landfill footprint and the associated construction areas for several reasons as described below:

- A bulking agent such as sawdust is required to assist in the bioremediation process (up to 40% by volume). The bulking agent would be required to be uniformly mixed or layered with the contaminated soil and sediments in the landfill to assist in the bioremediation process.
- A relatively shallow landfill is desired to maximize control over distribution of contaminants, bulking agents, nutrients, etc.
- Operational flexibility and control is afforded to the filling process (specifically what material goes where, and how deep it is placed, etc.), which would be needed to optimize the bioremediation.
- Contaminated sediments and soils would need to be mixed before placement to ensure a uniform distribution of dioxin throughout the landfill and to utilize the sediments as a potential microbial inoculum source for the soils. This would require a larger Temporary Storage and Dewatering Area than for the Passive Landfill alternative in order to be able to accommodate all contaminated soils and sediments.

Site Restoration and Demobilization
Same as Passive Landfill alternative.

Footprint
The area of the total footprint for the Active Landfill alternative is estimated to be 334,950 m^2, consisting of:

- 167,700 m^2 of area of contaminated soils and sediments to be excavated;
- 53,000 m^2 for the Temporary Storage and Dewatering Area;
- 74,000 m^2 for haul road upgrade and widening; and
- 40,250 m^2 for the landfill footprint.

Construction and Operation Schedule

It is expected that the Active Landfill alternative would be constructed over a 2-year period. For cost estimation purposes, it is assumed that the Active Landfill would require long-term O&M for 10 years after closure to achieve GVN cleanup standards; however, the rate of dioxin degradation is unknown.

The main schedule components for implementation of the Active Landfill alternative are as follows (Figure 10):

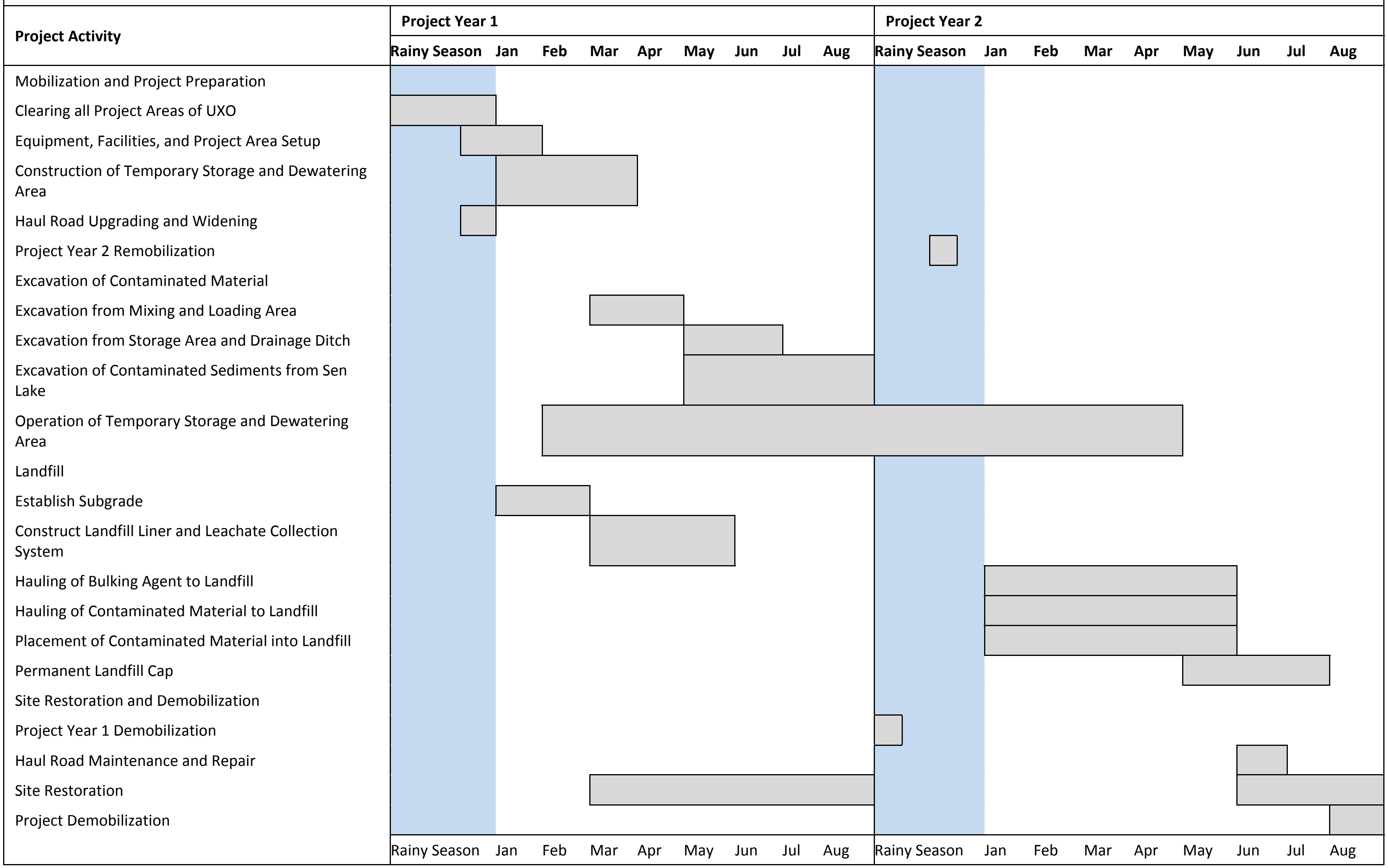
Year 1

- UXO Clearance: September – December (4 months, rainy season)
- Mobilization and Preparation: completed in March (~3 months)
- Excavation: March through August (6 months)
- Operation of Storage and Dewatering Area: February into Year 2 (14 months total)
- Landfill Construction: January through May (5 months)
- Site Restoration and Demobilization: March through September (~7 months)

Year 2

- Remobilization and Preparation: completed before December (~1 month)
- Operation of Storage and Dewatering Area: Year 1 through April (14 months total)
- Landfill Construction: January through July (7 months)
- Site Restoration and Demobilization: June through August (3 months)

FIGURE 10. INDICATIVE PROJECT SCHEDULE FOR ACTIVE LANDFILL ALTERNATIVE



Effectiveness

Effective for containment – The containment aspect of the design for the Active Landfill would be very similar to the Passive Landfill. As noted for the Passive Landfill alternative, hazardous waste landfills have been used successfully for decades worldwide in containing a variety of contaminants, including dioxins, furans, and other persistent organic pollutants. Design guidance and regulations for such landfills are readily available in the U.S., Vietnam, and in many other countries. This is a proven containment strategy.

Unknown effectiveness for treatment – Field and Sierra-Alvarez (2008) published a review of the scientific literature on microbial degradation of chlorinated dioxins that spanned a period from 1980 to 2006. In this review, over 40 studies were included that evaluated 100 different biological culture and dioxin congener combinations. While some degradation of 2,3,7,8-TCDD was often observed, none of the studies included demonstrated degradation to less than 1,000 ppt for soils and 150 ppt for sediments. In addition, neither the BEM (2007) report nor the UNDP (2009) report identified any documented studies in which biodegradation was shown to treat dioxins below GVN cleanup standards. As noted on the USEPA's Technology Innovation Program:[71]

"Bioremediation is regarded as an attractive possibility for cleaning up dioxin-contaminated soil, but its real applicability and effectiveness is unknown. The following technical obstacles continue to limit the application of bioremediation: 1) only very specialized biological systems can be effective against the high toxicity, low volubility, and high absorptivity of dioxin; 2) a very stringent cleanup standard must be met; and, 3) it may be difficult to find a microorganism that can effectively deactivate dioxins under the different conditions present at existing dioxin-contaminated sites."

Potential biodegradation pathways for TCDD include aerobic, anaerobic, and aerobic cometabolic. In general, aerobic pathways have been shown to be more effective for lesser chlorinated dioxins, and the anaerobic pathway to be more effective for more chlorinated dioxins. A summary of the Field and Sierra-Alvarez (2008) review paper on chlorinated dioxin biodegradation is provided below.

- Aerobic (growth of bacteria on TCDD as a carbon and energy source in the presence of oxygen) – Only a few well-documented examples of this biodegradation pathway for chlorinated dioxins have been identified in the scientific literature. Of those four studies, none demonstrated biodegradation of TCDD. In fact, all four studies showed only degradation of monochlorinated dioxins. The bacteria responsible for the degradation in these studies included species of Sphingomonas, Pseudomonas, and Burkholderia.

- Anaerobic (growth of bacteria on TCDD as a carbon and energy source in the absence of oxygen) – Eight different studies were identified in the literature dating from 1995 to 2004 that evaluated 19 different congener and culture combinations. TCDD was not

[71] http://www.clu-in.org/contaminantfocus/default.focus/sec/Dioxins/cat/Treatment_Technologies/

tested directly in any of the combinations, although 1,2,3,4-tetrachloro-dibenzo-p-dioxin was tested in several combinations. In 17 out of the 19 combinations, either one or two chlorines was removed, while in two of the combinations, at least some dechlorination of three chlorines was reported. Percent removal ranged from 2.8% to 95.8% for the 17 cases where it was reported. The highest removal for the 12 cases that started with either 1,2,3,4-tetrachloro-dibenzo-p-dioxin (eleven) or 1,2,3,7,8-pentachloro-dibenzo-p-dioxin (one) was 89.7%. Nine of the twelve reported removals of 42.3% or less.

- Aerobic bacterial cometabolic (fortuitous degradation of chlorinated dioxins during growth on some other substrate) – Over 20 different studies from the literature dating from 1980 to 2006 evaluated 63 congener and culture combinations. Most (84%) of the evidence reported is for degradation of mono- or dichloro-dibenzo-p-dioxins. Only two of the combinations included TCDD, with one reporting 61.2% degradation in 244 days, and the other did not report a percent removal. Two other combinations included 1,2,3,4-TCDD, and those reported 13.2% and 18% removal. The bacteria implicated included species of Alcaligenes, Rhodococcus, Sphingomonas, Terrabacter, Pseudomonas, Bacillus, Burkholderia, Beijerinckia, Klebsiella, and Erwinia.

- Aerobic fungal cometabolic – Seven different studies from 1985 to 2005 were identified in the literature review reporting degradation of chlorinated dioxins by fungi. It appears that only one of those studies evaluated TCDD. The lignin peroxidase and manganese peroxidase enzymes were the focus of these studies. The highest percent removal reported in these studies by Field and Sierra-Alvarez (2008) was 55% for a dichloro-dibenzo-p-dioxin.

While strategies to accomplish biodegradation of TCDD to sufficiently low levels might be demonstrated in the future, documentation of such strategies has not yet been obtained. As a result, a basis for design of an effective active landfill is not readily available. Some specific data gaps that need to be addressed to ensure treatment effectiveness include the following:

What degradation pathway should an active landfill be designed to stimulate – aerobic, aerobic cometabolic, anaerobic, or a combination?

- What examples are available of well-documented studies that show degradation of TCDD to below target cleanup levels by the design mechanism, especially at a large scale?

- What examples are available that demonstrate how to engineer a full-scale active landfill for TCDD to ensure all of the soil is subjected to the desired conditions without any physical mixing after initial emplacement?

- If necessary, will inoculation of microorganisms be feasible and successful when increasing the scale by five orders of magnitude relative to the pilot test? If it is not necessary, how would a sufficiently uniform distribution of native microorganisms (which are notoriously heterogeneous) be ensured at the scale of a landfill to achieve the necessary destruction throughout without physical mixing?

A primary reason for retaining this alternative for consideration is that a pilot bioremediation study is being undertaken at the Airport. After 180 days of treatment, the extent of degradation of TCDD under various experimental conditions was approximately 25 to 40% (concentrations reduced from between 40,000 ppt and 50,000 ppt to approximately 30,000 ppt)[72]. TCDD concentrations remained more than 30 times the target soil cleanup level (1,000 ppt) at that time. It is not known whether the bioavailability of TCDD has become limiting (even for extracellular enzymes) as concentrations have decreased. This and the stringent cleanup standard were two of the three technical obstacles to biodegradation of dioxins noted on the USEPA website quoted above. The degradation pathway cannot be determined from the pilot test data; however, growth of bacteria such as Sphingomonas and actinomycetes has apparently been measured in the aerobic treatment cells. It is not yet clear which actinomycetes are being measured, but Rhodococcus and Terrabacter, reported in the literature review to play a role in aerobic cometabolism of chlorinated dioxins, are both actinomycetes. Actinomycetes have been shown to produce angular dioxygenase enzymes, which have been documented to degrade dioxins and furans cometabolically.[73]

Implementabilty

For containment, an Active Landfill has the same implementability issues as the Passive Landfill alternative. In addition, the Active Landfill has the following implementability issues:

Landfill size – Due to the added volume of the bulking material, the landfill area size will increase to approximately 100 m by 270 m (excluding support facilities), or slightly larger than five football fields in size. This will also increase the amount of fill material required (~200,000 m^3) for construction, operation, and closure. These items are primarily cost issues, although they have potential environmental impacts as well.

Electrical service – The distribution system will require electrical service to the landfill. Depending upon the electrical loads required and the availability of such service nearby, this cost impact could vary.

For treatment, implementability is unknown – Challenges to implementation include the following:

- It is not clear which degradation pathway is appropriate for design (aerobic, aerobic cometabolic, anaerobic, or a combination).
- Contaminated sediments and soils would need to be mixed before placement to ensure a uniform distribution of dioxin throughout the landfill and to utilize the sediments as a potential microbial inoculum source for the soils. This would require a larger Temporary Storage and Dewatering Area than for the Passive Landfill alternative in order to be able to accommodate all contaminated soils and sediments.

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[72] Allen 2010.
[73] Iida et al. 2002.

- More operational control would be required regarding where and when material is placed in the landfill and the thickness of the material that is laid down. This, plus the fact that the Active Landfill alternative would require more material to be placed than the Passive Landfill alternative, means that more time would be needed to fill the landfill.
- This alternative has not yet been successfully demonstrated at a small scale, and it is therefore not possible to determine whether the conditions required to facilitate the desired results are implementable at full scale. Some key issues to be resolved include: distribution of microbes, distribution of nutrients and/or substrates, bioavailability of TCDD, longevity of nutrients and/or substrates relative to persistence of TCDD, ability to maintain desired geochemical conditions, etc.
- The GVN and Da Nang Airport Authority have commented that a landfill with a height of 4 m and a footprint of 180 m by 180 m (which would provide the estimated volume required for an active landfill) is too large. In preliminary discussions, USEPA indicated that a 2-m height would be ideal for an active landfill, but it now appears the height might need to be 6 m or more to satisfy the footprint limitations.

The above exceptions are reflected in the indicative schedule for the Active Landfill alternative. For cost estimation purposes (see Appendix A3), it is assumed that the Active Landfill bioremediation system would require O&M for 10 years after closure.

Cost

At the alternatives evaluation stage, the design for the remedial alternatives are still conceptual, not detailed, and the cost estimates are considered to be "order-of-magnitude." The cost engineer must make assumptions about the detailed design in order to prepare the cost estimate. As noted previously, costs for remedial alternatives are expected to have accuracies between -30% to +50% of actual costs, based on the scope presented. A detailed cost estimate backup is provided in Appendix A3. The total cost estimate for this alternative is $30.7M, comprising construction ($15.5M), excavation and disposal ($11.5M), O&M ($0.7M), and monitoring and mitigation ($3.0M).

The construction cost estimate for this alternative is split into two sections: the "Landfill Active" estimate includes work that is specific to this alternative, and the "Landfill Disposal" estimate includes work that is common to the Passive Landfill alternative. Main elements of the “Landfill Active” section of this cost estimate are listed below and elements of the “Landfill Disposal” section are the same as the Passive Landfill. A summary of the overall Active Landfill alternative cost is provided in Table 19 and detailed backup of the cost estimate is provided in Appendix A3.

TABLE 19. SUMMARY OF COST ESTIMATE FOR ACTIVE LANDFILL ALTERNATIVE

COST ESTIMATE SUMMARY
ENVIRONMENTAL ASSESSMENT OF PROJECT ALTERNATIVES

Project Alternative 3

Active Landfill

Client:	USAID Vietnam
Site:	Da Nang Airport
Location:	Da Nang, Vietnam
Phase:	Environmental Assessment of Project Alternatives
Level of Project Definition:	10% (Conceptual)
Base Year (Year 0):	2nd Quarter, Fiscal Year 2010 (FY10)
Date:	February 8, 2010

Description: While no proven dioxin bioremediation technology currently exists (CDM International 2010, Appendix A5), the Active Landfill Alternative nevertheless considers a general Project configuration that could potentially accommodate a bioremediation technology.

CONSTRUCTION CAPITAL COSTS: (Assumed to be Incurred During Years 1 and 2)

SPREADSHEET REPORT DESCRIPTION	QTY	UNIT(S)	UNIT COST	TOTAL	NOTES
Landfill Active	1	LS	$8,557,266	$8,557,266	Includes subgrade fill and preparation, liners, leachate collection system, waste placement, cover, and air distribution wells. Excludes bioremediaition distribution system.
SUBTOTAL				$8,557,266	
Contingency (Scope and Bid)	25%			$2,139,317	15% Scope, 10% Bid (Low end of recommended range in EPA 540-R-00-002).
SUBTOTAL				$10,696,583	
Project Management	5%			$534,829	Percentage from Exhibit 5-8 in EPA 540-R-00-002 was used.
Remedial Design	6%			$641,795	Percentage from Exhibit 5-8 in EPA 540-R-00-002 was used.
Construction Management	6%			$641,795	Percentage from Exhibit 5-8 in EPA 540-R-00-002 was used.
Technical Support	15%			$1,604,487	Middle value of the recommended range in EPA 540-R-00-002 was used.
TOTAL				$14,119,489	
TOTAL with VAT (assumed 10%)	10%			$15,531,438	
TOTAL CAPITAL COST				**$15,531,000**	Total capital cost is rounded to the nearest $1,000.
CAPITAL COST PER YEAR (YEARS 1 THROUGH 2)	2	YR	$15,531,000	**$7,765,500**	Annual capital cost over the assumed duration.

CONSTRUCTION CAPITAL COSTS: (Assumed to be Incurred During Years 1 and 2)

SPREADSHEET REPORT DESCRIPTION	QTY	UNIT(S)	UNIT COST	TOTAL	NOTES
Landfill Disposal	1	LS	$6,243,038	$6,243,038	Includes site clearing/preparation, excavation, decontamination, dewatering, hauling, backfilling, site restoration, and UXO screening and clearing of excavation and landfill areas. Excludes demolition of munitions bunkers at landfill site.
SUBTOTAL				$6,243,038	
Contingency (Scope and Bid)	25%			$1,560,760	15% Scope, 10% Bid (Low end of recommended range in EPA 540-R-00-002).
SUBTOTAL				$7,803,798	
Project Management	5%			$390,190	Percentage from Exhibit 5-8 in EPA 540-R-00-002 was used.
Remedial Design	8%			$624,304	Percentage from Exhibit 5-8 in EPA 540-R-00-002 was used.
Construction Management	6%			$468,228	Percentage from Exhibit 5-8 in EPA 540-R-00-002 was used.
Technical Support	15%			$1,170,570	Middle value of the recommended range in EPA 540-R-00-002 was used.
TOTAL				$10,457,090	
TOTAL with VAT (assumed 10%)	10%			$11,502,799	
TOTAL CAPITAL COST				**$11,503,000**	Total capital cost is rounded to the nearest $1,000.
CAPITAL COST PER YEAR (YEARS 1 THROUGH 2)	2	YR	$11,503,000	**$5,751,500**	Annual capital cost over the assumed duration.

Project Alternative 3

Active Landfill

COST ESTIMATE SUMMARY
ENVIRONMENTAL ASSESSMENT OF PROJECT ALTERNATIVES

Client:	USAID Vietnam
Site:	Da Nang Airport
Location:	Da Nang, Vietnam
Phase:	Environmental Assessment of Project Alternatives
Level of Project Definition:	10% (Conceptual)
Base Year (Year 0):	2nd Quarter, Fiscal Year 2010 (FY10)
Date:	February 8, 2010

Description: While no proven dioxin bioremediation technology currently exists (CDM International 2010, Appendix A5), the Active Landfill Alternative nevertheless considers a general Project configuration that could potentially accommodate a bioremediation technology.

ANNUAL OPERATIONS AND MAINTENANCE (O&M) COSTS-MAINTENANCE (Years 3 through 10)

SPREADSHEET REPORT DESCRIPTION	QTY	UNIT(S)	UNIT COST	TOTAL	NOTES
Active Landfill O&M	1	LS	$44,401	$44,401	Includes annual landfill O&M; assume 0.3% of landfill construction direct capital costs.
SUBTOTAL				$44,401	
Contingency (Scope and Bid)	25%			$11,100	15% Scope, 10% Bid (Low end of recommended range in EPA 540-R-00-002).
SUBTOTAL				$55,501	
Project Management	10%			$5,550	Percentage from Exhibit 5-8 in EPA 540-R-00-002 was used.
Construction Management	15%			$8,325	Percentage from Exhibit 5-8 in EPA 540-R-00-002 was used.
Technical Support	15%			$8,325	Middle value of the recommended range in EPA 540-R-00-002 was used.
TOTAL				$77,701	
TOTAL with VAT (assumed 10%)	10%			$85,471	
TOTAL ANNUAL O&M COST				**$85,000**	Total O&M cost is rounded to the nearest $1,000.
TOTAL O&M COST (YEARS 3 THROUGH 10)	8	YR	$85,000	**$680,000**	Annual O&M Cost over the assumed duration.

ANNUAL OPERATIONS AND MAINTENANCE (O&M) COSTS-MONITORING (Years 1 through 11)

SPREADSHEET REPORT DESCRIPTION	QTY	UNIT(S)	UNIT COST	TOTAL	NOTES
Environmental Mitigation and Monitoring Plan (EMMP) Implementation	1	LS	$148,004	$148,004	Includes sampling and analysis required by the EMMP; assume 1% of landfill construction direct capital costs.
SUBTOTAL				$148,004	
Contingency (Scope and Bid)	25%			$37,001	15% Scope, 10% Bid (Low end of recommended range in EPA 540-R-00-002).
SUBTOTAL				$185,005	
Project Management	8%			$14,800	Percentage from Exhibit 5-8 in EPA 540-R-00-002 was used.
Construction Management	10%			$18,501	Percentage from Exhibit 5-8 in EPA 540-R-00-002 was used.
Technical Support	15%			$27,751	Middle value of the recommended range in EPA 540-R-00-002 was used.
TOTAL				$246,057	
TOTAL with VAT (assumed 10%)	10%			$270,663	
TOTAL ANNUAL O&M COST				**$271,000**	Total O&M cost is rounded to the nearest $1,000.
TOTAL O&M COST (YEARS 1 THROUGH 11)	11	YR	$271,000	**$2,981,000**	Annual O&M Cost over the assumed duration.

Notes:
The cost summary and present value analyses provided are based on guidance presented in "A Guide to Developing and Documenting Cost Estimates During the Feasibility Study", EPA 540-R-00-002 (July 2000).
Percentages used for professional/technical services costs are based on guidance from Section 5.0 of "A Guide to Developing and Documenting Cost Estimates During the Feasibility Study", EPA 540-R-00-002 (July 2000).
Costs presented for this alternative are expected to have an accuracy between -30% to +50% of actual costs, based on the scope presented. They are prepared solely to facilitate relative comparisons between alternatives for evaluation purposes. Costs are prepared solely to facilitate relative comparisons between alternatives for evaluation purposes and do not represent annual appropriations or total budgetary expenditures required.

Abbreviations:

EA	Each	O&M	Operations and Maintenance
LS	Lump Sum	QTY	Quantity
NA	Not Applicable	UXO	Unexploded Ordinance

The "Landfill Active" estimate includes the following costs:

Landfill Construction

- Site preparation: clearing and grubbing of the proposed landfill location, but not demolition of the munitions bunkers, and not UXO clearing or disposal.
- Grading: placement of subgrade fill to bring the landfill above the flood level, and fill for the perimeter berm and longitudinal slope.
- Liner system installation: placement of the bottom liner layers, leachate collection system piping, and the leachate treatment manhole.

Landfill Operation

- Spreading and compaction contaminated soils and sediments and bulking material in place at the landfill.
- Installation of the bioremediation distribution system (which is highly speculative at this stage).
- Installation of the remaining leachate treatment system components.
- Monitoring well network installation.

Landfill Closure – installation of the cap layers.

Indirect Costs – permits, insurance, and bonds; general conditions; overhead; and profit; but not tax, escalation, or contingency (contingency is added later).

5.3.4. ISTD/IPTD ALTERNATIVE

Conceptual Design

The ISTD/IPTD alternative would include excavation of contaminated soil and sediment, and transport to stockpile areas at the north end of the airport for treatment.

Dioxins are particularly recalcitrant to remediation, as they do not partition well into either soil, gas or groundwater from soil. However, at higher temperatures, the dioxins can be volatilized and either completely oxidized or pyrolized into coke, depending on the presence of oxygen. Dioxins still present in the aqueous phase can be destroyed via hydrolysis or hydrous pyrolysis at higher temperatures. Therefore, thermal treatments can be effective for dioxins.[74]

In past applications, dioxins have been treated in the presence of other contaminants, such as PAHs or PCBs. When these contaminants are present at high levels, they do not interfere with dioxin treatment, but they generally require more elaborate off-gas treatment system components, such as thermal or catalytic oxidizers. Analysis of recent soil samples collected at

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[74] ENSR 2000, Baker and La Chance 2003, Baker et al. 2007 and Heron et al. 2010.

the Da Nang site indicated that only low levels of organic contaminants were present (Appendix A1). This would simplify treatment of off-gas because it would focus primarily on dioxins, which require only GAC as the base available technology. However, it should be noted that GAC is also very effective for removal of most organic contaminants from vapor as long as concentrations are not too high.

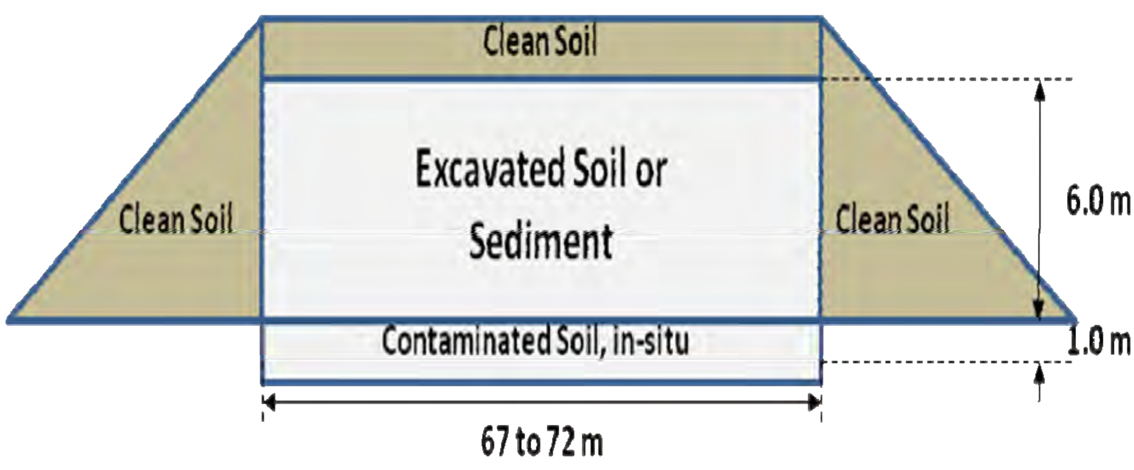
With the ISTD/IPTD alternative, contaminated soil from the MLA, SA, Drainage Ditch, Eastern Hotspot, and PISA as well as contaminated sediments from the Drainage Ditch, Sen Lake, and Eastern Wetland would be excavated, stockpiled, and thermally treated to below GVN cleanup standards. The general location of the components (excavation/hotspot areas, Contaminated Soil Stockpile, and Contaminated Sediment Stockpile) are shown in Figure 5. Similar to the landfill alternatives, it is expected that the ISTD/IPTD would also be implemented over a 2-year period.

A conceptual drawing of a stockpile of contaminated material for combined ISTD/IPTD is shown in Figure 11. The following two contaminated material stockpiles would be required:

- Contaminated Soil Stockpile: stockpile consisting of contaminated material from the SA, MLA, Eastern Hotspot, and PISA with contaminated material occupying a volume of approximately 67 m by 67 m by 6 m above-grade (27,000 m^3) and a total area, including a clean soil berm, of approximately 7,300 m^2.

- Contaminated Sediment Stockpile: stockpile consisting of contaminated sediments from Sen Lake, Eastern Wetland, and the Drainage Ditch with contaminated material occupying a volume of approximately 72 m by 72 m by 6 m (31,000 m^3), and a total area, including a clean soil berm, of approximately 8,100 m^2.

FIGURE 11. CONCEPTUAL DESIGN OF ISTD/IPTD CONTAMINATED MATERIAL STOCKPILES



Mobilization and Project Preparation

Clearing all Project Areas of UXO – All existing UXO within the Project area (excavation areas, Contaminated Soil Stockpile, and Contaminated Sediment Stockpile) would be detected and cleared prior to the commencement of any Project activities.

Equipment, Facilities, Project Setup – Equipment and a vendor would be procured, an equipment decontamination station would be constructed in the area of the hotspots, and the Project work areas would be set up. The set up would include establishing surface water runoff diversions around the main Project work areas to minimize the amount of project-affected water requiring treatment before being returned to existing drainages. It is expected that diverted surface runoff would be conveyed to the natural drainage entering the eastern wetland.

Creation of Contaminated Soil Stockpile

Preparation of Contaminated Soil Stockpile – The Contaminated Soil Stockpile would be located on top of a portion of the SA hotspot. The ground would be cleared, grubbed, and leveled, and a drainage system and a sump would be set up to manage any water that drains from the stockpile.

Excavation of Contaminated Material from the SA – Contaminated soil from the remaining SA hotspot (i.e., not covered with the stockpile) would be excavated, transported to, and placed in the Contaminated Soil Stockpile. To minimize the generation of project-affected water from precipitation and groundwater seepage, excavated areas would be filled with clean soil as soon as practicable after excavation. Water normally conveyed by the Drainage Ditch would be re-routed to the natural drainage entering the eastern wetland.

Estimates of the locations to be excavated and depths to which excavation would be required are described in Appendix A2. Confirmation sampling will be needed to determine the final excavation limits within the SA.

Excavation of Contaminated Material from the MLA, PISA, and Eastern Hotspot – An estimated 21,400 m^3 of contaminated soil from the MLA, PISA, and Eastern Hotspot would be excavated, transported to, and placed in the Contaminated Soil Stockpile. The Contaminated Soil Stockpile will have dimensions of approximately 67 m by 67 m by 6 m (27,000 m^3), and have a total footprint, including a clean soil berm, of approximately 7,300 m^2. A conceptual cross section of the stockpile is shown in Figure 11. As with excavation in the SA, excavated areas in the MLA, PISA, and Eastern Hotspot would be filled with clean soil as soon as practicable after excavation so as to minimize the generation of project-affected water from precipitation and groundwater seepage.

Estimates of the locations to be excavated and depths to which excavation would be required are described in Appendix A2. Confirmation sampling will be needed to determine the final excavation limits within the MLA.

Importing of Clean Fill to Form Contaminated Soil Stockpile and Creation of Clean Soil Berm – The Contaminated Soil Stockpile would require approximately 22,000 m^3 of clean fill on all sides and the top to provide stability during the ISTD/IPTD process. This clean fill would be hauled to the Project site from borrow pits off the Airport property.

Thermal Treatment of Contaminated Soil Stockpile

<u>Installation of Non-Pile Equipment</u> – All the non-pile equipment required for ISTD/IPTD would be installed while the Contaminated Soil Stockpile is constructed.

<u>Installation of In-Pile Equipment</u> – Heater boreholes spaced approximately 3 m apart, heated vapor extraction wells spaced approximately 10 m apart, and air inlet and vapor recovery wells spaced approximately 10 m and 15 m apart, respectively, would be installed once construction of the Contaminated Soil Stockpile is complete. A vapor cover would also be installed, with all heating elements, off-gas vapor systems, and pile monitoring systems installed. The vapor cover will likely consist of a light concrete aggregate, as well as a layer of clean fill. The combination of the vapor cover and the vacuum on the air inlet wells will prevent any vapor from escaping the piles. The cover will also prevent water from entering the pile and representing an additional heat sink that would waste energy being applied for heat treatment. While the top of the cover will be warm, its thickness and exposure to the atmosphere will prevent it from being so hot that it will boil water. Thus, steam generation from rainfall on the cover would be insignificant.

In the case of the Contaminated Soil Stockpile, it is anticipated that the pile will be located on the southern half of the SA (Figure 5). This will allow contaminated soils underneath the pile to be treated in place (i.e., the entire SA will not require excavation). Based on the 2010 data (Appendices A1 and A2), the average depth of contamination above target treatment levels in the southern half of the SA is 0.54 m. Assuming the water table is present at a depth of 1 m, heater wells could be installed through the pile to just below the bottom of the contaminated interval without entering the water table. This will allow in situ treatment of those soils to occur while the soil pile is treated, without undue loss of energy caused by heating the groundwater. If it is determined during the final design that 0.46 m is not enough separation to prevent unwanted heat loss to groundwater, the entire SA will be excavated, and the bottom of the soil treatment pile and the associated heater wells will be at ground surface.

<u>Thermal Treatment of Contaminated Soil Stockpile</u> – Thermal treatment of the contaminated soil stockpile would then proceed. The following steps would be required: shakedown; heating to boiling temperature, boiling and drying (to reduce water content in the pile), heating to target temperature, sampling and analysis, and cooldown. Successful treatment of the dioxins requires soil temperatures be elevated to approximately 335°C. This would be accomplished via the placement of heater boreholes that raise the temperature of adjacent soil or sediment within the stockpile. Soil temperature near the heater boreholes would be approximately 700 to 800°C so as to achieve sufficient heating between boreholes.

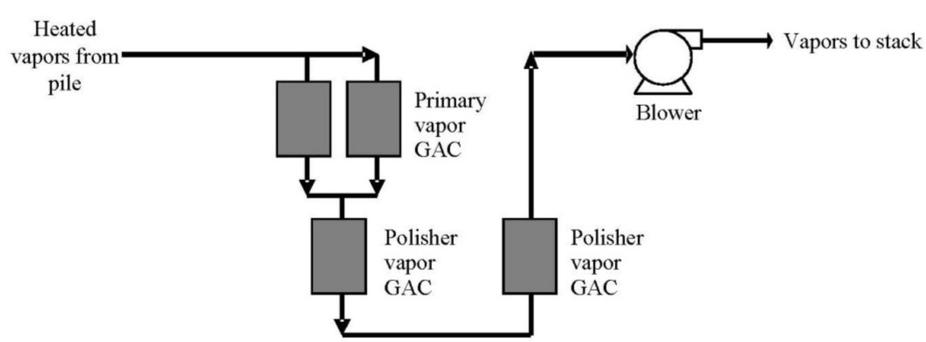
The time for the pile to reach the boiling temperature of water is estimated to be about 30 days. Once that temperature is reached, it will remain there until most of the water content of the soil and/or sediment in the pile is evaporated. Based on the estimated water content of the piles, the time required for this phase is estimated to be about 60 days. The higher the water content, the longer this stage will take. Approximately 80 more days will be required to heat the piles to the target temperature (minimum of 335 C between heater wells).

It should be noted that the highest temperatures in the piles (700 to 800°C adjacent to the heater wells) will be well below the temperature required for vitrification to occur. Vitrification of sand occurs at greater than 1000°C, as the glass transition temperature for quartz sand is 1175°C.

Approximately 95% of the dioxins would be destroyed in the piles by the mechanisms of oxidation, hydrolysis, and/or hydrous pyrolysis. Recovery of the remaining dioxins would be accomplished via heated vapor extraction wells. Air inlet wells would be installed to allow sufficient flow through the stockpile. Based on conceptual modeling of this system, it is anticipated that heater boreholes would be installed with 3-m spacing, and air inlet and vapor recovery wells would be installed with 10-m and 15-m spacing, respectively. For the 67 m by 67 m Contaminated Soil Stockpile, it would be expected that approximately 550 heater borings, 50 heated vapor extraction wells, and 25 air inlet wells would be needed. As noted above, the combination of a vacuum constantly applied to the heated vapor extraction wells and the vapor cover will prevent any contaminated vapor from escaping the pile through a route other than the vapor extraction and treatment system. An air-to-air heat exchanger would be used to minimize power consumption by transferring energy from the extracted air to the pile inlet air.

Dioxins in off-gas can be effectively treated via vapor-phase GAC. No other hazardous byproducts of this treatment process for dioxins have been observed in past applications. Concentrations of dioxins in the treated off-gas are expected to be orders of magnitude lower than the most strict air regulations in the U.S., as evidenced by application of the technology in California. For this site, extracted soil vapor would be pulled into vessels containing GAC. The first two vessels would be arranged in parallel, due to the expected high mass loading, and the following two vessels would be arranged in series to polish the vapor stream prior to discharge. A process flow diagram is shown in Figure 12. The stack releasing treated off-gases would be strategically located to maximize the distance from populated areas.

FIGURE 12. PROCESS FLOW DIAGRAM FOR ISTD/IPTD EXTRACTED FLUIDS TREATMENT SYSTEM



Estimated contaminant mass = 200 kg

A small water condensate stream will be produced by the air treatment system. Given the low aqueous solubility of dioxins, it is believed that concentrations of dioxins in the condensate will be extremely low. However, it is likely that the condensate stream would be treated by GAC as a polishing step prior to discharge as a precautionary step both for dioxins and for any other organic co-contaminants that might be present.

It is expected that treatment of each pile would require approximately 21,000,000 kwh of power. The Da Nang Power Company has indicated that a dedicated line can be brought into the site from a nearby substation with sufficient power to support the Project.

Removal of In-Pile Equipment – All the in-pile equipment would be removed after the cooldown phase from the clean soil pile for use in the Contaminated Sediments Stockpile.

Creation of Contaminated Sediment Stockpile

Preparation of Contaminated Sediment Stockpile – The contaminated sediment stockpile would be located east-northeast of the SA (Figure 5). The area would be cleared, grubbed, and leveled, and a bottom liner with a drainage system and a sump would be laid down to manage the water that drains from the stockpile. In addition, a temporary unpaved haul road would be constructed from Sen Lake to the Contaminated Sediment Stockpile.

Excavation of Contaminated Material from Sen Lake – Excavation of contaminated sediments from Sen Lake, Eastern Wetland, and the Drainage Ditch would proceed in the same manner as described above for the Passive Landfill alternative. After excavation from Sen Lake, the excavated material would be conveyed directly to the Contaminated Sediment Stockpile. The Contaminated Sediment Stockpile will have dimensions of approximately 72 m by 72 m by 6 m (31,000 m^3), and have a total footprint, including a clean soil berm, of approximately 8,100 m^2. Similar to the Contaminated Soil Stockpile, it is anticipated that heater boreholes would be installed with 3-m spacing, and air inlet and vapor recovery wells would be installed with 10-m and 15-m spacing, respectively. For the 72 m by 72 m Contaminated Sediment Stockpile, it would be expected that approximately 600 heater borings, 60 heated vapor extraction wells, and 30 air inlet wells would be needed.

Importing of Clean Fill to Form Contaminated Sediment Stockpile and Creation of Clean Soil Berm – The Contaminated Sediment Stockpile would require approximately 24,000 m^3 of clean fill on all sides and the top to provide stability during the thermal desorption process. This clean fill would be hauled to the Project site from borrow pits off the Airport property.

Thermal Treatment of Contaminated Sediment Stockpile

Thermal treatment of the Contaminated Sediment Stockpile, consisting of installation of in-pile equipment, thermal treatment, and removal of in-pile equipment would proceed in the same manner as for the thermal treatment of the Contaminated Soil Stockpile.

Site Restoration and Demobilization

Disposal of Treated Soil Stockpile – The treated soil stockpile would be disposed of in a location to be determined in consultation with GVN. For cost estimation purposes (see Appendix A3), it is assumed that the treated soil would be placed, graded, and seeded in a permanent stockpile at/near the treatment area.

<u>Disposal of Treated Sediment Stockpile</u> – The treated sediment stockpile would be disposed of in a location to be determined in consultation with GVN. For cost estimation purposes (see Appendix A3), it is assumed that the treated sediment would be placed, graded, and seeded in a permanent stockpile at/near the treatment area.

<u>Site Restoration</u> – Site restoration activities would be decided upon in consultation with the Airport Authority and would generally consist of returning project-affected areas to pre-Project or better conditions.

<u>Project Demobilization</u> – All Project equipment and facilities would be removed from the Project area.

Footprint

The area of the total footprint for the ISTD/IPTD alternative is estimated to be 183,100 m^2, consisting of:

- 167,700 m^2 of area of contaminated soils and sediments to be excavated;
- 7,300 m^2 for the footprint for the contaminated soil stockpile; and
- 8,100 m^2 for the footprint for the contaminated sediment stockpile.

Construction and Operation Schedule

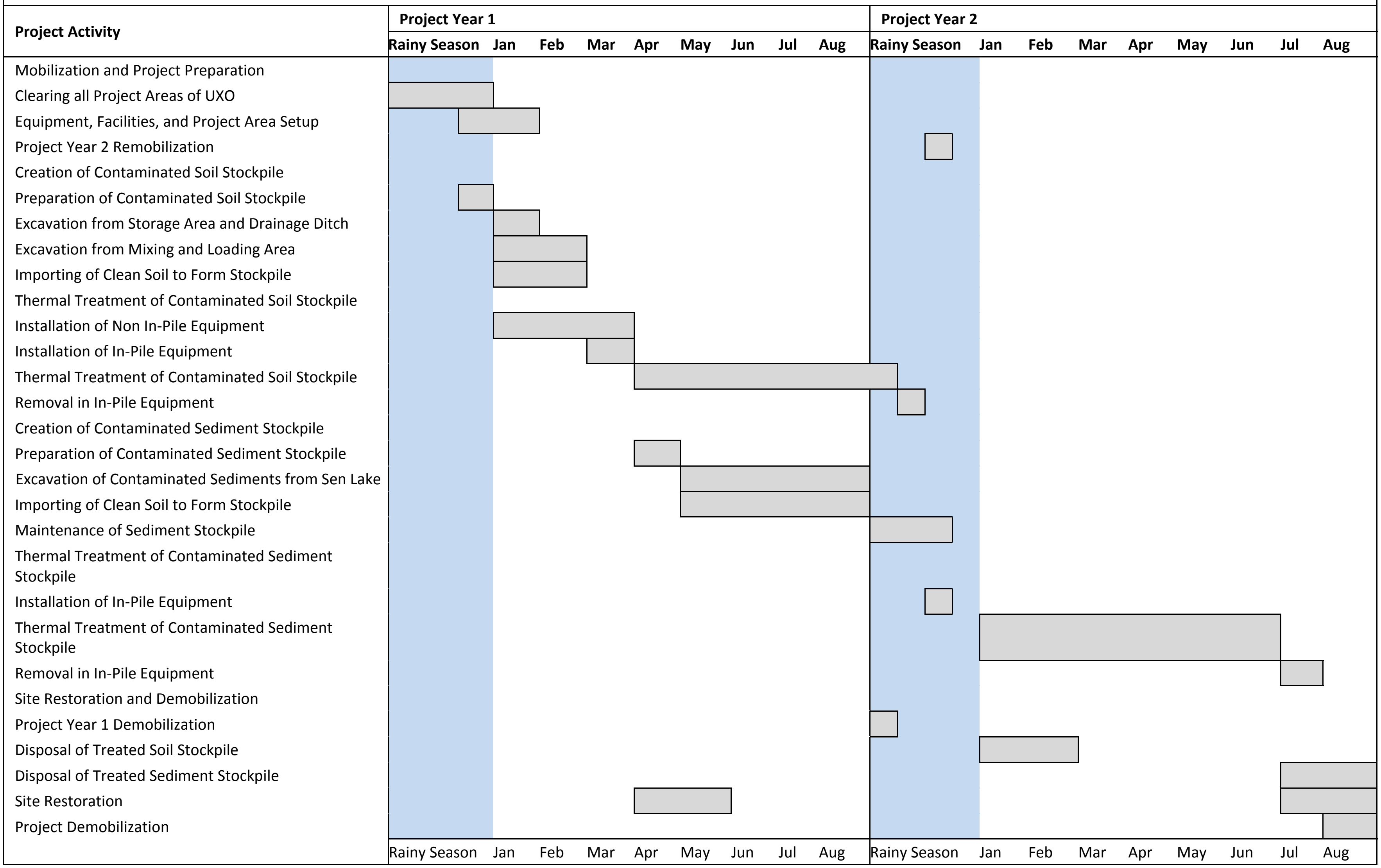
It is expected that the ISTD/IPTD alternative would be constructed and operated over a 2-year period. Dioxin concentrations would be reduced to or below GVN cleanup standards by the end of operation; therefore, no long term O&M would be required.

The main schedule components for implementation of the ISTD/IPTD alternative are as follows (see Figure 13):

<u>*Year 1*</u>

- UXO Clearance: September – December (4 months, rainy season)
- Mobilization and Preparation: completed in January (~2 months)
- Soil Stockpile Creation: December through February (3 months)
- Soil Stockpile Treatment: January into Year 2 Rainy Season (~6 months)
- Sediment Stockpile Creation: April into Year 2 Rainy Season (~8 months)
- Site Restoration and Demobilization: April through May (2 months)

FIGURE 13. INDICATIVE PROJECT SCHEDULE FOR ISTD/IPTD ALTERNATIVE



Year 2

- Soil Stockpile Treatment: Year 1 into Rainy Season (~7 months)
- Remobilization and Preparation: completed before December (~1 month)
- Sediment Stockpile Creation: Year 1 into Rainy Season (~8 months total)
- Sediment Stockpile Treatment: Year 2, Rainy Season through July (~7 months)
- Site Restoration and Demobilization: Rainy Season through August (12 months, but intermittent)

Effectiveness

Effective for treatment (no long-term containment required) – Several well-documented case studies[75] have shown that ISTD or IPTD can treat chlorinated dioxins, including TCDD, to concentrations well below the target cleanup goals for either soil or sediment. Of particular interest is a full-scale site in Alhambra, California, where the regulatory agency determined all cleanup goals were met and the site was appropriate for unrestricted land use with no further action.[76] Also, a recent demonstration in Japan provided sufficient results to gain approval from the Japanese Ministry of Environment for applying the technology to treat dioxins in Japan.[77] Table 20 summarizes the results of these key case studies. In all cases, initial concentrations were of a similar order of magnitude expected for stockpiles to be treated at the Airport, and final concentrations were below even the treatment standard for sediment of 150 pg TEQ/g.

Multiple studies have demonstrated that over 95% of dioxins and other high-boiling point compounds are destroyed *in situ* using ISTD/IPTD. For example, the Rocky Mountain Arsenal Hex Pit Treatability Study, which was overseen by the USEPA SITE Program, included a mass balance for PCDD/furans . The SITE program report stated, "These data further suggest that the application of the ISTD thermal well technology at the Hex Pit site will reduce the mass of these contaminants by greater than 95% *in situ*, while producing process condensate and process vapor with relatively low contaminant concentrations".[78] In other examples, treatability testing has shown that PAH-contaminated soils treated at 300°C (572 degrees Fahrenheit [°F]) for three days achieved much lower residual contaminant concentrations than soils treated at 400°C (752°F) for just one day.[79] There are two primary reasons for the successful treatment of high-boiling point compounds such as PAHs, PCBs, and PCDD/furans at temperatures significantly lower than their respective boiling points. First, heating the subsurface to above 300°C increases the contaminants' vapor pressures over one million-fold. Second, longer

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[75] ENSR 2000, Baker and La Chance 2003, Baker et al. 2007 and Heron et al. 2010.
[76] Baker et al. 2007.
[77] Heron et al. 2010.
[78] ENSR 2000.
[79] Baker et al. 2007.

residence times in the heated zone have resulted in significantly higher removals of various PCB Aroclors,[80] and the same was seen for PAHs.[81]

Concentrations of dioxins in exhaust gas for all case studies (Table 20) were within orders of magnitude below regulatory limits. Adsorption on GAC is considered a Best Available Technology for removal of compounds like dioxins and furans (PCDD/furans) that have a high octanol-water partitioning coefficient. PCDD/furans are bound tenaciously to GAC, and especially with a lead-polish configuration of GAC vessels cannot break through. Again, based on measurements from past projects, over 95% of the dioxins are expected to be destroyed in-situ. If detailed design calculations were to show that use of serial GAC vessels alone will not meet the standards, then the need for a thermal oxidizer would be considered. Dispersion between the stack and property boundaries or locations of other receptors would be considered in this analysis.

TABLE 20. PERTINENT CASE STUDY DATA FOR ISTD/IPTD FOR TREATMENT OF DIOXINS

Site	Target Media	Average Pre-Treatment Concentration (pg-TEG/g)	Average Post-Treatment Concentration (pg-TEG/g)	Exhaust Gas Concentration (ng-TEG/nm^3)
Yamaguchi, Japan[1]	Sediment	1,800	67.75	0.000018
Alhambra, California, USA[2]	Soil	18,000	110	0.0071
Cape Giradeau, Missouri, USA[3]	Soil	6,500	3.2	0.0029
Ferndale, California, USA[3]	Soil	3,200	7.3	0.0055

Notes:
1 - Heron et al. 2010.
2 – Baker et al. 2007.
3 – Baker and LaChance 2003.

Implementability

The ISTD/IPTD alternative would require a footprint of about 15,400 m^2 distributed in two separate stockpiles. However, one of those stockpiles would be located on top of the SA, so a new area would not be disturbed. ISTD/IPTD is implementable with the associated challenges described in the subsections below.

Energy Usage

It is estimated that about 21,000,000 kwh will be required for each of the two stockpiles to be treated, for a total of 42,000,000 kwh. This is on the order of a light to medium-sized industrial facility. The local power company in Da Nang has indicated it can provide this power and has

[80] Heron et al. 2010.
[81] Baker et al. 2007.

provided a cost estimate for running power to the site from the nearest substation. This cost is included in the preliminary estimate.

Mobilization

Much of the equipment and technical expertise for this technology will have to come from overseas (probably the U.S.). This will impact cost, and has been included in the preliminary cost estimate.

Air Monitoring

Significant air monitoring will be required to ensure emissions do not exceed designated limits. This was also the case for the Alhambra, California project and can be included in the operations.[82] Based on the previous case studies, it is anticipated that the use of multiple GAC units will be sufficient to meet all air emissions regulations.

Soil Integrity

Limited quantitative data are available regarding the impact of ISTD/IPTD on geotechnical properties of soil. However, for the Alhambra, California project,[83] the California Department of Toxic Substances Control requested geotechnical testing of the post-treatment soils. Samples were tested for parameters of dry and wet bulk density, calculated porosity, as-received moisture content, saturated hydraulic conductivity by the falling-head method, and particle size analysis. It was concluded that ISTD treatment did not significantly affect the geotechnical properties of the soil.[84] This conclusion was based on the fact that post-treatment soil samples exhibited saturated hydraulic conductivity and total porosity values consistent with sandy loam material, and consistent with the texture of the pre-treated soil. Thus, for the sandy soils at the Airport, it is likely that they could be used as fill for a variety of purposes following treatment, but geotechnical testing should be performed before using the soils as structural fill. It is possible that treatment of the sediments with a high organic fraction might have a greater impact on geotechnical properties; however, such material would likely be unsuitable for structural fill even without thermal treatment. It is currently assumed that treated soils and sediment would simply be spread on the land surface and revegetated, but testing of the soils could be performed to determine whether other beneficial uses are possible following treatment.

Cost

At the alternatives evaluation stage, the design for the remedial alternatives are still conceptual, not detailed, and the cost estimates are considered to be "order-of-magnitude." The cost engineer must make assumptions about the detailed design in order to prepare the cost estimate. A detailed cost estimate backup is provided in Appendix A3. The total cost estimate for this alternative is $33.74M, comprising construction ($24.38M), excavation and disposal ($8.77M), and monitoring and mitigation ($0.59M). No long term O&M beyond the 2-year operating timeframe would be required.

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[82] Baker et al., 2007.
[83] Heron et al. 2009.
[84] Heron et al. 2009.

The construction cost estimate for this alternative is split into two sections: the "ISTD/IPTD" estimate, which mainly includes work performed by the thermal subcontractor, and the "ISTD/IPTD Disposal" estimate, which includes work the excavation of the contaminated soils and sediments and placement into stockpiles. Main elements of the two sections of this cost estimate are listed below. A summary of the overall ISTD/IPTD alternative cost is provided in Table 21 and detailed backup of the cost estimate is provided in Appendix A3.

The "ISTD/IPTD" estimate includes the following costs:

Design and Installation – Design, permitting, procurement, mobilization, furnishing of power to the stockpile site and related equipment, pile construction, drilling and installation of pile wells, installation of the vapor cover and the treatment system, all mechanical and electrical work, and commissioning.

Operation – Maintenance, spare parts, subcontractor labor, travel, and per diem, process monitoring, waste and GAC disposal, and equipment rental fees.

Demobilization – Removal of treatment equipment, reporting, and electrical power costs.

The "ISTD/IPTD Disposal" estimate includes the following costs:

Site Preparation – Installation and maintenance of decontamination areas at excavation sites, traffic control, health and safety oversight during all phases of work, clearing and grubbing the sites, construction of soil storage and dewatering areas, and UXO clearing or disposal.

Excavation – At the MLA, SA, Drainage Ditch, Eastern Hotspot, PISA, Sen Lake and the Eastern Wetland (using Aqua Dam bladders for Sen Lake).

Hauling – From excavation sites to treatment piles.

Site Restoration – Removal of temporary facilities, and restoration of the site.

Indirect Costs – Permits, insurance, and bonds, general conditions, overhead, and profit, but not tax, escalation, or contingency (contingency is added later).

TABLE 21. SUMMARY OF COST ESTIMATE FOR ISTD/IPTD ALTERNATIVE

Project Alternative 4

Thermal (ISTD / IPTD)

COST ESTIMATE SUMMARY
ENVIRONMENTAL ASSESSMENT OF PROJECT ALTERNATIVES

Client:	USAID Vietnam
Site:	Da Nang Airport
Location:	Da Nang, Vietnam
Phase:	Environmental Assessment of Project Alternatives
Level of Project Definition:	10% (Conceptual)
Base Year (Year 0):	2nd Quarter, Fiscal Year 2010 (FY10)
Date:	February 8, 2010

Description: In this alternative, contaminated soil from the MLA and the SA, as well as contaminated sediments from the drainage ditch and Sen Lake, would be excavated, stockpiled, and thermally treated to below regulatory limits. Figure 2 outlines the general location of each of the major components of the ISTD/IPTD thermal alternative. It is expected that the ISTD/IPTD alternative will also be implemented over a 2-year period.

CONSTRUCTION CAPITAL COSTS: (Assumed to be Incurred During Years 1 and 2)

SPREADSHEET REPORT DESCRIPTION	QTY	UNIT(S)	UNIT COST	TOTAL	NOTES
Thermal Alternative	1	LS	$16,789,205	$16,789,205	Includes permitting, mobilization/demobilization of system from overseas, system construction and installation, power, commissioning, operation, monitoring, effluent/GAC treatment.
SUBTOTAL				$16,789,205	
Contingency (Scope and Bid)	0%			$0	20% scope and bid contingency included in treatment subcontractor estimate.
SUBTOTAL				$16,789,205	
Project Management	5%			$839,460	Percentage from Exhibit 5-8 in EPA 540-R-00-002 was used.
Remedial Design	6%			$1,007,352	Percentage from Exhibit 5-8 in EPA 540-R-00-002 was used.
Construction Management	6%			$1,007,352	Percentage from Exhibit 5-8 in EPA 540-R-00-002 was used.
Technical Support	15%			$2,518,381	Middle value of the recommended range in EPA 540-R-00-002 was used.
TOTAL				$22,161,750	
TOTAL with VAT (assumed 10%)	10%			$24,377,925	
TOTAL CAPITAL COST				**$24,378,000**	Total capital cost is rounded to the nearest $1,000.
CAPITAL COST PER YEAR (YEARS 1 THROUGH 2)	2	YR	$24,378,000	**$12,189,000**	Annual capital cost over the assumed duration.

CONSTRUCTION CAPITAL COSTS: (Assumed to be Incurred During Years 1 and 2)

SPREADSHEET REPORT DESCRIPTION	QTY	UNIT(S)	UNIT COST	TOTAL	NOTES
ISTD/IPTD Alternative	1	LS	$4,760,183	$4,760,183	Includes site clearing/preparation, excavation, decontamination, dewatering, hauling, backfilling, permanent stockpiling of treated soil/sediment, site restoration, and UXO screening and clearing of excavation areas.
SUBTOTAL				$4,760,183	
Contingency (Scope and Bid)	25%			$1,190,046	15% Scope, 10% Bid (Low end of recommended range in EPA 540-R-00-002).
SUBTOTAL				$5,950,229	
Project Management	5%			$297,511	Percentage from Exhibit 5-8 in EPA 540-R-00-002 was used.
Remedial Design	8%			$476,018	Percentage from Exhibit 5-8 in EPA 540-R-00-002 was used.
Construction Management	6%			$357,014	Percentage from Exhibit 5-8 in EPA 540-R-00-002 was used.
Technical Support	15%			$892,534	Middle value of the recommended range in EPA 540-R-00-002 was used.
TOTAL				$7,973,306	
TOTAL with VAT (assumed 10%)	10%			$8,770,637	
TOTAL CAPITAL COST				**$8,771,000**	Total capital cost is rounded to the nearest $1,000.
CAPITAL COST PER YEAR (YEARS 1 THROUGH 2)	2	YR	$8,771,000	**$4,385,500**	Annual capital cost over the assumed duration.

Project Alternative	**4**
Thermal (ISTD / IPTD)	

COST ESTIMATE SUMMARY
ENVIRONMENTAL ASSESSMENT OF PROJECT ALTERNATIVES

Client:	USAID Vietnam
Site:	Da Nang Airport
Location:	Da Nang, Vietnam
Phase:	Environmental Assessment of Project Alternatives
Level of Project Definition:	10% (Conceptual)
Base Year (Year 0):	2nd Quarter, Fiscal Year 2010 (FY10)
Date:	February 8, 2010

Description: In this alternative, contaminated soil from the MLA and the SA, as well as contaminated sediments from the drainage ditch and Sen Lake, would be excavated, stockpiled, and thermally treated to below regulatory limits. Figure 2 outlines the general location of each of the major components of the ISTD/IPTD thermal alternative. It is expected that the ISTD/IPTD alternative will also be implemented over a 2-year period.

ANNUAL OPERATIONS AND MAINTENANCE (O&M) COSTS-MONITORING (Years 1 through 3)

SPREADSHEET REPORT DESCRIPTION	QTY	UNIT(S)	UNIT COST	TOTAL	NOTES
Environmental Mitigation and Monitoring Plan (EMMP) Implementation	1	LS	$107,747	$107,747	Includes sampling and analysis required by the EMMP; assume 0.5% of treatment and disposal direct capital costs.
SUBTOTAL				$107,747	
Contingency (Scope and Bid)	25%			$26,937	15% Scope, 10% Bid (Low end of recommended range in EPA 540-R-00-002).
SUBTOTAL				$134,684	
Project Management	8%			$10,775	Percentage from Exhibit 5-8 in EPA 540-R-00-002 was used.
Construction Management	10%			$13,468	Percentage from Exhibit 5-8 in EPA 540-R-00-002 was used.
Technical Support	15%			$20,203	Middle value of the recommended range in EPA 540-R-00-002 was used.
TOTAL				$179,130	
TOTAL with VAT (assumed 10%)	10%			$197,043	
TOTAL ANNUAL O&M COST				**$197,000**	Total O&M cost is rounded to the nearest $1,000.
TOTAL O&M COST (YEARS 1 THROUGH 3)	3	YR	$197,000	**$591,000**	Annual O&M Cost over the assumed duration.

Notes:
The cost summary and present value analyses provided are based on guidance presented in "A Guide to Developing and Documenting Cost Estimates During the Feasibility Study", EPA 540-R-00-002 (July 2000).
Percentages used for professional/technical services costs are based on guidance from Section 5.0 of "A Guide to Developing and Documenting Cost Estimates During the Feasibility Study", EPA 540-R-00-002 (July 2000).
Costs presented for this alternative are expected to have an accuracy between -30% to +50% of actual costs, based on the scope presented. They are prepared solely to facilitate relative comparisons between alternatives for evaluation purposes. Costs are prepared solely to facilitate relative comparisons between alternatives for evaluation purposes and do not represent annual appropriations or total budgetary expenditures required.

Abbreviations:

EA	Each
GAC	Granular Activated Carbon
LS	Lump Sum
NA	Not Applicable
O&M	Operations and Maintenance
QTY	Quantity
UXO	Unexploded Ordinance

Section 6. Affected Environment

This section presents a description of the environmental resources of the Airport and Da Nang City that may be potentially influenced by one or more of the remedial alternatives.

Existing baseline information on most environmental resources is limited. In particular, a detailed description of the temporal and spatial variability of most of the environmental resources does not exist. This includes COPCs that may be either associated with dioxin contamination or with the operation of an Air Force military base and international airport.

The quality of the current environmental baseline does not limit the ability to assess the environmental effects of the remedial alternatives. However, it will be necessary to continue to augment the environmental baseline with additional field programs prior to the start of Project construction in order to properly monitor the environmental effects of the Project.

6.1. Main Catchments

Three small catchments drain the Airport property.[85] The environmental conditions of two of these catchments are relevant to the potential environmental effects of the remedial alternatives:

- March 29 Lake-Phu Loc River Catchment – This approximately 900 ha catchment drains the northern section of the Airport. It contains the four dioxin hotspots, the lakes and wetlands at the northern end of the Airport, and surrounding area; it is where many of the Project activities would occur. The majority of the catchment that is within the Airport boundary drains out of the Airport property via a culvert on the north side of Sen Lake, which leads to a covered municipal stormwater drain that empties into the Phu Loc River as it flows into Da Nang Bay.

- West of Airport-Han River Catchment – This approximately 700 ha catchment drains the southwestern section of the Airport where the landfill would be constructed and operated. Drainage from this catchment flows via a covered municipal stormwater drain into the Han River that also flows eventually into Da Nang Bay.

During the high rain months of October and November, flooding is common in Da Nang City, including the Airport.

[85] Da Nang Urban Environmental Company 1998.

6.2. Physical Environmental Resources

6.2.1. CLIMATE

The climate in Da Nang City (Figure 14) is characterized by:

- An average annual temperature of 25.9°C, with a "winter" season from October to March in which the temperatures are somewhat cooler than the "summer" season from April to September.
- An average humidity of 82%.
- An average annual rainfall of approximately 2,000 millimeters (mm).
- A dry season lasting generally from January to August and a rainy season lasting generally from September to December. Approximately 75% of the total annual rainfall occurs during the rainy season, with 30% of total annual rainfall occurring in October.
- Approximately four typhoons and tropical storms annually.
- Predominantly east-southeast, north-northwest, and south-southwest winds in the dry season and predominantly north-northwest winds in the rainy season.

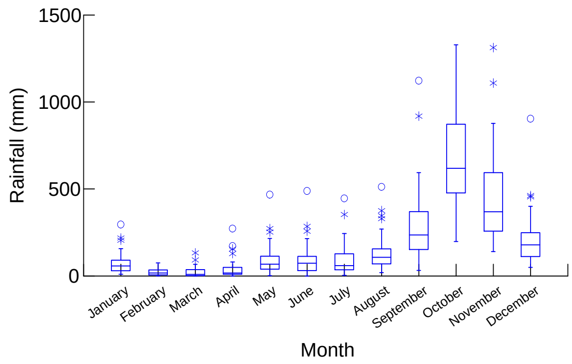
6.2.2. SOILS AND SEDIMENTS

The physical and chemical characterization of soils and sediments in the March 29 Lake-Phu Loc River and the West of Airport-Han River catchments is currently incomplete. Other than the dioxin characterization studies there has to date been little baseline environmental characterization of the soils and sediments in these parts of the Airport.

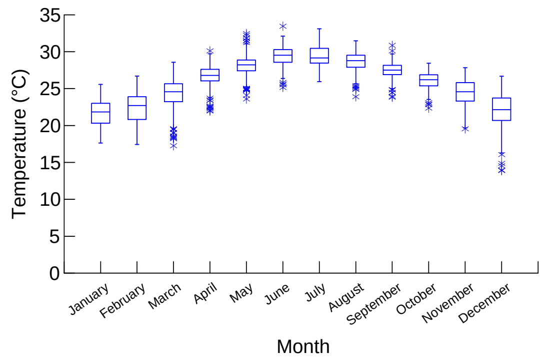
Figure 15 contains the location of the soil and sediment sampling on which the description of current soil and sediment conditions presented below is based. Detailed soils and sediment baseline data are provided in Appendix A4.

FIGURE 14. SUMMARY OF CLIMATIC CONDITIONS FOR DA NANG CITY

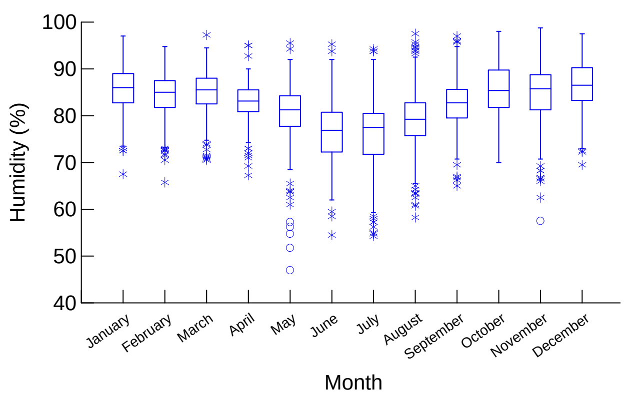
PRECIPITATION



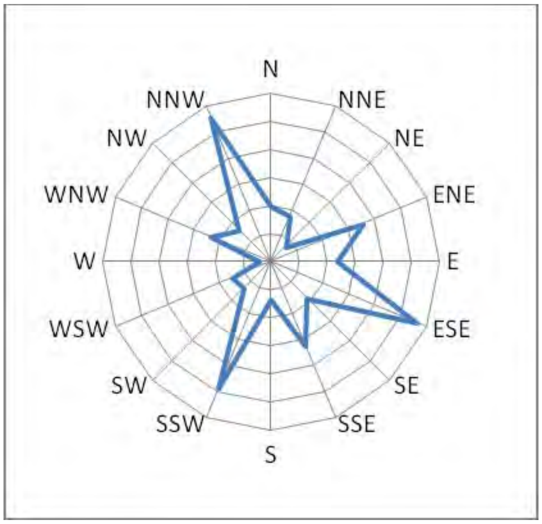
TEMPERATURE



HUMIDITY



WIND DIRECTION, DRY SEASON



WIND DIRECTION, RAINY SEASON

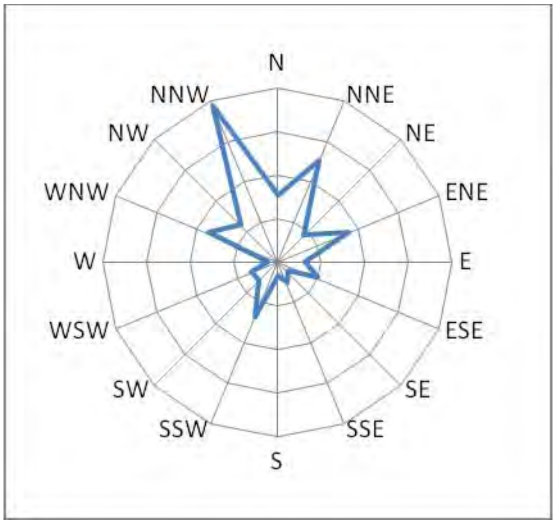
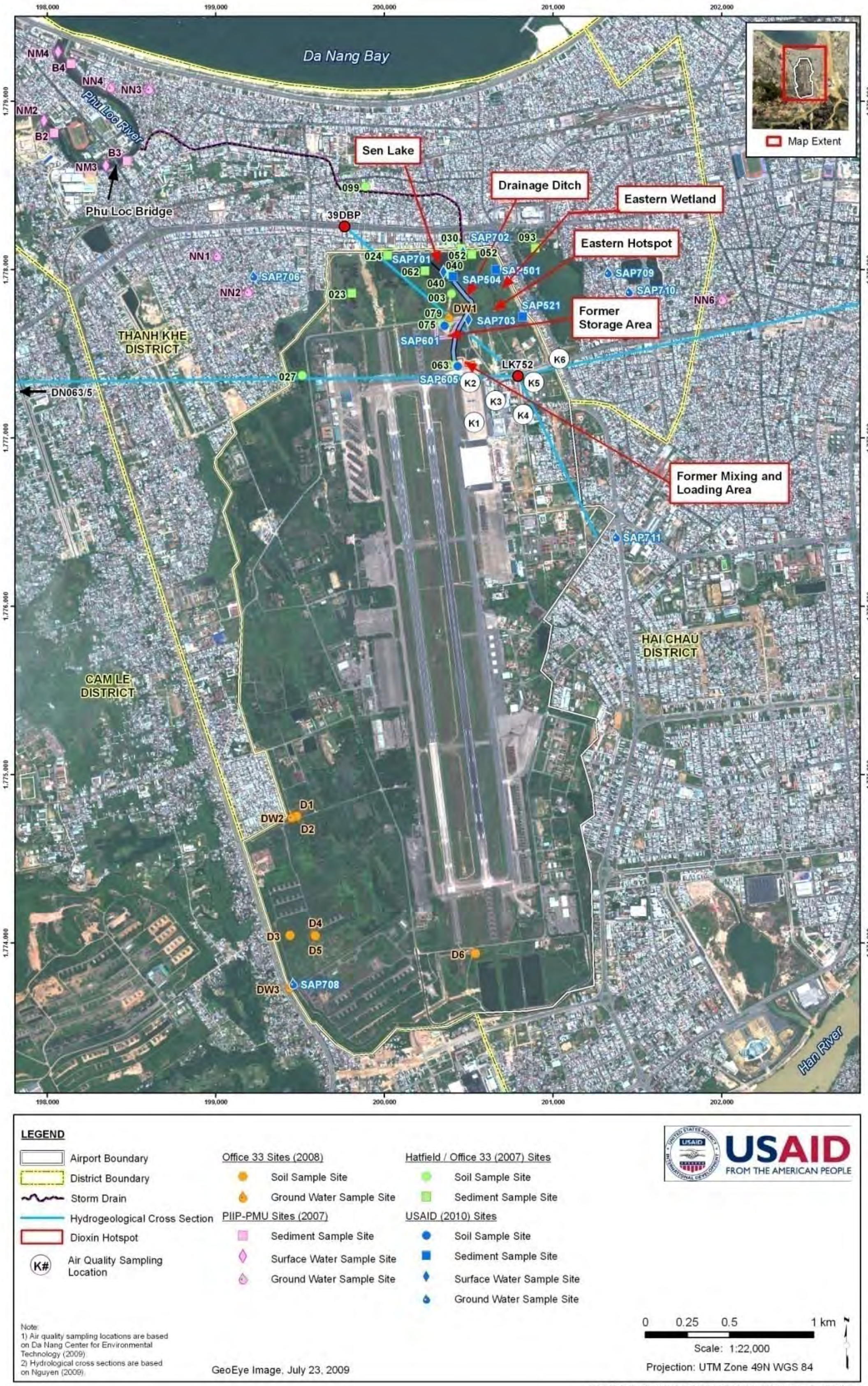


FIGURE 15. LOCATION OF BASELINE COPC SAMPLES FOR DA NANG AIRPORT



March 29 Lake-Phu Loc River Catchment

Soils in the March 29 Lake-Phu Loc River catchment are sandy with generally low organic content (less than 1.0% TOC), and are generally acidic, while sediments in the lakes of the March 29 Lake-Phu Loc River catchment are acidic, comprised of approximately 50% sand, 30% silt, and 20% clay, and contain approximately 7% TOC (Table A4.1). Soil boring logs prepared during the January 2010 field program[86] confirm that surface soils in the MLA and SA (to a depth of 2.1 m) are comprised entirely of loose fine quartz sands.

In addition to the known major herbicides (Agents Orange, Purple, Blue, Pink, Green and White), other chemicals including fungicides, insecticides, wetting agents, wood preservatives, insect repellants and other herbicides are known to have been used in Vietnam by US and Australian forces.[87] Unlike 2,3,7,8-TCDD contamination, which can be linked to Agent Orange usage, linking other COPCs to USG activities is not possible without detailed information about the types (formulations), quantities, and locations where these chemicals were stored and used. Similarly, information regarding the potential usage and storage of COPCs by the GVN at Da Nang Airport post-1975 is lacking. A summary of the existing information on COPC concentrations in the March 29 Lake-Phu Loc River catchment soils and sediments is presented below (COPC information for sediments exists only for Sen Lake):

- In the absence of soil standards, measured concentrations of PCBs in soils were below existing standards for sediments (Table A4.2).
- Measured concentrations of total PCBs in Sen Lake sediments were above existing standards (Table A4.2). This exceedence is due to elevated concentrations of PCB-118 (Aroclor).
- Measured concentrations of a number of organochlorine pesticides were above existing standards in some locations, including dieldrin, hexachlorobenzene, aldrin, as well as some forms of chlordane and endosulphan (Table A4.3).
- Measured concentrations of most PAHs in soils were below existing standards (Table A4.4).
- Measured concentrations of a number of PAHs in Sen Lake sediments were above existing standards (Table A4.4).
- Measured concentrations of petroleum hydrocarbons (Table A4.5) and chlorophenols (Table A4.6) were generally below detection limits for both soils and sediments.
- Measured concentrations of a number of metals in Sen Lake sediments have exceeded sediment standards (Table A4.7). Measured exceedances have occurred in the top 6 cm

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[86] Dong 2010.
[87] IOM 1994.

of lake sediments, with most measured exceedances occurring in the top 2 cm of lake sediments.

- Metals concentrations in soil in the MLA and SA exceeded USEPA Region 5 standards for antimony, arsenic, barium, copper, lead, vanadium, and zinc. Method detection limits (MDLs) also exceeded soil standards for cadmium, cobalt, and thallium (Table A4.8). The small amount of sediment sampling that has been conducted in the Phu Loc River indicates concentrations of a number of metals exceed existing standards (Table A4.9). There is no information on concentrations of other COPCs in Phu Loc River sediments.

West of Airport-Han River Catchment

Less information is available for soils in the West of Airport-Han River catchment (the catchment in which the landfill would be located), than for the March 29 Lake-Phu Loc River catchment. Visual observations made during sampling for dioxin characterization studies suggest soils in this part of the Airport are also sandy. The measured concentrations of most metals are below existing standards, with the exception of mercury (Table A4.10). No information exists on the concentration of other COPCs in the West of Airport-Han River catchment.

6.2.3. GROUNDWATER RESOURCES

Two hydrogeological cross-sections created for other projects[88] transect the March 29 Lake-Phu Loc River Catchment (Figure 16). Nguyen (2009a) and Office 33 (2008) describe the main aquifers in this hydrogeological sequence which is found throughout the Airport property.

The uppermost Holocene aquifer consists of yellow-grey, fine to medium sand and clayey sand and ranges in thickness from 8 m to 15 m. Groundwater levels range seasonally between 0.3 m to 3 m below ground level (bgl), with groundwater levels generally ranging between 2 m to 3 m bgl in the dry season. The permeability of the Holocene aquifer ranges between 1.42 and 1.9 m/d.[89] Groundwater flow direction in the March 29 Lake-Phu Loc River catchment is to the north and in the West of Airport-Han River Catchment is to the south,[90] which corresponds to the direction of surface water flows in these catchments.

An aquitard, less than 5 m thick, underlies the unconfined Holocene Aquifer, and is comprised largely of clays. The Lower Pleistocene and Cambrian Ordovician Aquifers underlie the aquitard and are the source for much of the drinking and domestic water supply of Da Nang City.

6.2.4. GROUNDWATER QUALITY

The current understanding of groundwater quality information for the March 29 Lake-Phu Loc River and the West of Airport-Han River catchments is poor. Only basic groundwater quality information is available for a few locations, and little information exists on concentrations of many COPCs.

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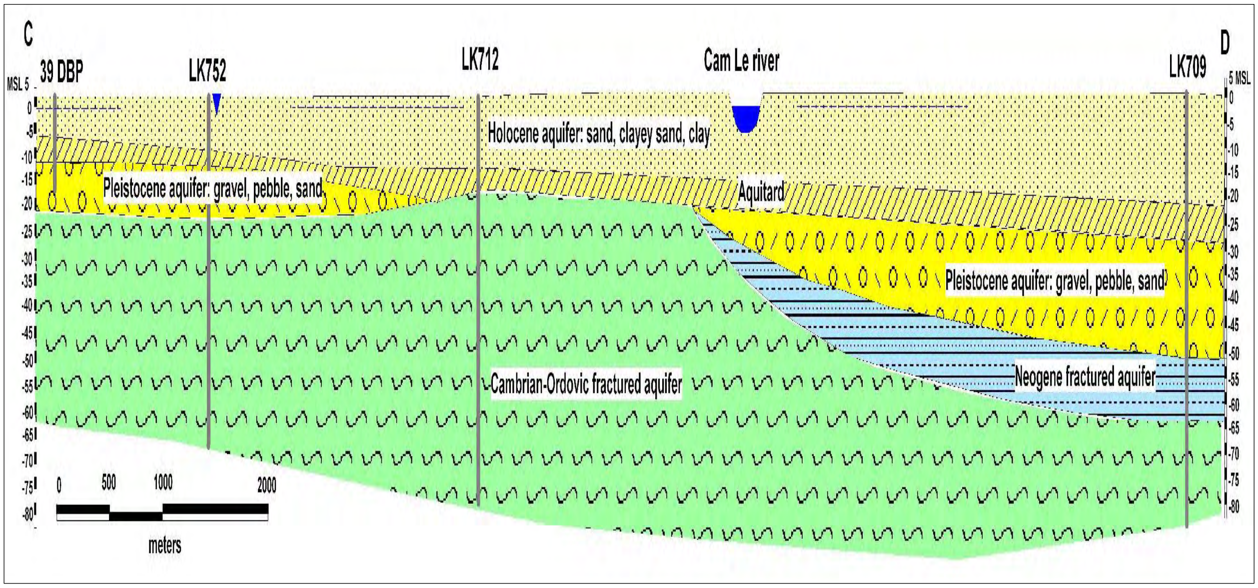
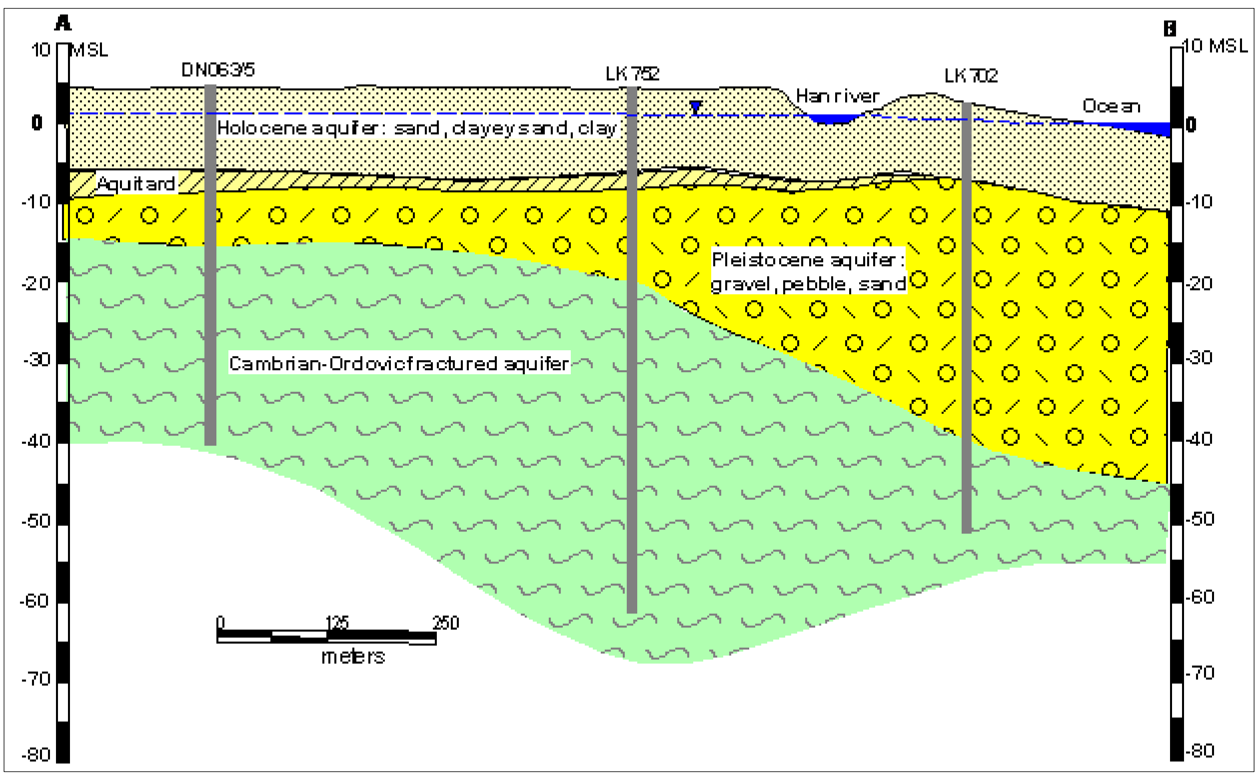
[88] Nguyen 2009a.
[89] Nguyen 2009a.
[90] Office 33 2008.

FIGURE 16. HYDROGEOLOGICAL CROSS-SECTIONS TRANSECTING THE MARCH 29 LAKE-PHU LOC RIVER CATCHMENT



See Figure 15 for location of cross-section.
Note: Airport property within March 29 Lake-Phu Loc River catchment is to immediate left of LK752.



See Figure 15 for location of cross-sections.
Note: Airport property within March 29 Lake-Phu Loc River catchment is between 39DBP and LK752.

March 29 Lake-Phu Loc River Catchment

Groundwater quality information exists for a single well in the March 29 Lake-Phu Loc River catchment within the Airport property, although some groundwater quality data have been collected for the catchment outside the Airport property (Table A4.11 to A4.14). Relatively few measured exceedances of either Vietnamese or USEPA standards are found in metals, although manganese is the most common exceedance outside the Airport Property. Sampling conducted in January 2010 indicated that PCBs, PAHs, and VOCs all were below guidelines and/or MDLs.

West of Airport-Han River Catchment

In the West of Airport-Han River Catchment, groundwater was sampled historically in two wells and in the January 2010 program at one location. COPCs measured include metals, PCBs, PAHs, and VOCs (Table A4.11 to A4.14). The dataset indicates a few metals exceedances (either Vietnamese or USEPA standards) in the two wells that were sampled historically, while no exceedances were noted in the January 2010 sampling.

6.2.5. SURFACE WATER QUALITY

March 29 Lake-Phu Loc River Catchment

Until the sampling conducted in January 2010, there was little characterization of surface water quality in the lakes and wetlands in the March 29 Lake-Phu Loc River catchment that comprises the north part of the Airport. A range of COPCs (in addition to Agent Orange and other major herbicides) were used by U.S. military forces prior to 1971; however, detailed information about these chemicals (quantities, formulations, storage and usage etc.) is lacking, and therefore linking present day concentrations to past activities is difficult. Similarly, information regarding the potential storage and usage of COPCs by the GVN post-1975 at Da Nang airport is lacking. Sen Lake has been sampled for metals, PCBs, PAHs, and VOCs with the concentrations of dissolved oxygen, biological oxygen demand (BOD), chemical oxygen demand (COD), ammonia, iron, and oil exceeding GVN surface water quality guidelines for domestic purposes; however, all water samples met the guidelines for non-domestic.

January 2010 samples analyzed from Sen Lake and the drainage canal showed exceedances of USEPA and/or Vietnamese guidelines with respect to arsenic, aluminum, manganese, and iron.

Water quality in the Phu Loc River downstream of the Airport is characteristic of many polluted urban watercourses and reflects inputs of biological and industrial waste (Table A4.17, Table A4.18). BOD, dissolved oxygen levels, suspended solids (SS) concentrations, oil, and total coliform counts are routinely above national Vietnamese standards; concentrations of a number of metals, particularly lead, iron, and cadmium are above Vietnamese and USEPA standards.

West of Airport-Han River Catchment

The water quality of the minor watercourses and water bodies in the West of Airport-Han River Catchment is unknown.

6.2.6. AIR QUALITY

Air quality information on the Airport property collected in support of the Airport expansion EIA[91] indicates concentrations of all measured air quality variables were below existing standards (Table A4.19).

6.3. Natural and Biological Resources

6.3.1. TERRESTRIAL ECOSYSTEMS AND BIODIVERSITY

March 29 Lake-Phu Loc River Catchment

The terrestrial ecosystems on the Airport property within the March 29 Lake-Phu Loc River catchment are degraded, consisting primarily of grasses and shrubs, with patches of planted exotic tree species such as eucalyptus. These terrestrial ecosystems have scant biodiversity value (Photo 7 and Photo 8). In addition, because urban settlements cover the entire area between the northern boundary of the Airport and Da Nang Bay, there are no significant biodiversity areas in the March 29 Lake-Phu Loc River catchment downstream of the Airport property.

West of Airport-Han River Catchment

The terrestrial ecosystems on the Airport property within the West of Airport-Han River Catchment are also degraded, although less so than the March 29 Lake-Phu Loc River catchment. However, much of the vegetation consists of scrub grasses and shrubs, with little tree cover (Photo 9 and Photo 10). These terrestrial ecosystems have negligible biodiversity value. In addition, because urban settlements cover the entire area between the southern boundary of the Airport and the Han River, there are no biodiversity concerns in the West of Airport-Han River catchment downstream of the Airport property.

6.3.2. AQUATIC ECOSYSTEMS AND BIODIVERSITY

March 29 Lake-Phu Loc River Catchment

The lakes and wetlands in the March 29 Lake-Phu Loc River catchment in the northern part of the Airport (Sen Lake, Lake B, Lake C, Xuan Lake and March 29 Lake) are part of a coastal plain running the entire length of Da Nang City. Aquatic resources have historically been harvested by local residents in these lakes and wetlands. Harvesting of aquatic resources from these lakes and wetlands at the north end of the Airport was prohibited in 2007 following the detection of high dioxin levels in fish tissues and higher than normal dioxin levels in the blood samples of persons using the lake for economic purposes.

West of Airport-Han River Catchment

Aquatic ecosystems in the part of the Airport property within the West of Airport-Han River Catchment is largely restricted to surface drainages conveying airport runoff, as well as four

[91] Da Nang Centre for Environmental Technology 2009.

small artificial lakes formed at the time of Airport construction.[92] These lakes are used for aquaculture and are dredged every year.

6.3.3. Endangered Species

A baseline survey of terrestrial and aquatic biodiversity will be conducted in the initial stages of Project implementation and will include surveys to identify the possible presence of rare and endangered species. The EMMP will contain explicit descriptions regarding how rare and endangered species will be handled during the Project.

[92] Office 33 2008.

Section 7. Environmental Consequences

This section presents a complete description of the potential environmental impacts associated with each remedial alternative.

7.1. Environmental Impacts Not Considered

The ESS indicated a number of environmental resources could likely be excluded from the EA; additional environmental information obtained since the ESS was prepared confirms that the environmental resources listed in this section do not need to be considered in this EA.

- Nature Reserves and Protected Areas – There are three nature reserves and protected areas in Da Nang City, the closest of which is at the northwestern end of Da Nang Bay (Son Tra Nature Reserve) approximately 7 km from the northern part of the Airport property. None of the remedial alternatives would negatively influence any of the nature reserves and protected areas.

- Cultural and Historic Sites – There are no designated cultural and historic features on the Airport property, and none of the remedial alternatives would negatively influence cultural and historic sites outside of the Airport property.

- Tourism Resources –While there are significant tourism resources throughout Da Nang City, these are located far from the Airport property. None of the remedial alternatives would negatively influence tourism resources in Da Nang City.

7.2. Potential Effects on Land Use

7.2.1. Description of Effects

Potential effects on Land Use are associated with the land disturbance area (in m^2) of each of the alternatives.

7.2.2. Impact Analysis

Table 22 shows the land disturbance area associated with the four alternatives.

The Active Landfill alternative is associated with the greatest land disturbance area, and is almost twice that of the ISTD/IPTD alternative and 13% greater than the Passive Landfill alternative. The disturbance area of the Passive Landfill alternative is 60% greater that of the ISTD/IPTD alternative.

The current land use of the Airport Property is already limited by residential housing on all borders and Da Nang Bay to the north. The runway expansion planned in the future for the northern portion of the Airport will limit encroachment upon the eastern portion of Lake C, which may impact the excavation of Sen Lake. Height limitations of the landfill are also critical, due to the close proximity to the end of the runways.

TABLE 22. COMPARISON OF LAND DISTURBANCE AREA FOR THE REMEDIAL ALTERNATIVES

Alternative	Remediation Step	Land Disturbance Area (m^2)
No Action	Mixing Loading Area (footprint)	19,600
	Storage Area (footprint)	16,200
	Drainage Ditch (footprint)	35,600
	Eastern Hotspot (footprint)	7,700
	Sen Lake and Eastern Wetland (footprint)	85,400
	PISA (footprint)	3,200
	Total Land Disturbance Area	167,700
Passive Landfill	Total Area to be Excavated with (footprint of all areas to be excavate)	167,700
	Footprint of Temporary Storage and Dewatering Area	21,000
	Haul Road Upgrade and Widening	74,000
	Landfill Footprint	33,350
	Total Land Disturbance Area	296,050
Active Landfill	Total Area to be Excavated with (footprint of all areas to be excavate)	167,700
	Footprint of Temporary Storage and Dewatering Area	53,000
	Haul Road Upgrade and Widening	74,000
	Landfill Footprint	40,250
	Total Land Disturbance Area	334,950
ISTD/IPTD	Total Area to be Excavated with (footprint of all areas to be excavate)	167,700
	Footprint of Contaminated Soil Stockpile	7,300
	Footprint of Contaminated Sediment Stockpile	8,100
	Total Land Disturbance Area	183,100

7.2.3. ASSESSMENT

Land use impacts are assessed as **Significant** for all three alternatives, with the ISTD/IPTD alternative having the lowest potential land use impact and the Active Landfill alternative having the greatest potential land use impact.

7.3. Potential Environmental And Health Impacts Associated With Cleanup Of Unexploded Ordnance

7.3.1. DESCRIPTION OF EFFECTS

Given that the Airport has served as a military base, surveying for and clearing UXO would be required for all Project areas under any remedial alternative.

7.3.2. Impact Analysis

The proposed landfill siting location in the southwestern part of the Airport property has a number of munitions bunkers whose age, contents, and overall integrity are unknown (Photo 6). The level of environmental contamination being generated by these munitions bunkers, and the length of time that might be required to remediate these facilities and dispose of them in order for a landfill to be properly constructed, are unknown. These impacts are applicable to both the Passive and Active Landfill alternatives. The northern part of the Airport, where many of the Project activities would be located under all three remedial alternatives, has no such munitions bunkers; more standard protocols for surveying and clearing of UXO would be required in this Project area.

7.3.3. Assessment

The potential environmental and associated human health risks associated with cleanup of UXO and munitions are assessed as **Significant** for all three remedial alternatives. However, as the potential risk from UXO is related to the size of the footprint for each alternative, the potential risk from UXO is greatest for the Active Landfill alternative and lowest for the ISTD/IPTD alternative. In addition, the requirements for remediating munitions bunkers (and possibly other similar facilities located in the southwestern part of the Airport property) in order for the Passive or Active Landfill alternatives to proceed, is unknown.

7.4. Effects on Surface Water Hydrology

7.4.1. Description of Effects

Implementation of any of the three alternatives would result in changes to surface water hydrology. These changes to surface water hydrology would occur from:

- Clean water diversions around Project areas in order to manage surface runoff and to minimize the generation of project-affected water, and to enable certain Project activities to occur such as the excavation of the Drainage Ditch hotspot.
- Potential changes to the hydrology of Sen Lake, and possibly the eastern wetland area, during the removal of contaminated sediments from the lake.

7.4.2. Impact Analysis

The impacts of any of the remedial alternatives on surface water hydrology would be short in duration, reversible, and generally low in magnitude:

- The area over which the Project activities would occur is small relative to both the total area of the Airport property and the total area of the two catchments.
- The diversion of Sen Lake inflows via the Drainage Ditch to the Eastern Wetland during excavation of Sen Lake sediments (and the reverse if eastern wetland sediments need to be excavated), would by itself have no effect on Sen Lake hydrology.
- The road currently designated as the haul road for the Passive and Active Landfill alternatives already incorporates culverts and surface runoff drainage systems to

accommodate watercourse flows. These would be maintained and enhanced as required when the road is upgraded under these alternatives.

- The excavation of sediments from Sen Lake is a required component of all three remedial alternatives. Mitigation measures may be required to limit the hydrologic effects of excavating Sen Lake sediments, but these would be applied irrespective of the remedial alternative that is selected.

7.4.3. ASSESSMENT

Project effects on surface water hydrology are assessed as **Insignificant** for all remedial alternatives.

7.5. Effects on Surface Water Quality

7.5.1. DESCRIPTION OF EFFECTS

All three alternatives would have potential impacts on surface water quality due to the generation of project-generated contaminated waste water.

Passive and Active Landfill Alternatives

The major sources of project-affected water in the Passive and Active Landfill alternatives would be:

- Precipitation on the Temporary Storage and Dewatering Area during its operation
- Precipitation on the landfill during placement of contaminated material
- Precipitation on contaminated soil during excavation
- Groundwater seepage into open excavations
- Dredging of Sen Lake and dewatering of sediments
- Generation of landfill leachate

ISTD/IPTD Alternative

The major sources of project-affected water in the ISTD/IPTD alternative would be:

- Precipitation on contaminated soil during excavations
- Groundwater seepage into open excavations
- Precipitation on the soil and sediment stockpiles during set-up, maintenance, and treatment

7.5.2. Impact Analysis

Appendix A5 provides detailed calculations and assumptions for the volume of project-affected water generated for each remedial alternative; these are summarized in Table 23.

Passive Landfill Alternative

The amount of project-generated contaminated wastewater under the Passive Landfill alternative is estimated at approximately 262,240 m^3. Most of this is generated as landfill leachate, assuming a 50-year lifespan and 60 percent of wet season precipitation being generated as leachate.[93] Operation of the Temporary Storage and Dewatering Area, and water associated with sediments excavated from Sen Lake, are estimated together to generate approximately 6,675 m^3 of project-affected water, while other Project activities are estimated to generate smaller amounts of project-affected water requiring treatment.

Active Landfill Alternative

The amount of project-affected water generated under the Active Landfill alternative is estimated at approximately 137,600 m^3 (Table 23). Less project-affected water would be generated by landfill leachate under the Active Landfill alternative (10 year lifespan), assuming successful implementation. Project-affected water generated by operation of the Temporary Storage and Dewatering Area would be significantly greater than in the Passive Landfill alternative (68,200 m^3), as this facility would be larger and would have to remain in place longer in order to accommodate the requirement to uniformly mix contaminated soil and sediments prior to placing in the Active Landfill. Other Project activities (groundwater seepage into excavations, Sen Lake dredgate water) are estimated to generate smaller amounts of project-affected water requiring treatment.

ISTD/IPTD Alternative

The amount of project-affected water generated under the ISTD/IPTD alternative is estimated at approximately 23,600 m^3. The lower volume of project-affected water in this alternative (as compared to the two Landfill alternatives) is because there would be no operation of a Temporary Storage and Dewatering Area and there would be no landfill leachate. This is partially offset by the project-affected water that would be generated from the construction and operation of the Contaminated Soil and Contaminated Sediment Stockpiles.

7.5.3. Assessment

The ISTD/IPTD alternative is assessed as having the lowest potential environmental impact on water quality of the three remediation alternatives, while the Active Landfill alternative is assessed as having the highest potential impact on water quality.

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[93] Visvanathan et al. 2003.

TABLE 23. ESTIMATED VOLUMES OF CONTAMINATED WASTEWATER FOR THE REMEDIAL ALTERNATIVES

			Passive Landfill		Active Landfill		ISTD/IPTD	
	Project Activity	**Effect**	**Impact Analysis**	**Amount (m^3)**	**Impact Analysis**	**Amount (m^3)**	**Impact Analysis**	**Amount (m^3)**
A.	Operation of temporary storage and dewatering area[1]	Precipitation	11 months duration, 21,000 m^2 area, dry season, 100% exposure[8]. Assume 80% infiltration[2].	3,336	14 months duration (11 months dry season, 4 months wet season). Area is 53,000 m^2, temporary cover during wet season[8]. Assume 80% infiltration (dry season) and 30% infiltration (wet season)[2,3].	68,209	---	---
B.1	MLA Excavation (includes PISA) [1]	Precipitation[2,8]	2 months total duration (dry season). Total excavation area = 22,800 m^2. One quarter open for a maximum of 2 weeks (5,700 m^2). Assume 50% infiltration	102.9	2 months total duration (dry season). Total excavation area = 22,800 m^2. One quarter open for a maximum of 2 weeks (5,700 m^2). Assume 50% infiltration	102.9	2 months total duration (dry season). Total excavation area = 22,800 m^2. One quarter open for a maximum of 2 weeks (5,700 m^2). Assume 50% infiltration	102.9
B.2		Groundwater seepage	Total excavation area = 22,800 m^2. Excavation depth estimated at 1.1 m. One quarter open for a maximum of 2 weeks (4,900 m^2).Q (flow) estimated at 0 as proposed excavation is above modeled groundwater elevation (1.5 m bgl)[4].	0	Total excavation area = 22,800 m^2. Excavation depth estimated at 1.1 m. One quarter open for a maximum of 2 weeks (4,900 m^2).Q (flow) estimated at 0 as proposed excavation is above modeled groundwater elevation (1.5 m bgl)[4].	0	Total excavation area = 22,800 m^2. Excavation depth estimated at 1.1 m. One quarter open for a maximum of 2 weeks (4,900 m^2).Q (flow) estimated at 0 as proposed excavation is above modeled groundwater elevation (1.5 mbgs)[4].	0
C.1	SA & Drainage Ditch Excavation[1]	Precipitation[2,8]	2 months total duration (dry season). Total excavation area = 51,800 m^2. One quarter open for a maximum of 2 weeks (12,950 m^2). Assume 50% infiltration	234	2 months total duration (dry season). Total excavation area = 51,800 m^2. One quarter open for a maximum of 2 weeks (12,960m^2). Assume 50% infiltration	234	1 month total duration (dry season). Total excavation area = 51,800 m^2. One quarter open for a maximum of 1 week (12,950 m^2). Assume 50% infiltration	116.9

TABLE 23. ESTIMATED VOLUMES OF CONTAMINATED WASTEWATER FOR THE REMEDIAL ALTERNATIVES

			Passive Landfill		Active Landfill		ISTD/IPTD	
	Project Activity	**Effect**	**Impact Analysis**	**Amount (m^3)**	**Impact Analysis**	**Amount (m^3)**	**Impact Analysis**	**Amount (m^3)**
C.2		Groundwater seepage	Total excavation area = 51,800 m^2. Excavation depth estimated at 1.6 m. One quarter open for a maximum of 2 weeks (12,950m^2). Q (flow) estimated at 0.026 - 0.35 m^3/day[4].	5.2	Total excavation area = 51,800 m^2. Excavation depth estimated at 1.6 m. One quarter open for a maximum of 2 weeks (12,960 m^2). Q (flow) estimated at 0.026 - 0.35 m^3/day[4].	5.2	Total excavation area = 51,800 m^2. Excavation depth estimated at 1.6 m. One quarter open for a maximum of 2 weeks (12,960 m^2). Q (flow) estimated at 0.026 - 0.35 m^3/day[4].	5.2
D.	Sediment Excavation[5]	Management of dredgate	Initial saturation = 30%, where n=Vv/V, Porosity (n) = 0.35, Porosity volume (V_v) = 11,130 m^3.	3,339	Initial saturation = 30%, where n=Vv/V, Porosity (n) = 0.35, Porosity volume (V_v) = 11,130 m^3.	3,339	Initial saturation = 30%, where n=Vv/V, Porosity (n) = 0.35, Porosity volume (V_v) = 11,130 m^3.	3,339
E.	Placement of contaminated material in landfill[1]	Precipitation[2,8]	4 months duration, dry season (2 weeks/cell). Filled sequentially. 8 cells, maximum exposure 1/4 of landfill. Assume 80% infiltration.	75.8	4 month duration, dry season (1.3 weeks/cell). Filled sequentially. 12 cells, maximum exposure ¼ of landfill. Assume 80% infiltration.	97.5	---	---
F.1	Pile Construction & Treatment[1]	Precipitation on soil stockpile[2,3,8]	---	---	---	---	7,300 m^2 area of soil stockpile - 1 month pile construction (dry season), 100% exposure, 95% infiltration; treatment - 5 months (dry season), 1 month (wet season) - vapor barrier capped, 10% infiltration	5,045

TABLE 23. ESTIMATED VOLUMES OF CONTAMINATED WASTEWATER FOR THE REMEDIAL ALTERNATIVES

			Passive Landfill		**Active Landfill**		**ISTD/IPTD**	
	Project Activity	**Effect**	**Impact Analysis**	**Amount (m^3)**	**Impact Analysis**	**Amount (m^3)**	**Impact Analysis**	**Amount (m^3)**
F.2		Precipitation on sediment stockpile[2,3,8]	---	---	---	---	8,100 m^2 sediment stockpile - maintenance and setup - 3 months (dry season) 100% exposure, 95% infiltration, 4 months (wet season) temporary cap (10% infiltration); treatment - 6 months (dry season) - vapor barrier capped, 10% infiltration	14,994
G.	Operation of Landfill	Leachate[7]	50 year lifespan[8]. Footprint (excluding support facilities) = 21,000 m^2. Leachate generation estimated at zero during the dry season, ~ 60% of precipitation during the wet season appears as leachate[6].	255,150	10 year lifespan[8].Footprint (excluding support facilities) = 27,000 m^2.Leachate generation estimated at zero during the dry season, ~ 60% of precipitation during the wet season appears as leachate[6].	65,610	---	---
	Total			**262,242**		**137,597**		**23,603**

Notes:

Impact analysis based on conceptual design of each remedial alternative and indicative schedules outlined in Figures 8, 10, and 13.

1 Infiltration rates based on professional judgment and literature values (Wanielista et al. 1997; Vesilind et al. 2002).

2 Dry season 1970-2009 Monthly average rainfall (mm) used.

3 Wet season 1970-2009 Monthly average rainfall (mm) used.

4 Q = 0.2 - 2.9 m^3 based on range of K values. Q= (dh/dl)KA, where, K = Hydraulic conductivity (Nguyen Hoang Van 2009a), dh/dl = hydraulic gradient (assumed from topographic relief and MOD personal communication), A = cross-sectional area (assumed entire length of open excavation (square) perimeter to estimate worst case flows) and groundwater estimated at 1.5 mbgs (dry season) (Office 33, 2008 - measured groundwater at 2-2.5 mbgs).

5 ISTD/IPTD Cost Estimate (Appendix A3).

6 Visvanathan et al. 2003. Effects of Monsoon Conditions on generation and composition of landfill leachate – lysimeter experiments with various input and design features.

7 Wet season 1970-2009 Annual Average rainfall (mm) used.

8 Assumptions made as site specific data unavailable at time of analysis.

Rainfall data source - Nguyen (2009a).

7.6. Effects on Groundwater

7.6.1. Description of Effects

The ESS identified the following potential effects of the Project on groundwater:

- The depth of groundwater would influence depth of excavation possible for landfill. It would also influence amount of groundwater seepage into excavations, and amount of pumping and treatment required from excavations before discharge into the natural environment.
- There is the potential for contamination of shallow groundwater due to the generation of landfill leachate, although with use of a landfill lining, the potential for this contamination is low.

7.6.2. Impact Analysis

All excavation activities are scheduled to occur in the dry season when groundwater levels are at the lowest. For this reason, the amount of groundwater seepage into excavations is expected to be minimal, and would comprise an insignificant portion of the total volume of project-affected water generated by any of the remedial alternatives (Table A5.1 and Table A5.2).

Under the Passive and Active Landfill alternatives, a sufficient amount of clean fill would be imported to raise the landfill above flood levels and shallow groundwater. The Temporary Storage and Dewatering Area for the Landfill alternatives, and the stockpiles for the ISTD/IPTD, are not currently designed above flood levels and may in the rainy season be subject to flooding by shallow groundwater. This would generate additional project-contaminated wastewater requiring treatment. The presence of a uniform aquitard beneath the shallow aquifer means impacts to the deeper aquifers are unlikely.

7.6.3. Assessment

Project effects on groundwater are assessed as **Insignificant** for all alternatives.

7.7. Potential Effects of Dioxin-Contaminated Material on Air Quality

7.7.1. Description of Effects

This section assesses the potential environmental effects of extracting, dewatering, stockpiling, transporting, containing, and treating dioxin-contaminated material causing a release of this material into the air, transport, and dispersion of this material through the air, and potential exposure to this material by persons working and living on or near the Airport property.

7.7.2. IMPACT ANALYSIS

Appendix A6 provides the detailed calculations and modeling assumptions in assessing the potential effects of extraction, transport, containment, and treatment of dioxin-contaminated materials on air quality.

Passive Landfill Alternative

The main sources of potential exposure in the Passive Landfill alternative are the existence of two larger stationary Project areas in which dioxin-contaminated material would be exposed to the environment for an extended period of time: the Temporary Storage and Dewatering Area, and the landfill itself. Landfill cells would be covered once they have been filled with contaminated material but would need to remain open during filling. In addition, the Temporary Storage and Dewatering Area would need to be partially exposed so that trucks can be loaded with contaminated material for transport to the Landfill site.

The transport of contaminated material along the haul road is a major potential source of dioxin contamination. Trucks conveying dioxin-contaminated material are significant sources of dioxin that require mitigation and monitoring. Without appropriate engineering controls in place, there would be a risk of potential exposure to dioxin along those parts of the haul road alignment that are near residential areas on the Airport and near the main airport entrance. However, the dioxin exposure associated with temporary storage, dewatering, and deposition of contaminated soil and sediment into the landfill are much higher than material transport.

Active Landfill Alternative

The relative potential for human exposure to dioxin contaminated fugitive dust emissions as a result of excavation, dewatering, stockpiling, transporting, containing, and treating dioxin-contaminated material in the Active Landfill alternative is estimated to be the highest of any of the three remedial alternatives.

The main source of additional potential dioxin exposure in the Active Landfill alternative, as compared to the Passive Landfill alternative, is the additional total exposure caused by:

- The longer operation of the Temporary Storage and Dewatering Area
- The longer time required to fill the landfill due to having to layer in the bulking agent
- A likely higher proportion of the total landfill area that would need to be open at any given time given the pattern required of laying down the contaminated material

ISTD/IPTD Alternative

The ISTD/IPTD alternative is predicted to result in less potential exposure to poorer air quality caused by extracting, dewatering, stockpiling, transporting, containing, and treating dioxin-contaminated material. The main reason for this is that the ISTD/IPTD alternative would have no large facilities in which dioxin-contaminated material would be exposed to the environment for an extended period of time. The Contaminated Soil and Contaminated Sediment Stockpiles would be exposed while they are being constructed, but would be covered by clean fill on all sides to create the stockpile and the clean soil berm. This potential exposure would be limited relative to the potential exposure generated by the Temporary Storage and Dewatering Area and the landfill in either of the two Landfill alternatives.

7.7.3. Assessment

The ISTD/IPTD alternative is expected to result in the lowest total potential dioxin exposure from air emissions of any of the three remedial alternatives. The need in both Landfill alternatives to operate the Temporary Storage and Dewatering Area and the landfill - two large facilities in which dioxin-contaminated material would be exposed to the environment for an extended period of time – create a level of potential exposure that is not expected to be generated under the ISTD/IPTD alternative. The gender differences in effects of exposure to dioxin make the differences in potential dioxin exposure among the three remedial alternatives even more significant.

7.8. Potential Effects of Other COPCs and Dust on Air Quality

7.8.1. Description of Effects

This section assesses the potential environmental effects of emissions of other COPCs and dust on air quality, transport, and dispersion of these pollutants, and potential exposure to this material by persons working and living on or near the Airport property.

7.8.2. Impact Analysis

The following are expected to be the potential sources of other COPCs and dust:

- Excavation of contaminated materials and transport to the stockpiles, dewatering areas, or to the landfill
- Transport of clean fill and other materials into the Project area
- Emissions from the stack in the ISTD/IPTD alternative

All three remedial alternatives require the excavation, hauling, and manipulation of large volumes of contaminated soil and sediment. The release of other COPCs and dust is a potential significant environment impact for all three remedial alternatives.

The Passive and Active Landfill alternatives would require greater amounts of contaminated soil and sediment to be handled and transported than in the ISTD/IPTD alternative. The amount of other COPCs and dust being generated from excavation and transport is therefore likely to be greater in the two Landfill alternatives than in the ISTD/IPTD alternative. Stack emissions during stockpile thermal treatment in the ISTD/IPTD alternative may contain other COPCs that are released into the air and this is a potential source of contamination relevant only to ISTD/IPTD. Other COPCs in treatment system off-gas would be sequestered by GAC. In any case, data from samples collected in January 2010 suggest no other COPCs are present at high enough concentrations to cause a problem in off-gas from an ISTD/IPTD system. If new data suggest other COPCs are present at levels of concern, their presence can be mitigated during the design of the off-gas treatment system so as to prevent any potential risk.

7.8.3. ASSESSMENT

Potential effects on emissions of other COPCs and dust on air quality and human exposure to other COPCs and dust are assessed as **Significant** for all alternatives.

7.9. Potential Effects on Greenhouse Gas Emissions

7.9.1. DESCRIPTION OF EFFECTS

Implementation of any of the three remedial alternatives would result in effects on climate change, specifically due to the generation of greenhouse gases (GHGs). For the purposes of this analysis, CO_2, and carbon dioxide equivalent (CO_{2e}) will be referred to collectively as GHG emissions.

Passive and Active Landfill Alternatives

The following activities have been excluded from the analysis due to insufficient data and/or having an assumed minimal contribution: 1) mobilization of materials/equipment to Vietnam; 2) operation of decontamination areas; 3) electricity requirements of passive landfill operations; 4) landfill gas emissions during operations; and 5) maintenance of the stockpiles and disposal of the treated soil for the thermal desorption alternative. Clearing and grubbing of the landfill area, SA and MLA have been excluded from the analysis as the potential Project effects for all three remedial alternatives are Insignificant.

The major sources of GHGs in both Landfill alternatives would be:

- Operation of equipment to construct Temporary Storage and Dewatering Area
- Operation of equipment to upgrade the roads
- Operation of equipment to construct the landfill
- Operation of equipment to construct decontamination areas
- Operation of equipment during excavations
- Operation of equipment to dredge Sen Lake
- Transportation of contaminated material to the dewatering area and landfill
- Importing of fill to construct Temporary Storage and Dewatering Area, build landfill subgrade, backfill excavated areas and construct the decontamination areas
- Operation of equipment to provide a temporary and final cap landfill
- Transportation of bulking agents to landfill to adequately mix the contaminated material for bioremediation (Active Landfill alternative only)

ISTD/IPTD Alternative

The major sources of GHGs in the ISTD/IPTD alternative would be:

- Operation of equipment required to construct the treatment stockpiles
- Operation of equipment to construct the ISTD/IPTD treatment system
- Operation of equipment to construct decontamination areas
- Operation of equipment during excavations
- Operation of equipment to dredge Sen Lake
- Transportation of contaminated material to the stockpiles
- Importing of fill to construct the stockpiles, backfill excavated areas, and construct the decontamination areas
- Electricity required for treatment of the stockpiles

7.9.2. IMPACT ANALYSIS

Appendix A7 provides detailed calculations and assumptions for the GHG emissions generated for each remedial alternative.[94] Table 24 provides a summary of the results.

Passive Landfill Alternative

The GHG emissions generated under the Passive Landfill alternative are estimated at 3,925 t. These estimated GHG emissions are split more or less evenly between GHG emissions generated from construction and excavation activities and hauling of materials.

Active Landfill Alternative

The GHG emissions generated under the Active Landfill alternative are estimated at 5,060 t. The differences in GHG emissions between the two Landfill alternatives are:

- More clean fill is required for the Active Landfill alternative as compared to the Passive Landfill alternative. Additional clean fill is needed for the larger Temporary Storage and Dewatering Area to ensure uniform mixing for bioremediation.
- Requirements for electricity to operate the Active Landfill for a 10-year period, and the fact that 14% and 38% of Vietnam's electricity is generated from coal and natural gas, respectively (Appendix A7).
- The requirement for, and transport of, bulking agents increases the GHG emissions by 321 t.

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[94] For the purposes of this analysis CO_2 is the primary GHG of concern, except in the case of the transportation where methane (CH_4) and nitrous oxide (N_2O) are included and shown as CO_{2e}.

TABLE 24. COMPARISON OF ESTIMATED GHG EMISSIONS FOR THE REMEDIAL ALTERNATIVES

	Project Activity	Passive Landfill		Active Landfill		ISTD/IPTD	
		Impact Analysis	**Amount (t)**	**Impact Analysis**	**Amount (t)**	**Impact Analysis**	**Amount (t)**
A.	Construction & Operation of Temporary Storage & Dewatering Area	Construction: Dozer, Compactor, Grader, 14 m^3 trucks; 2 month duration, 24,900 m^3 (imported soil, boulders), 30 km round-trip[2]. Operation: Dozer, 11 months duration	774	Construction: Dozer, Compactor, Grader, 14 m^3 trucks; 2 month duration, 63,000 m^3 (imported soil, boulders), 30 km round-trip[2]. Operation: Dozer, 14 months duration	1322.5	---	---
B.	Road Upgrades[2]	Assume 1 paver, 14 m^3 truck; 1 month duration	55.3	Assume 1 paver; 14 m^3 truck; 1 month duration	55.3	---	---
C.	Landfill Construction - Establish subgrade & liner and leachate collection system	Dozer, Grader. 75,000 m^3 import fill. 14 m^3 trucks, import fill source 30 km round-trip, 5 months duration[2]	1192.7	Dozer, Grader. 100,000 m^3 import fill. 14 m^3 trucks, import fill source 30 km round-trip, 5 months duration[2].	1498.2	---	---
D.	Pile Construction	---	---	---	---	Dozer, Compactor, Grader; 14 m^3 trucks[2]; 22,000 m^3 import fill soil stockpile (2500 m^3 gravel); 24,000 m^3 fill sediment stockpile (2,500 m^3 gravel) [2]; 6 months importing; 5 months pile preparation	976.6
E.	Thermal Treatment System Construction	---	---	---	---	GHGs generated equivalent to landfill construction - Dozer, Grader [2]	276.4
F.	Construction of Decontamination Areas[2]	Dump Trucks, Dozer, Grader, Compactor. 0.5 months for 2 stations; 1,200 m^3 gravel/cobbles	56.1	Dump Trucks, Dozer, Grader, Compactor. 0.5 months for 2 stations; 1,200 m^3 gravel/cobbles	56.1	Dump Trucks, Dozer, Grader, Compactor. 0.25 months for 1 station; 600 m^3 gravel/cobbles	28.1
G.	Hauling contaminated soil/sediment to Dewatering Area	14/27 m^3 trucks. 28,400/23,300 m^3 soil/sediment. 200/400 meter distance (PISA 1,400 m^3, 7.5 km) [2]	22.2	14/27 m^3 trucks. 28,400/23,300 m^3 soil/sediment. 200/400 meter distance (PISA 1,400 m^3, 7.5 km) [2]	22.2	---	---

TABLE 24. COMPARISON OF ESTIMATED GHG EMISSIONS FOR THE REMEDIAL ALTERNATIVES

	Project Activity	Passive Landfill		Active Landfill		ISTD/IPTD	
		Impact Analysis	**Amount (t)**	**Impact Analysis**	**Amount (t)**	**Impact Analysis**	**Amount (t)**
H.	Hauling contaminated soil/sediment to Stockpiles	---	---	---	---	36,900/23,300 m^3 soil/sediment. 4 month duration. MLA to SA Stockpile 200 m; Sen Lake to sediment stockpile 400 m	82.8
I.	Hauling contaminated soil/sediment to Landfill	14/27 m^3 trucks. 4 month duration. 61,600 m^3 to be hauled; return distance of 15 km^2 (PISA 200 m)	389.4	14/27 m^3 trucks. 4 month duration. 61,600 m^3 to be hauled; return distance of 15 km^2 (PISA 200 m)	389.4	---	---
J.	SA Excavation	Dozer, Grader, Art-Wheel Loader (3.6 m^3). 2 month duration. 8,900 m^3	165.8	Dozer, Grader, Art-Wheel Loader (3.6 m^3). 2 month duration. 8,900 m^3	165.8	Dozer, Grader, Art-Wheel Loader (3.6 m^3). 1 month duration. 8,900 m^3	82.9
K.	MLA/PISA Excavation	Dozers, Grader, Art-Wheel Loader (3.6 m^3). 2 month duration. (MLA), 0.25 month (PISA). 19,500 m^3 (MLA), 1,400 m^3 (PISA)	186.5	Dozers, Grader, Art-Wheel Loader (3.6 m^3). 2 month duration (MLA), 0.25 month (PISA). 19,500 m^3 (MLA), 1,400 m^3 (PISA)	186.5	Dozers, Grader, Art-Wheel Loader (3.6 m^3). 2 months duration (MLA), 0.25 month (PISA). 19,500 m^3 (MLA), 1,400 m^3 (PISA)	186.5
L.	Sediment Excavation	3 Dozers; 4 month duration; 31,800 m^3	331.6	3 Dozers; 4 month duration; 31,800 m^3	331.6	3 Dozers; 4 month duration; 31,800 m^3	331.6
M.	Backfilling Excavations	Dozer, Compactor, 4 rear dump trucks (14 m^3). 1 month duration[2]; 29,800 m^3 import fill, 30 km round-trip	419.4	Dozer, Compactor, 4 rear dump trucks (14 m^3). 1 month duration[2]; 29,800 m^3 import fill, 30 km round-trip	419.4	Dozer, Compactor, 4 rear dump trucks (14 m^3). 1 month duration[2]; 29,800 m^3 import fill, 30 km round-trip	419.4
N.	Importing Bulking Material	---	---	14 m^3 trucks[2]. 4 month duration. 40% of contaminated soil/sediment required for bulking materials (24,080 m^3)	321	---	---
O.	Landfill Capping[2]	Dozer, Compactor, Grader. Temporary Cap 1 month. Final Cap 3 months	331.6	Dozer, Compactor, Grader. Final Cap 3 months	248.7	---	---
P.	Stockpile Removal	---		---		Removal of two stockpiles and use of material on Airport property	237.8

TABLE 24. COMPARISON OF ESTIMATED GHG EMISSIONS FOR THE REMEDIAL ALTERNATIVES

	Project Activity	Passive Landfill		Active Landfill		ISTD/IPTD	
		Impact Analysis	**Amount (t)**	**Impact Analysis**	**Amount (t)**	**Impact Analysis**	**Amount (t)**
Q.	Operations	-3	---	Two pumps and a blower running 4 hours per day for ten years	41.9	21,000,000 kWh/pile; 6 months treatment time/pile; 2 piles	5304.1
	Total		**3925**		**5059**		**7926**

[1] Assumptions based on Soil & Sedimentation Remediation Opinion of Probable Construction Cost, January 2010 (Landfill & Thermal) (CDM 2010a) unless stated otherwise

[2] Assumptions made by Hatfield as site specific data unavailable at time of analysis

[3] GHGs due to landfill operations has been excluded from this analysis

ISTD/IPTD Alternative

The GHG emissions generated under the ISTD/IPTD alternative are estimated at 7,926 t. The higher GHG emissions are caused by the electricity requirements for ISTD/IPTD treatment of the two contaminated material stockpiles (Appendix A7). This is significantly greater than the reduced requirements for transporting contaminated material to a landfill or importing clean fill for various facilities in the Passive and Active Landfill alternatives.

7.9.3. Assessment

The Passive Landfill alternative has the lowest potential environmental impact with respect to GHG emissions, while the ISTD/IPTD alternative has the highest potential environmental impact with respect to GHG emissions as a result of the requirement for large amounts of electricity for thermal treatment of the stockpiles.

7.10. Potential Effects on Terrestrial Ecosystems and Biodiversity

7.10.1. Description of Effects

Implementation of any three of the remedial alternatives would result in the temporary loss of some terrestrial habitat and associated biodiversity:

- In the northeast part of the Airport, as a result of excavation of dioxin hotspots, creation and operation of Temporary Storage and Dewatering Areas (Landfill alternatives), creation and operation of Contaminated Soil and Sediment Stockpiles (ISTD/IPTD alternative), as well as construction laydown areas.
- Along the haul road alignment in the southwestern area of the Airport property (as a result of widening).
- Loss of terrestrial habitat associated with the landfill (both Landfill alternatives).

7.10.2. Impact Analysis

The impacts of any of the remedial alternatives on terrestrial ecosystems and biodiversity are assessed based on limited baseline data available. The impacts are considered small in magnitude, short in duration, and largely reversible because:

- The terrestrial habitats on the Airport property are highly-altered and degraded as a result of human activities, and contain negligible terrestrial biodiversity value.
- Excavation and construction areas would be reclaimed and restored once the Project is complete; the landfill cap would be vegetated, thereby creating terrestrial habitat with a habitat value that would likely be similar to existing terrestrial ecosystems.

The relative impacts of the landfill alternatives are approximately three times that of the ISTD/IPTD alternative, based on the area of disturbance.

7.10.3. ASSESSMENT

Potential environmental impacts on terrestrial ecosystems and biodiversity are assessed as **Insignificant** for all Project alternatives. A baseline survey of terrestrial biodiversity, including surveys for possible presence of rare and endangered species, will be conducted in the initial stages of Project implementation to confirm this assessment.

7.11. Potential Effects on Wetlands, Aquatic Ecosystems, and Aquatic Biodiversity

7.11.1. DESCRIPTION OF EFFECTS

Most of the wetlands, aquatic ecosystems, and aquatic biodiversity that may be affected by the Project are located in the northern part of the Airport property. Potential effects on these aquatic environmental resources may occur as a result of changes in hydrologic conditions in Sen Lake and its associated wetlands, and changes in water quality.

7.11.2. IMPACT ANALYSIS

Project effects on surface water hydrology have been assessed as **Insignificant** for all three remedial alternatives. The impacts of any of the remedial alternatives on wetland, aquatic ecosystems, and aquatic biodiversity are assessed based on limited baseline data available.

With respect to the effect of any changes in hydrologic conditions on Sen Lake and its associated wetlands:

- The diversion of Sen Lake inflows via the Drainage Ditch to the Eastern Wetland during excavation of Sen Lake sediments (and the reverse if eastern wetland sediments need to be excavated) would have no effect on Sen Lake hydrology.

- The excavation of sediments from Sen Lake would be a required component of all three remedial alternatives. Mitigation measures may be required to limit the hydrologic effects of excavating Sen Lake sediments and disposal of contaminated fish, but these would be applied irrespective of the remedial alternative selected.

There would be no long-term effect on wetlands from hydrologic changes; post-construction hydrologic conditions would be essentially the same as pre-construction so that flows to the wetlands are not altered. Based on area of disturbance, the impacts of the landfill alternatives and the ISTD/IPTD alternative are identical.

With respect to potential effects via changes in surface water quality, all project-affected water would be treated to the required standards prior to release.

7.11.3. ASSESSMENT

Potential environmental impacts on wetlands, aquatic ecosystems, and aquatic biodiversity are assessed as **Insignificant** for all Project alternatives. A baseline survey of aquatic biodiversity, including surveys for possible presence of rare and endangered species, will be conducted in the initial stages of Project implementation to confirm this assessment.

7.12. Potential Effects on Noise Levels

7.12.1. Description of Effects

All three remedial alternatives would require the use of equipment and machinery for construction of Project facilities such as the landfill, contaminated material stockpiles, and the Temporary Storage and Dewatering Area. They would also require truck movement and hauling of contaminated from the hotspots to these facilities, as well as clean materials from off-site borrow sources. This equipment, machinery, and truck hauling would increase noise levels on, and in the vicinity of, the Airport.

7.12.2. Impact Analysis

Two indicators of the amount of noise that would be generated for each remedial alternative are provided in Table 25: the estimated duration with which equipment and machinery would be used; and, the total estimated distance driven by trucks for materials hauling.

TABLE 25. COMPARISON OF NOISE IMPACTS FOR THE REMEDIAL ALTERNATIVES[95]

	Passive Landfill	Active Landfill	ISTD/IPTD
Total Estimated Duration of Heavy Machinery Equipment Use (hr)	7,340	7,780	3,020
Total Distance Driven by Hauling Equipment (km)	369,920	580,570	230,600

The values of both of these indicators are estimated to be lowest for the ISTD/IPTD alternative, because there would be less material to transport and a set of facilities that, cumulatively, would be smaller than for the other two remedial alternatives. Conversely, the values of both these indicators would be highest for the Active Landfill alternative because there would be the most material to transport and a set of facilities that, cumulatively, would be larger than for the other two remedial alternatives.

7.12.3. Assessment

The ISTD/IPTD alternative is assessed as having the lowest potential environmental impact on noise levels associated with the Project.

[95] Estimates generated from GHG calculations (Appendix A7).

7.13. Potential Effects on Natural or Depletable Resource Requirements

7.13.1. DESCRIPTION OF EFFECTS

All three remedial alternatives would require the importation of clean fill, gravel and, in the case of the Active Landfill alternative, a bulking agent to mix with contaminated materials before placing in the landfill. The sources of these materials are unknown, and there may be environmental effects associated with providing these materials for the Project. There may also be cumulative environmental effects, particularly when considered in the context of the demands for these types of materials throughout Da Nang City, especially clean fill and gravel.

7.13.2. IMPACT ANALYSIS

It is noted that fill used for constructing the dewatering area (Landfill alternatives) or the soil and sediment stockpiles (ISTD/IPTD alternative) could be used as the clean fill for backfilling the excavated areas. The conceptual designs of the alternatives currently have these excavated areas being filled in within two weeks of excavation in order to minimize the generation of project-affected water. The assessment conclusions described below and shown in Table 26 are based on the maximum required volumes of clean fill that may be required.

TABLE 26. COMPARISON OF CLEAN FILL REQUIRED FOR THE REMEDIAL ALTERNATIVES

Material Required	Amount Of Material Required (m^3)		
	Passive Landfill	**Active Landfill**	**ISTD/IPTD**
Landfill Construction (subgrade, liner, cap)	75,000	100,000	0
Decontamination Areas	1,200	1,200	600
Construction of Dewatering Area	24,900	63,000	0
Construction of Soil and Sediment Stockpiles	0	0	46,000
Clean Fill required to Fill Excavations in SA and MLA	38,300	38,300	38,300
Total	**138,200**	**201,300**	**84,300**

The Passive and Active Landfill alternatives would require approximately 140,000 and 200,000 m^3 of clean fill, respectively, while the ISTD/IPTD alternative would require approximately 60% of the clean fill required in the Passive Landfill alternative. These differences are due largely to the fill requirements to create the landfill subgrade, which are not required in the ISTD/IPTD alternative.

Vietnamese environmental legislation requires a full EIA to be prepared for any facility that extracts "minerals" to use as leveling and filling materials with a capacity of 100,000 m^3 of fill per year or greater.[96] If the clean fill for the Project were to be obtained from a new, single source, a full GVN EIA would be required specifically for the provision of clean fill for both the Passive Landfill and Active Landfill alternatives.

7.13.3. Assessment

Given that the clean fill requirements for both Landfill alternatives are greater than the EIA trigger in Vietnamese environmental regulations, potential environmental impacts on natural or depletable resources are assessed as **Significant** for both Landfill alternatives and **Insignificant** for the ISTD/IPTD alternative.

7.14. Potential Long-Term Environmental Risks Associated with Operation of the Project

7.14.1. Description of Effects

There may be potential environmental impacts associated with the operation of the Project once it has been constructed.

7.14.2. Impact Analysis

There are long-term environmental risks associated with the O&M of the landfill in the Passive Landfill alternative. The material within the Passive Landfill would still be contaminated above GVN dioxin remediation targets, and improper O&M of the Passive Landfill may result in the release of this contaminated material back into the natural environment. This is assessed as Significant and requiring mitigation.

The long-term environmental risks associated with the operation of the landfill in the Active Landfill alternative are Unknown, as the specific configuration and operation of a landfill for dioxin remediation cannot be described at this time.

For the ISTD/IPTD alternative, Project operation is the actual thermal treatment of the contaminated material stockpiles. There are insignificant risks associated with the operational phase of the ISTD/IPTD alternative.

7.14.3. Assessment

The ISTD/IPTD alternative is assessed as having the lowest potential long-term environmental risk of the alternatives.

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[96] Decree No. 21 2008.

Section 8. Results of the Environmental Assessment

8.1. No Action Alternative

The No Action alternative has no cost associated with implementation or long term O&M. However, there would be significant externalized costs (e.g., dealing with health effects of neighboring community, impact to Airport expansion, etc.) that cannot be accurately estimated.

The No Action alternative would result in continuation over the long term of the following environmental impacts:

- Soil concentrations that exceed GVN standards by 27 to 107 times the national cleanup goal of 1,000 ppt.[97]
- Sediment concentrations that exceed GVN standards by 20 to 67 times the national cleanup goal of 150 ppt.[98]
- Continued fish contamination at levels that exceed standards by more than 400 times the Health Canada consumption guidelines for edible fish tissue (20 pg/g TEQ wet weight).
- Continued exposure of airport workers.
- Continued potential exposure to area residents.
- Persistence of dioxin in soil and sediment that exceeds GVN standards for at least several more decades, with associated persistence of exposure pathways that could impact environmental, biological and human receptors.

8.2. Environmental Ranking of Remedial Alternatives

The overall potential environmental impact of all alternatives is substantial. All alternatives require the excavation, transport, and deposition of dioxin-contaminated soil from the hotspots into a landfill or stockpile. The wetland ecosystem (Sen Lake and Eastern Wetland) must be drained and dredged to remove contaminated sediments. Impacts to wetlands and terrestrial and aquatic biota are unavoidable over the short term, in order to eliminate the possibility of future dioxin exposure to humans and the environment. A summary of the environmental issues that are common to all three remedial alternatives is provided in Table 27.

The assessment results were used to rank the alternatives to identify the environmentally-preferred alternative which is the alternative with the lowest overall potential environmental impact. The results of the environmental impact analysis of the remedial alternatives are summarized in Table 28. For each assessment criterion, the three alternatives (excluding No Action) are ranked depending on their relative potential environmental impacts. A score of "1"

[97] TCVN 8183: 2009.
[98] TCVN 8183: 2009.

indicates the highest relative potential environmental impact and a score of "3" indicates the lowest potential environmental impact. Lower cumulative scores are associated with the greatest potential environmental impact among the evaluated alternatives. It should be noted that no weighting has been given to each of the impact assessment criteria.

TABLE 27. PROJECT ACTIVITIES AND ENVIRONMENTAL ISSUES COMMON TO THE REMEDIAL ALTERNATIVES

Activity	Environmental Issues
Excavation of hotspot soil areas	▪ Increased dust levels due to earthworks activities ▪ Increased noise and air emissions from construction equipment ▪ Management of surface water and groundwater inflows into excavations
Excavation of sediment from Sen Lake	▪ Increased noise and air emissions from construction equipment ▪ Increased turbidity and pollutant dispersion in Sen Lake ▪ Potential increase in odor levels ▪ Requires drainage of a wetland system with potential impacts on aquatic biota ▪ Management of contaminated water with the dewatering of sediments
Construction of dewatering area, surface water management system, and decontamination areas	▪ Increased dust levels due to earthworks activities ▪ Increased noise and air emissions from construction equipment ▪ Management of project-affected and 'clean' surface water
Hauling contaminated soil/sediment to dewatering area	▪ Increased dust levels due to transportation activities ▪ Increased noise and air emission from construction equipment ▪ Management of dredgate ▪ Management of project-affected surface water
Import of backfill materials	▪ Increased traffic levels on transportation route from backfill source quarry ▪ Increased dust levels on transportation route from backfill source quarry ▪ Increased noise and air emissions on transportation route from backfill source quarry
Backfill/reclaim excavation and construction areas	▪ Increased dust levels due to earthworks activities ▪ Increased noise and air emission from construction equipment ▪ Management of surface water and groundwater inflows into excavation ▪ Management of landscape restoration activities
Provide safe working environment for workers with gender specific requirements for women	▪ Potential presence of UXO ▪ Potential increased exposure levels to dust, noise, air emissions, and contaminated materials, particularly for the most sensitive receptors (children, women)
Provide sanitary facilities for workers	▪ Management of wastewater and domestic waste generated by workers

TABLE 28. COMPARISON OF POTENTIAL ENVIRONMENTAL IMPACTS OF THE REMEDIAL ALTERNATIVES

<table>
<tr><th rowspan="2">Potential Environmental Impact</th><th rowspan="2">Assessment Criterion</th><th colspan="3">Remedial Alternative
(Environmental Impact Ranking; 1 = Highest Impact Total Score. The Lower the Score, the Higher the Environmental Impact Ranking)</th></tr>
<tr><th>Passive Landfill
(Total Score = 29)</th><th>Active Landfill
(Total Score = 24)
Highest Potential Environmental Impact</th><th>ISTD/IPTD
(Total Score = 37)
Lowest Potential Environmental Impact</th></tr>
<tr><td rowspan="2">Potential Environmental and Associated Human Health Risks Associated with Cleanup of UXO and Munitions</td><td rowspan="2">Qualitative Assessment based on land area affected by Project</td><td>Significant
(2)</td><td>Significant
(1)</td><td rowspan="2">Significant
(3)</td></tr>
<tr><td colspan="2">Requirements to remediate munitions bunkers and possible other similar facilities in the southwestern part of the Airport property are unknown.</td></tr>
<tr><td>Potential Impacts on Surface Water Hydrology</td><td>Qualitative Assessment</td><td>Insignificant
(3)</td><td>Insignificant
(3)</td><td>Insignificant
(3)</td></tr>
<tr><td>Potential Impacts on Surface Water Quality</td><td>Volume of project-Affected Water Generated and Requiring Treatment before Release</td><td>262,242 m^3
(1)</td><td>136,597 m^3
(2)</td><td>23,603 m^3
(3)</td></tr>
<tr><td>Potential Impacts on Groundwater Resources</td><td>Qualitative Assessment</td><td>Insignificant
(3)</td><td>Insignificant
(3)</td><td>Insignificant
(3)</td></tr>
<tr><td>Potential Impacts on Groundwater Quality</td><td>Qualitative Assessment</td><td>Insignificant
(3)</td><td>Insignificant
(3)</td><td>Insignificant
(3)</td></tr>
<tr><td>Potential Effects of Extraction, Transport, Containment, and Treatment of Dioxin-Contaminated Material on Air Quality and Human Exposure</td><td>Relative Potential Exposure Index for Dioxin</td><td>Intermediate
(2)</td><td>Highest
(1)</td><td>Lowest
(3)</td></tr>
<tr><td>Potential Effects of Emissions of Other COPCs and Dust on Air Quality and Human Exposure</td><td>Qualitative Assessment</td><td>Significant
(1)</td><td>Significant
(1)</td><td>Significant
(1)</td></tr>
<tr><td>Potential Contribution to Greenhouse Gases</td><td>t of CO_2 generated by the Project</td><td>3,925 t
(3)</td><td>5,059 t
(2)</td><td>7,926 t
(1)</td></tr>
</table>

TABLE 28. COMPARISON OF POTENTIAL ENVIRONMENTAL IMPACTS OF THE REMEDIAL ALTERNATIVES

Potential Environmental Impact	Assessment Criterion	Remedial Alternative (Environmental Impact Ranking; 1 = Highest Impact Total Score. The Lower the Score, the Higher the Environmental Impact Ranking)		
		Passive Landfill (Total Score = 29)	Active Landfill (Total Score = 24) Highest Potential Environmental Impact	ISTD/IPTD (Total Score = 37) Lowest Potential Environmental Impact
Potential Effects on Terrestrial Ecosystems and Terrestrial Biodiversity	Qualitative Assessment	Insignificant (1)	Insignificant (1)	Insignificant (1)
Potential Effects on Wetlands, Aquatic Ecosystems, and Aquatic Biodiversity	Qualitative Assessment	Insignificant (1)	Insignificant (1)	Insignificant (1)
Potential Effects on Noise Levels	Total Estimated Duration of Equipment Use	7,340 hrs (2)	7,790 hrs (1)	3,030 hrs (3)
	Total Distance Driven by Hauling Equipment	369,920 km (2)	580,570 km (1)	230,600 km (3)
Potential Effects on Natural or Depletable Resource Requirements	Amount of clean fill required	138,200 m^3 (2)	201,300 m^3 (1)	84,300 m^3 (3)
Potential Effects on Land Use	Land Area Disturbed	296,050 m^2 (2)	334,950 m^2 (1)	183,100 m^2 (3)
Potential Long-Term Environmental Risks Associated with Operation of the Project	Qualitative Assessment	Significant (1)	Unknown (2)	Insignificant (3)

8.2.1. ENVIRONMENTALLY PREFERRED ALTERNATIVE - ISTD/IPTD

A comparison of potential environmental impacts (Table 28), effectiveness (Table 29), implementability (Table 30), and cost (Table 31), was made of the alternatives. Based on this, a simple ranking was prepared for each to identify the preferred remedial alternative (Table 32). The ISTD/IPTD alternative was found to have the lowest potential environmental impact of the three remedial alternatives for dioxin remediation at the Airport for the following reasons:

- The ISTD/IPTD alternative would have the lowest potential exposure of local residents to dioxin that might be released into the air and dispersed as a result of extraction, transport, containment, and treatment of contaminated soil and sediments.
- The ISTD/IPTD alternative would not require mitigation of the significant unknown risks associated with cleanup of munitions bunkers in the southwestern area of the Airport property being considered for the Landfill alternatives.
- The ISTD/IPTD alternative requirements for generation and treatment of project-affected water would be lower than for the Landfill alternatives.
- The ISTD/IPTD alternative would have the lowest potential impact on noise levels from Project activities, and would also have the lowest potential effect on natural or depletable resource requirements, as it would have the lowest requirements for clean fill.
- There are insignificant long-term environmental risks associated with the operational phase of the ISTD/IPTD alternative.
- The ISTD/IPTD alternative would have the highest GHG emissions of any of the three remedial alternatives; this would require some form of mitigation, perhaps in the form of purchasing carbon credits to offset emissions. Mitigation measures for ISTD/IPTD would be less expensive and easier to implement than mitigation required to: 1) minimize higher levels of potential dioxin exposure resulting from extraction, transport, containment, and treatment with the Landfill alternatives; 2) remove munitions bunkers prior to implementing either of the Landfill alternatives; or 3) minimize long-term environmental risk associated with operation of the Passive Landfill.

TABLE 29. COMPARISON OF EFFECTIVENESS EVALUATION OF THE REMEDIAL ALTERNATIVES

Passive Landfill	Active Landfill	ISTD/IPTD
Effective for containment: Proven containment strategy; hazardous waste landfills have been used successfully for decades worldwide; 50-year solution. **Ineffective for treatment**: Dioxins would be expected to persist for many decades and would require eventual treatment.	**Effective for containment:** Proven containment strategy; hazardous waste landfills have been used successfully for decades worldwide. **Unknown effectiveness for treatment:** Review of the scientific literature on microbial degradation of chlorinated dioxins[1] shows some degradation of 2,3,7,8-TCDD, but no studies demonstrate degradation below either GVN cleanup goals. Initial results from USEPA and VAST pilot study show approximately 50% dioxin degradation after 120 days[2]; however, it remains unclear whether cleanup goals can be met and scalability of the pilot study to full-scale application is uncertain.	**Effective for treatment (no long-term containment required):** Several well-documented case studies[3] have shown that ISTD/IPTD can treat 2,3,7,8-TCDD to concentrations below GVN cleanup standards. Concentrations of dioxins in exhaust gas in previous case studies were orders of magnitude below regulatory limits. • Over 95% of dioxins will be destroyed *in-situ*. • If design calculations show that GAC would not meet emissions standards for exhaust gas, then a thermal oxidizer would be considered. • Dispersion between the stack and property boundaries or locations of other receptors would be considered in this analysis as well.

Notes:

1 – Field and Sierra-Alvarez 2008.

2 – Allen and Fong 2009 and Allen 2010.

3 – ENSR 2000, Baker and La Chance 2003, Baker et al. 2007 and Heron et al. 2010.

TABLE 30. COMPARISON OF IMPLEMENTABILITY EVALUATION OF THE REMEDIAL ALTERNATIVES

Passive Landfill	Active Landfill	ISTD/IPTD
Landfill siting: an ideal site does not exist on Airport property. **Haul route:** long haul route and high number of truckloads required. **Fill material:** Significant amount of fill material (~140,000 m^3) required for landfill construction, operation, and closure. **Long term O&M:** 50 years after construction.	**Landfill siting:** an ideal site does not exist on Airport property. **Haul route:** long haul route and high number of truckloads required. **Fill material:** Significant amount of fill material (~200,000 m^3) required for landfill construction, operation, and closure. **Electrical use:** estimated ~33,200 kwh/yr required for nutrient distribution system operation (10 years). **Bioremediation design uncertainty:** • Target mechanism: aerobic, aerobic cometabolic, anaerobic, or combination? • Design basis for full scale: distribution of microbes and nutrients/substrates, bioavailability of TCDD, longevity of nutrients/substrates relative to persistence of TCDD, and ability to maintain desired geochemical conditions **Long term O&M:** assumed to be10 years after construction, but may be more if degradation does not occur.	**Electrical use:** estimated 21,000,000 kwh for 6 months of continuous treatment time per pile (two piles total). **Mobilization:** some equipment and technical expertise will have to come from overseas. **Air monitoring:** must ensure emissions do not exceed regulatory limits; GAC and/or thermal oxidizer would be used. **Geotechnical properties of soil post-treatment:** limited quantitative data available, but one study[1] indicated no significant effect. Conservative design assumptions made to stockpile soil and revegetate it post-treatment rather than to use it as structural fill.

Notes:
1 – Heron et al. 2009.

TABLE 31. COMPARISON OF ESTIMATED COSTS ($ MILLION) OF THE REMEDIAL ALTERNATIVES (COST RANGE -30%+50%)

Component	Passive Landfill	Active Landfill	ISTD/ IPTD	Cost Differentiators Between Alternatives
Disposal	$11.5	$11.5	$8.7	Less excavation, hauling, and site clearing/prep for ISTD/IPTD
Construction	$10.3	$15.5	$24.4	Various
Subtotal (First 2 years)	$21.8	$27.0	$33.1	
Long Term O&M	$3.2	$0.7	$0	Passive Landfill: 50 years Active Landfill: 10 years ISTD/IPTD: none
EMMP Implementation	$10.8	$3.0	$0.6	Passive Landfill: 50 years Active Landfill: 10 years ISTD/IPTD: none
Overall Total	**$35.8**	**$30.7**	**$33.7**	

TABLE 32. SUMMARY OF EA FINDINGS FOR DIOXIN REMEDIATION AT DA NANG AIRPORT

Alternative	Effectiveness (i.e., dioxin ≤ cleanup goals/"final remedy")?	Implementable	Environmental Assessment	Estimated Cost (in Millions) (-30% +50%)	Implementation Schedule
No Action	No	Yes	Highest overall potential environmental impact	Externalized	NA
Passive Landfill	No	Yes with challenges	Third-highest overall potential environmental impact	$35.8M	2-year construction, and 50 years long term O&M
Active Landfill (Bioremediation)	Uncertain	Yes with challenges	Second-highest overall potential environmental impact	$30.7M	2-year construction, and 10 years long term O&M
ISTD/IPTD	Yes	Yes with challenges	Lowest overall potential environmental impact	$33.7M	2-year construction and no long term O&M

Notes:
This table summarizes the results of the alternatives analysis in this EA; it also provides a summary of the implementation schedule for each remedy (additional details regarding schedule are provided in the conceptual designs of each alternative.

8.2.2. NEXT ENVIRONMENTALLY PREFERRED ALTERNATIVE – PASSIVE LANDFILL

The Passive Landfill alternative is ranked second in terms of potential environmental impacts associated with dioxin remediation at the Airport for the following reasons:

- The Passive Landfill alternative would have a higher potential exposure of local residents to airborne dioxin as a result of extraction, transport, containment, and treatment of contaminated soil and sediments than the ISTD/IPTD alternative. However, the Passive Landfill alternative would have a much lower potential exposure than the Active Landfill alternative.

- The Passive Landfill alternative would have the lowest estimated GHG emissions of the three remedial alternatives.

- The Passive Landfill alternative is the second-ranked alternative with respect to generation and required treatment of project-affected water.

- However, the Passive Landfill alternative would require mitigation of the significant unknown risks associated with cleanup of UXO, in particular, the munitions bunkers in the southwestern area of the Airport property being considered for the Landfill site.

8.2.3. LEAST ENVIRONMENTALLY PREFERRED ALTERNATIVE – ACTIVE LANDFILL

The Active Landfill alternative is the least-preferred remedial alternative for dioxin remediation at the Airport. The Active Landfill alternative would have the highest potential exposure of local residents as a result of release of dioxin into the air and dispersed during extraction, transport, containment, and treatment of contaminated soil and sediment. The potential exposure for the Active Landfill would be higher than the Passive Landfill because of the increased handling of contaminated material that would be required. This has significant negative implications for gender-specific effects of dioxin exposure generated by this alternative. In addition, as with the Passive Landfill alternative, the Active Landfill alternative would require mitigation of the significant risks associated with cleanup of UXO, in particular, the munitions

Section 9. Environmental Mitigation and Monitoring

9.1. Overview

After the EA is approved, detailed engineering designs, remediation workplan, health and safety plan, health and safety training plan, and sampling and analysis monitoring plan will be prepared for the alternative selected through the EA process. These will inform the final EMMP. The discussion below pertains to information that has been developed based on 10% conceptual designs of the three technology alternatives considered in the EA. However, the EA may need to be amended should the design and planning process lead to changes or identify additional environmental impacts. The Final EMMP will be developed based on engineering designs and plans for the selected alternative. The EMMP will be included as part of procurement documents used for solicitation of goods and services for remedial action.

9.2. Environmental Mitigation

The most important mitigation measure for controlling environmental impacts during the remediation process include worker personal protective measures during UXO clearance, worker protective measures during the remediation process, control of releases of dioxin contaminated material into surface water and air, control of noise and odor during remediation activities, and protection of threatened, endangered or sensitive species during the remediation process. Specific environmental issues and mitigation measures are outlined in Table 33.

TABLE 33. KEY ENVIRONMENTAL ISSUES AND MITIGATION MEASURES

Key Environmental Issues	Mitigation Measures
Threats to Endangered or Threatened species	A biological survey will be conducted prior to commencement of construction.
	A biologist will be employed during construction activities who is trained in identification of endangered or threatened species with habitats located in the geographic area of the Project site.
	If threatened or endangered species are identified during the construction phase, the contractor will immediately notify USAID and stop work until an effective management plan can be initiated.
Increased dust levels due to earth works activities and on transportation routes	Develop **air and noise quality management plan** to address issues relating to increased dust levels. Mitigation measures may include:
	Scheduling excavation activities to minimize time and area of excavation which remains open/exposed
	Frequent spraying/damping down of excavation areas, excavated soil, worksite surface, and sensitive areas along transportation route
	Covering stockpiles, dewatering area, and transportation vehicles to avoid windblown dust mobilization

TABLE 33. KEY ENVIRONMENTAL ISSUES AND MITIGATION MEASURES

Key Environmental Issues	Mitigation Measures
	Cleaning transportation vehicles and construction equipment in decontamination area prior to leaving excavation areas
	Cleaning transportation vehicles prior to exiting backfill source quarry
Increased noise and air emissions from construction equipment and on transportation routes	Develop **air and noise quality management plan** to address issues related to increased noise and air emissions. Mitigation measures may include:
	Ensuring all vehicles and machinery have a register of quality
	Scheduling regular maintenance of construction equipment and transportation vehicles
	Avoiding construction and transportation activities during night time
	Purchasing of carbon credits to provide offsets to mitigate project-generated GHG emissions
Management of project-affected and 'clean' water	Develop **water management plan** to address all water management issues relating to project-affected and 'clean' water including design details of:
	Clean water diversion systems around excavation/construction areas
	Project-affected water collection, storage and treatment systems (for excavation areas, including Sen Lake, and Temporary Storage and Dewatering Area)
	Operation of vehicle decontamination areas between excavation areas, landfill, dewatering area, and stockpiles
	Water testing and water release requirements
Increased turbidity and pollutant dispersion and potential increase in odor levels in Sen Lake	Develop **dredging management plan** which provides design details of how turbidity and odor impacts will be minimized using:
	Proposed aquadam bladder to divide lake into sections
	Pumps and pumping schedule to transfer water to alternate lake section prior to excavation
	Specific dredgate excavation equipment
	Odor suppressant materials
Management of UXO (Component 3: Health and Safety Plan)	Develop detailed **UXO management plan** to address how all Project areas will be surveyed and cleared of UXO prior to commencement of work activities including, but not limited to:
	Providing training and personal protective equipment (PPE) and safety procedures to Project workers

TABLE 33. KEY ENVIRONMENTAL ISSUES AND MITIGATION MEASURES

Key Environmental Issues	Mitigation Measures
	Providing education and mitigation measures for nearby residents and airport personnel and passengers during Project construction
Increased traffic levels on transportation route	Develop **traffic management plan** to address issues relating to traffic impact. Mitigation measures may include:
	Choosing most appropriate transportation route in reducing impact to humans (in consultation with community, where necessary)
	Choosing most appropriate route for truck size to minimize impact to road surface
	Scheduling transportation activities to avoid, where possible, times of maximum congestion (rush hours) and maximum disturbance (night times)
Management of landscape restoration	Develop **restoration and reclamation plan** to address how excavation and construction areas will be restored/reclaimed including details of:
	Schedule for restoration/reclamation activities
	Methods and materials for restoration (revegetation, etc.)
Potential increased exposure levels of dust, noise, and air emissions to Project workers and nearby residents. Potential increased exposure to Project workers and nearby residents, with particular concern to women (Component 3: Health and Safety Plan)	Develop **site specific health and safety plan** to address mitigative measures required for reducing potential impact to workers including, but not limited to:
	Gathering of data on the workers, including their age, sex, awareness on the dioxin issue, food consumption patterns and work history
	Distribution of awareness raising materials for workers, with a specific emphasis on women of child-bearing age, regarding the hazards of working in hotspot areas; and
	Training of field crews to ensure adequate protection and proper utilization of personal protective equipment.
Management of domestic waste and wastewater generated by Project workers	Develop **waste and wastewater management plan** to address all issues relating to the collection/disposal of solid waste and disposal/treatment of wastewater
Generation of GHGs during Project implementation	Purchase sufficient carbon credits to offset GHG emissions

Any ongoing activities found to be either inconsistent with the EMMP, or when new potentially significant environmental concerns are identified, activities shall be halted until an environmental review is conducted and USAID approves conditions for mitigation.

9.3. Environmental Monitoring

The existing baseline data on most environmental resources for this Project are limited. Therefore, prior to the start of Project construction, a comprehensive environmental baseline survey will be undertaken. These baseline data will act as indicators in monitoring environmental effects of the Project during construction and operation activities. Following this baseline survey, a targeted monitoring plan will be developed. This plan will outline where surveyed monitoring points should be established and parameters to be analyzed to determine baseline surface water, groundwater, sediment, and air quality conditions. This plan will provide specific details on the:

- Type of monitoring required (analytical testing, field measurements, visual inspections, etc.)
- Frequency of monitoring required (daily, weekly, monthly, annually, etc.)
- Monitoring roles and responsibilities (contractor, environmental monitor, etc.)
- Reporting responsibilities

9.4. Gender Considerations In Environmental Mitigation And Monitoring Plan (EMMP) Design And Implementation

In conjunction with development of engineering designs and plans, CDM will also prepare a gender assessment in relationship to environmental remediation at the Airport. The assessment will evaluate functional labor categories of the remediation process and determine whether there are gender-specific regulatory restrictions that must be considered or whether there are gender-specific behaviors that might lead to greater risk-taking in the work environment. If such issues are identified, specific measures for controlling these will be included in the remediation workplan and in the final EMMP.

The construction and transportation industries in Vietnam are male-dominated industries. This could imply that a low percentage of women would seek employment related to the remediation activities. Women that do seek remediation employment opportunities will be offered strong protection under Vietnam law to protect them from being exposed to hazardous environments. However, since women may not be aware of, or do not exercise the rights accorded to them by law and regulations,[99] it is important that the Project implement specific provisions to protect women. When considering Project activities, it is important to consider how men's and women's different responsibilities within society make them more or less susceptible to health problems that could arise as a result of the Project.

If women's access to employment opportunities related to the remediation activities is limited due to legal restrictions concerning female employees involved with remediation activities, consideration should be given to alternative income generation activities, as required under

[99] ADB 2005.

Vietnam Labor Law. Under Article 109 of Chapter X[100], women should be offered equal employment opportunities to men, even in non-traditional jobs. In that article, the State ensures the right to equality of women with men in all domains of work and shall adopt policies or encouraging labor users to create conditions for women laborers to have regular jobs. It shall also apply the system of work according to a flexible time schedule. Employers are strictly prohibited from conduct which is discriminatory towards a female employee or conduct which degrades the dignity and honor of a female employee. An employer must implement the principle of equality of males and females in respect of recruitment, utilization, wage increases, and wages. Furthermore, they will need to be paid equally to men, and receive the same benefits, according to Article 111.[101]

The Health and Safety Plan under development includes the use of PPE to prevent dioxin exposure. However, due to the cumbersome nature of the equipment, especially in tropical climates, alternative solutions to standard PPE may need to be proposed before the equipment can be used effectively.

The Project will result in positive impacts for both men and women living and working on or around the airbase. The risk of potential dioxin exposure will be significantly reduced as a result of the successful completion of the remediation activities; however, extreme caution needs to be exercised in removing and transporting contaminated material both for workers and Da Nang residents.

Consideration should be given to dioxin transport and exposure pathways for Da Nang residents, during the removal and transportation of contaminated soil. Exposure pathways include dietary exposure, soil ingestion, dermal absorption and inhalation. The potential increased exposure levels for Da Nang residents from dust and air will be addressed through the Health and Safety Plan. Specific recommendations related to prevention of potential dioxin exposure for all workers will be a critical component of the Health and Safety Plan.

The Traffic Management Plan will ensure that the most appropriate route is selected to minimize the impacts to humans. The Traffic Management Plan should be communicated to Da Nang residents as part of the awareness campaign to ensure that they take extra precautions to reduce exposure during transport times.

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[100] Viet Nam Labour Code: Article 109 of Chapter X: The State ensures the right to equality of women with men in all domains of work and shall adopt policies or encouraging labour users to create conditions for women labourers to have regular jobs. It shall also apply the system of work according to a flexible time schedule.

[101] Viet Nam Labour Code: Article 111 of Chapter X: 1. Employers are strictly prohibited from conduct which is discriminatory towards a female employee or conduct which degrades the dignity and honour of a female employee. An employer must implement the principle of equality of males and females in respect of recruitment, utilization, wage increases, and wages.

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