Environmental and Human Health Assessment of Dioxin Contamination at Bien Hoa Airbase, Viet Nam

Final Report

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ENVIRONMENTAL AND HUMAN HEALTH ASSESSMENT OF DIOXIN CONTAMINATION AT BIEN HOA AIRBASE, VIET NAM

SUMMARY OF FINDINGS

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SUMMARY OF FINDINGS

This report presents the results, conclusions, and recommendations of three recent studies conducted by Hatfield Consultants and the Government of Viet Nam (GVN) to determine the extent and level of dioxin contamination in the environment and the exposed human populations in and around the Bien Hoa Airbase, Viet Nam. The 10-80 Division of Viet Nam's Ministry of Health led the first of these studies in 2004-2005, while the second (in 2008) was conducted under the direction of the Viet Nam-Russia Tropical Centre (VRTC) of the Ministry of National Defence (MND). The Office of the National Steering Committee 33 (Office 33) was responsible for implementation of the current study; Hatfield Consultants (North Vancouver, Canada) collaborated closely with the Vietnamese agencies on all three studies. The current (2010) study, and the 2004-2005 investigations, were funded by the Ford Foundation Special Initiative on Agent Orange Dioxin, while the 2008 study was funded by the United Nations Development Program (UNDP).

Bien Hoa was the largest U.S. Department of Defence (DOD) Operation Ranch Hand site in Viet Nam, in terms of the number of C-123 aircraft sorties and volume of herbicides stored and used. Dioxin contamination at Bien Hoa Airbase is the result of the storage, loading, spillage, and handling of Agent Orange and other toxic herbicides during the US-Viet Nam war, especially between 1965 and 1971.

A total of 97 environmental samples (including 57 soil, 20 sediment, and 20 fish tissues), and 64 human blood serum and breast milk were collected and analyzed for dioxin[1] and furan concentrations over the course of the three Hatfield/10-80/VRTC/Office 33 studies. Human tissue sampling was performed on a volunteer basis and followed internationally-accepted protocols to ensure consent of donors. All samples were analyzed at AXYS Analytical Laboratories (Sidney, BC, Canada), a WHO-accredited independent laboratory for dioxin and furan analyses. The 2005 data, consisting of soil and sediment samples, were part of a larger reconnaissance survey of former US military bases and suspected Agent Orange dioxin hotspots in southern Viet Nam. The 2008 sampling focused on soils/sediments from the most highly contaminated areas in Bien Hoa and Phu Cat Airbases. These earlier studies, and the work of other Vietnamese and international scientists, confirmed Bien Hoa Airbase to be a significant dioxin hotspot.

Interim mitigation measures are currently being implemented at Bien Hoa to protect the local population from continued exposure to dioxins from the Airbase. Remediation measures implemented with funding provided by GVN include soil excavation and construction of a passive landfill at the Z1 Area (former herbicide storage area) on the Airbase. Approximately 43,000 m^3 of contaminated soils have been excavated and placed in a secure landfill, completed in 2009. Soils throughout the Z1 Area at Bien Hoa Airbase are now heavily disturbed due to these remediation efforts. Rapid urban development in Bien Hoa City has also significantly changed the urban landscape in recent years, including local topography, hydrological patterns, and potential dioxin exposure pathways.

[1] In this report, dioxin or TCDD refers specifically to 2,3,7,8-tetrachlorodibenzo-p-dioxin; TEQ is based on 2005 WHO TCDD Toxic Equivalent factors (using one-half of the detection limit). PCDD and PCDF are general terms for all dioxin or furan congeners, respectively. Note that "ppt" is the same as "pg/g".

The 2010 environmental and human population studies at Bien Hoa Airbase and Bien Hoa City have provided a more complete picture of the overall dioxin contamination issue in Bien Hoa. As a result, a clearer understanding of dioxin contaminated areas has emerged, including exposure pathways, and affected populations in Bien Hoa. These data will help facilitate ongoing and future remediation efforts for Bien Hoa Airbase, and reduce or eliminate risk to public health. Results are presented below, as well as in the attached figures.

Dioxins in soils and sediments[2]:

- There are clearly a number of distinct dioxin hotspots at Bien Hoa Airport, apart from the historical herbicide storage area (Z1 Area), and landfill area. Elevated dioxin concentrations were measured at several locations in the western, southern, and eastern areas of the Airbase. Samples collected from the northern area of the Airbase had lower levels of dioxin contamination, although some lake sediments require remediation (Figure 1; Figure 2; Figure 3).

- Remediation efforts undertaken by the GVN and MND in the Z1 Area appear to have significantly reduced dioxin concentrations in soils in the south central area of the Airbase. However, other dioxin hotspots at the Airbase will require remediation, particularly in the Pacer Ivy Area in the western section of the Airbase.

- Significant quantities of TCDD, the dioxin contaminant in Agent Orange, were detected in soil samples analyzed from the Pacer Ivy Area on Bien Hoa Airbase in January 2008, and again in November 2010 (Figure 2). Dioxin levels at this location exceed Vietnamese and international standards and guidelines for these chemicals. TCDD concentrations ranged from non-detectable levels to 61,400 pg/g dry weight in samples collected from the Pacer Ivy Area in 2010.

- Dioxin concentrations in sediments collected from lakes and ponds located at and around the Pacer Ivy Area exceeded the Vietnamese guideline of 150 pg/g TEQ; TEQs from 2008 and 2010 sediment samples from the Pacer Ivy sites ranged from 30.9 to 5,970 pg/g dry weight (Figure 2).

- Dioxin congener profiles confirmed that the main source of dioxin contamination at Bien Hoa Airbase was Agent Orange and other dioxin-containing herbicides. TCDD contributed over 80% of the TEQ (TCDD toxic equivalents) in most soil and sediment samples analyzed from the Airbase.

- High TEQ levels were measured in some soil samples collected from the Z1 Area (outside the landfill) in the southern area of the Airbase in November 2010 (Figure 4). Three (3) samples exhibited TEQ concentrations exceeding the Vietnamese guideline of 1,000 pg/g, while TEQ levels in other samples remained low (ranging from 1.46 to 237 pg/g dry weight). Highest levels of contamination

[2] Vietnamese TEQ guidelines are 1,000 pg/g for soils and 150 pg/g for sediments (Viet Nam National Standard TCVN 8183:2009.

in soils from Bien Hoa were found in the Z1 Area in 2008 prior to completion of the landfill, at a depth of 60-90 cm (262,000 ppt; 99% TCDD). All samples collected at different depths at this sampling point exhibited >26,400 ppt TEQ. These highly contaminated soils were subsequently contained in the new landfill.

- High TCDD levels were also recorded in a small area at the southwest corner of the Bien Hoa Airbase during the January 2008 program (Figure 3). In November 2010, additional samples were collected from areas surrounding the identified hotspot. All samples collected in 2010 exhibited low concentrations (between 7.84 and 124 ppt TCDD), suggesting that dioxin contamination is limited to a small area in the southwestern portion of the Airbase.

- Soil samples collected from the northern perimeter of the Airbase exhibited low TCDD concentrations, ranging between 8.47 to 425 pg/g; none exceeded the Vietnamese guideline of 1,000 pg/g. However, sediments sampled from two lakes in this area exhibited elevated TCDD values (372 pg/g and 268 pg/g) (Figure 5; Figure 6).

- Generally low TEQ concentrations were recorded in soil and sediment samples collected from the northeastern perimeter of the Airbase in 2010 (Figure 5). One soil sample (1,040 pg/g) and one sediment sample (633 pg/g) from this area exceeded the Vietnamese guidelines.

- Sediment samples were collected from Bien Hung Lake and 'Gate 2 Lake', located in Bien Hoa City (south of the Airbase) (Figure 6). None of the samples exceeded the Vietnamese sediment dioxin guideline; however, elevated TEQ concentrations were recorded at Bien Hung Lake (95.6 pg/g). Sediment samples collected from this lake during the 2005 sampling program (Hatfield/10-80 2006) exhibited TEQ values ranging from 36 to 131 pg/g dry weight.

- The present study and previous work by Hatfield/10-80 Division/Office 33/VRTC demonstrated that the highest concentrations of dioxins are generally in the top 10 cm layer; however, migration of dioxins to deeper layers of soil was observed in the Hatfield/VRTC (2009) study (Z1 Area), where high concentrations of herbicides were stored and used.

- Other contaminants are likely present in the environment of Bien Hoa, which contribute to total PCDD/PCDF load (including polychlorinated biphenyls, organochlorine pesticides, and hydrocarbons). These other contaminants were not investigated in the current study, but have been identified at Da Nang Airbase (another former Ranch Hand site).

- This study and previous investigations confirm high contaminations of dioxins in soils and sediments at a number of locations on Bien Hoa Airbase, and that Bien Hoa Airbase is a significant dioxin hotspot. The samples collected from the northern and eastern areas of the Airbase exhibit lower dioxin contamination than samples collected from the southern, and western areas.

Dioxins in fish tissues[3] and dioxin exposure pathways:

- The evidence indicates that dioxin moves from the former Agent Orange storage and washing/loading area (Z1 Area), and the Pacer Ivy Area into surrounding drainage ditches, small creeks, ponds and lakes, and ultimately into humans (via ingestion of contaminated fish, ducks and molluscs, direct dermal contact with soils and sediments, and likely via inhalation of dust), and is directly linked to historical Agent Orange use on the Bien Hoa Airbase. The most contaminated soils from the Z1 Area have recently (2009) been contained in a secure landfill by the MND, and public access has been restricted to reduce the risk of dioxin exposure to local populations. However, there is extensive aquaculture pond development and agricultural activities being conducted on the Airbase itself, which poses a significant risk to the population of Bien Hoa City.

- Tilapia, the most common fish captured and raised in aquaculture ponds on the Bien Hoa Airbase property, exhibited TEQ concentrations ranging from 4.54 to 4,040 pg/g wet weight in fat tissues; the median TEQ value in fat tissues was 1,440 pg/g (Figure 7).

- The maximum TEQ concentration recorded in Tilapia fat from 'Mr. Hoc Lake' in the Pacer Ivy Area in 2010 (4,040 pg/g wet weight basis) is more than 200 times the acceptable level established by Health Canada. Tilapia fat tissue samples from 'Mr. Quy Lake' (2,460 pg/g), 'NE Perimeter Lake' (1,680 pg/g), 'Gate 2 Lake' (1,520 pg/g), and 'Z1 Lake' (1,440 pg/g) all exceed this guideline by more than 70 times (Figure 7).

- Muscle samples analyzed from Tilapia and other fish species from lakes inside and outside the Bien Hoa Airbase property in 2010 generally exhibited lower dioxin levels, ranging from 0.0782 to 33.5 pg/g TEQ wet weight, and were below the Health Canada guideline (Figure 7).

- Dioxin levels recorded in whole-fish tissues of small Tilapia composites collected from 'Pacer Ivy Lake' and 'Z1 Lake' in 2010 also exhibited high TEQ concentrations (622 pg/g and 96.5 pg/g, respectively), well above the Health Canada guideline (Figure 7).

- Tilapia muscle and fat tissues sampled from Bien Hoa Market and Gate 2 Market, where fish raised from inside the Airbase are occasionally sold, exhibited low TEQ concentrations (5.9 pg/g and 4.54 pg/g dry weight, respectively). These levels are below the Health Canada guideline. The fish sampled from the markets in the current study, however, likely originated from aquaculture cages in the Dong Nai River (Figure 7).

[3] Health Canada consumption guideline for edible fish tissue is 20 pg/g TEQ wet weight.

Dioxins and furans in human blood and breast milk:[4]

- TCDD concentrations in human blood serum collected from Airbase workers exhibited elevated TCDD and TEQ levels; TEQ concentrations ranged from 19.3 to 2,020 pg/g lipid basis (Figure 8). Given the high percentage of TCDD in the TEQ (range from 56.4% to 98.3%) in human blood serum analyzed, it is clear that dioxin levels recorded are related to exposure to historical Agent Orange use at the Airbase.

- Dioxin/furan levels in human serum lipid were compared to exposure standards calculated based on the WHO's Tolerable Daily Intakes (1998). A chronic intake of 4 pg/kg bw/day corresponds to 30 pg/g TEQ; all but one serum sample analyzed exceeded this guideline.

- Extremely high dioxin/furan levels (1,080 – 2,020 pg/g TEQ) were found in blood serum of three (3) individuals who actively harvest fish and other aquatic animals (e.g., ducks) from the Bien Hoa Airbase (Figure 8). TCDD accounted for more than 96% of the TEQ in these workers. TEQ concentrations in these three samples were more than 35 times greater than the WHO 1998 standard (30 pg/g).

- Individuals who consumed fish caught exclusively inside the Airbase exhibited higher average serum TCDD and TEQ concentrations (at a statistically significant level, α=0.01) compared to those who caught fish from lakes and ponds both inside and outside the Airbase, and compared to those who fish exclusively outside the Airbase. No significant gender- and age-related effects on serum dioxin levels were discovered.

- Dioxins and furans were recorded in all breast milk samples analyzed in 2010 (N=22) (Figure 9). Maximum levels were detected in a mother (age 29) who was breastfeeding her 2nd child (30.3 pg/g TCDD lipid basis), and who previously consumed fish from 'Z1 Lake' and 'Gate 2 Lake'. Average Daily Intake of breast milk per infant was calculated based on WHO/Euro (1989); Total TEQ ingested by infants ranged from 5 to 172 pg TEQ/kg bw/d.

- All breast milk samples analyzed exhibited TEQs exceeding the WHO Tolerable Daily Intake guideline of 4 pg TEQ/kg bw/d. High dioxin and furan levels in breast milk are cause for concern, and emphasize the need for raising awareness of potential contaminated food items originating from Bien Hoa Airbase.

- Comparison of Bien Hoa (2010) breast milk data to those recorded in Hatfield/Office 33 (2007, 2009) studies at Da Nang Airport indicates that TEQ levels observed in Bien Hoa are generally lower; Average Daily Intakes in breast

[4] The typical range of TCDD in the general population of industrialized countries has been reported as 3 to 7 pg/g (lipid-based) (ATSDR 1998). ATSDR also indicated that TCDD in human blood rarely exceeds 10 pg/g and that typically, lower levels of this contaminant are recorded in less industrialized countries.

milk samples collected from in and around Da Nang Airport ranged from 23.4 to 2,320 pg TEQ/kg bw/d.

Recommendations:

- Planning and implementation of remediation measures, and clean-up of Bien Hoa Airbase, is urgently required to ensure protection of the local population from future exposure to dioxins from historical Agent Orange use at the site.

- Final remediation and clean-up efforts should focus on mitigating dioxin and furan contamination downstream of the Z1 Area and at the Pacer Ivy Area. Current remediation efforts have focused on the construction of drainage ditches and a secure onsite landfill in the Z1 Area. Final destruction of dioxin contaminated soils in the Z1 landfill will also be required in the future.

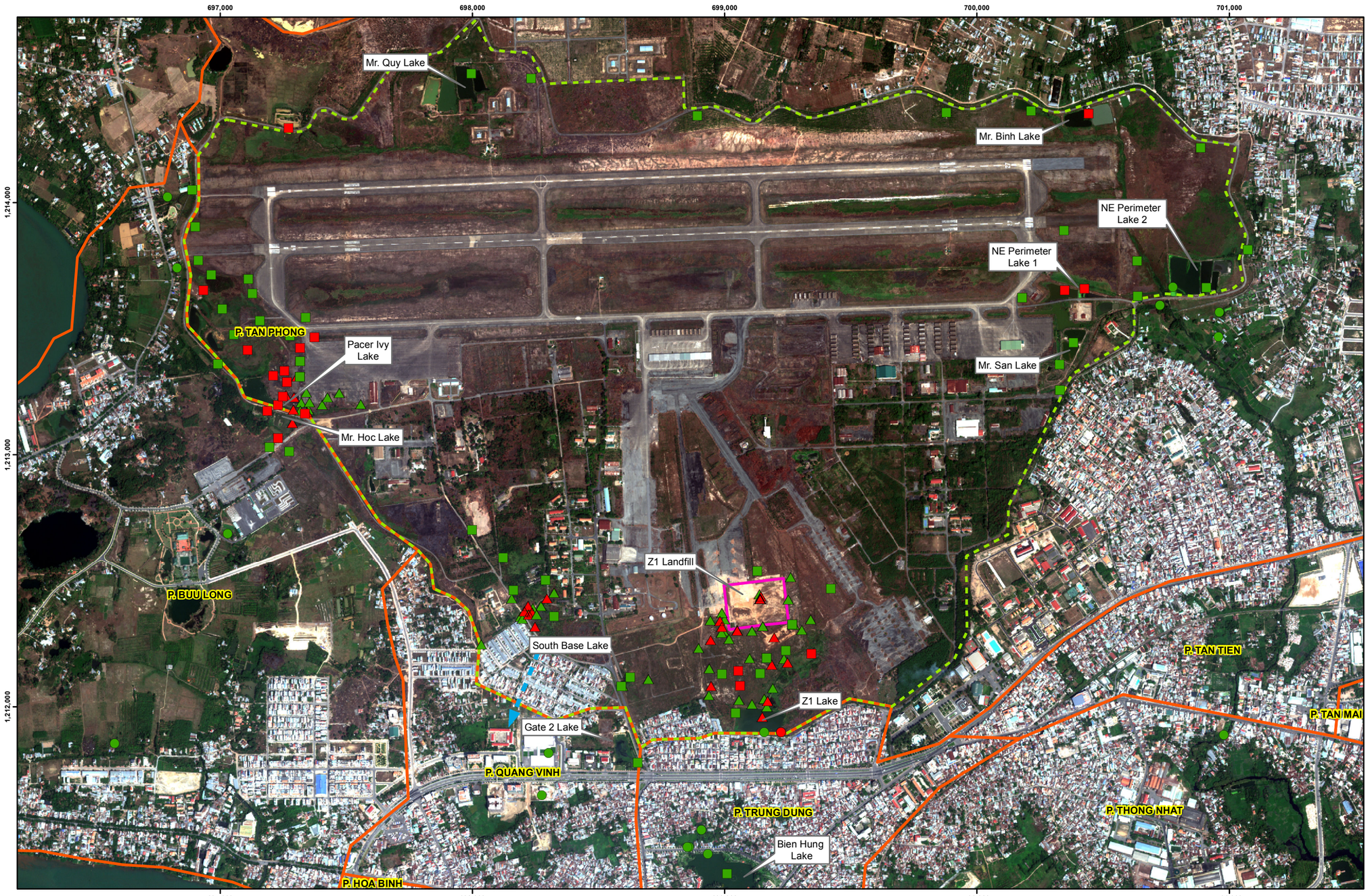
- Cultivation of Tilapia, other fish species and aquatic animals (e.g., ducks, molluscs, etc.) should be halted immediately. Investigation of potential dioxin contamination related to other agricultural activities (e.g., raising livestock) should be conducted.

- Other potential dioxin and furan contamination sources, particularly uncontrolled combustion and industrial emissions, should be identified, as well as other potential contaminated materials which may be present at the Airbase.

- Awareness raising of dioxin exposure pathways (eating contaminated fish and other food items raised on Bien Hoa Airbase, exposure to contaminated soil and sediment, uncontrolled combustion, etc.) is required to help reduce dioxin loads in local Bien Hoa residents, especially nursing mothers.

- Other major dioxin hotspots in Viet Nam, particularly Da Nang and Phu Cat, also require remediation and clean-up, to protect the local populations from continued exposure to Agent Orange and other herbicides used over 40 years ago during the US-Viet Nam war. Lessons learned from ongoing cleanup activities at Da Nang Airport (funded by the US and Vietnamese governments) will be invaluable for the future remediation of Bien Hoa and Phu Cat Airbases, and at other dioxin hotspots in Viet Nam.

Figure 1 Dioxin concentrations (TEQ, pg/g) in soil and sediment samples, Bien Hoa Airbase, Vietnam, 2004 to 2010.



Legend

- Direction of runoff
- Airport Boundary
- Ward Boundary
- Landfill

Soils/Sediment:

Soil and Sediment concentrations exeed Vietnamese National Standard.*

- 2010 (Hatfield/Office 33)
- 2008 (Hatfield/ VRTC)
- 2004/2005 (Hatfield/ 10-80)

Soil and Sediment concentrations below Vietnamese National Standard.*

- 2010 (Hatfield/Office 33)
- 2008 (Hatfield/ VRTC)
- 2004/2005 (Hatfield/ 10-80)

*Vietnamese National Standard for Dioxin TCVN 8183:2009 (1000 ppt Soil, 150 ppt Sediment).

Data Sources:
a) Image acquired from World View 2010
b) Sampling Locations from Hatfield/ VRTC and 10-80
c) Ward boundaries estimated from: KAP of Local Residents at a Dioxin Hotspot – Bien Hoa – Viet Nam on Preventing Dioxin Exposure Through Foods, Vietnam Public Health Association UK Presentation, 2008

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N

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Meters

1:16,000

Projection: WGS 84 UTM 49N

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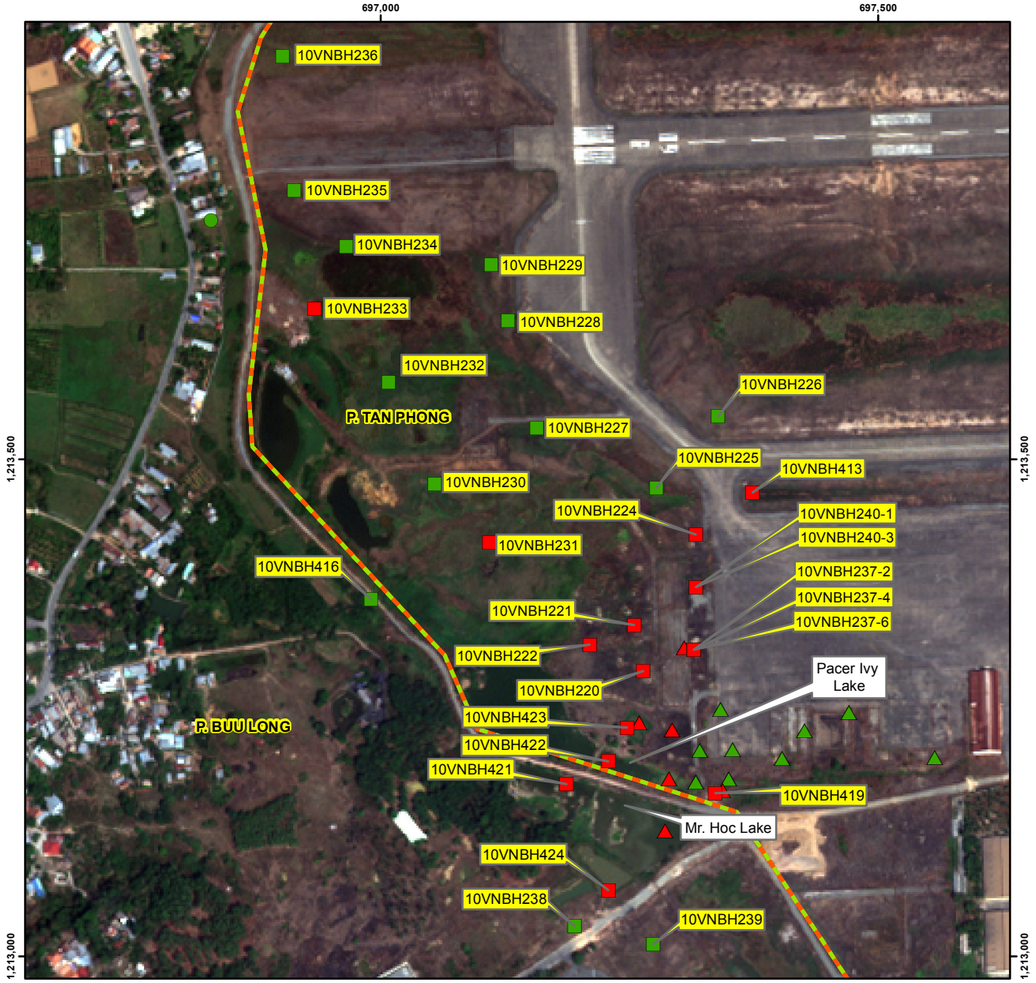
Figure 2 **Pacer Ivy Area of Bien Hoa Airbase soil and sediment sampling locations, 2004 to 2010.**



Legend

- Airport Boundary
- Direction of runoff
- Ward Boundary

Soild/Sediment:

Soil and Sediment concentrations exeed Vietnamese National Standard.*	Soil and Sediment concentrations below Vietnamese National Standard.*
2010 (Hatfield/Office 33)	2010 (Hatfield/Office 33)
2008 (Hatfield/ VRTC)	2008 (Hatfield/ VRTC)
2004/2005 (Hatfield/ 10-80)	2004/2005 (Hatfield/ 10-80)

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*Vietnamese National Standard for Dioxin TCVN 8183:2009 (1000 ppt Soil, 150 ppt Sediment).

0 0.05 0.1 0.2 Km

Scale: 1:6,000

Projection: WGS 1984 UTM Zone 48N

Data Sources:
a) Image acquired from World View 2010
b) Sampling Locations from Hatfield/ VRTC and 10-80
c) Ward boundaries estimated from: KAP of Local Residents at a Dioxin Hotspot – Bien Hoa – Viet Nam on Preventing Dioxin Exposure Through Foods, Vietnam Public Health Association UK Presentation, 2008

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Pacer Ivy Area of Bien Hoa Airbase: Dioxin concentrations (TCDD and TEQ; pg/g) in soil and sediment samples, 2010.

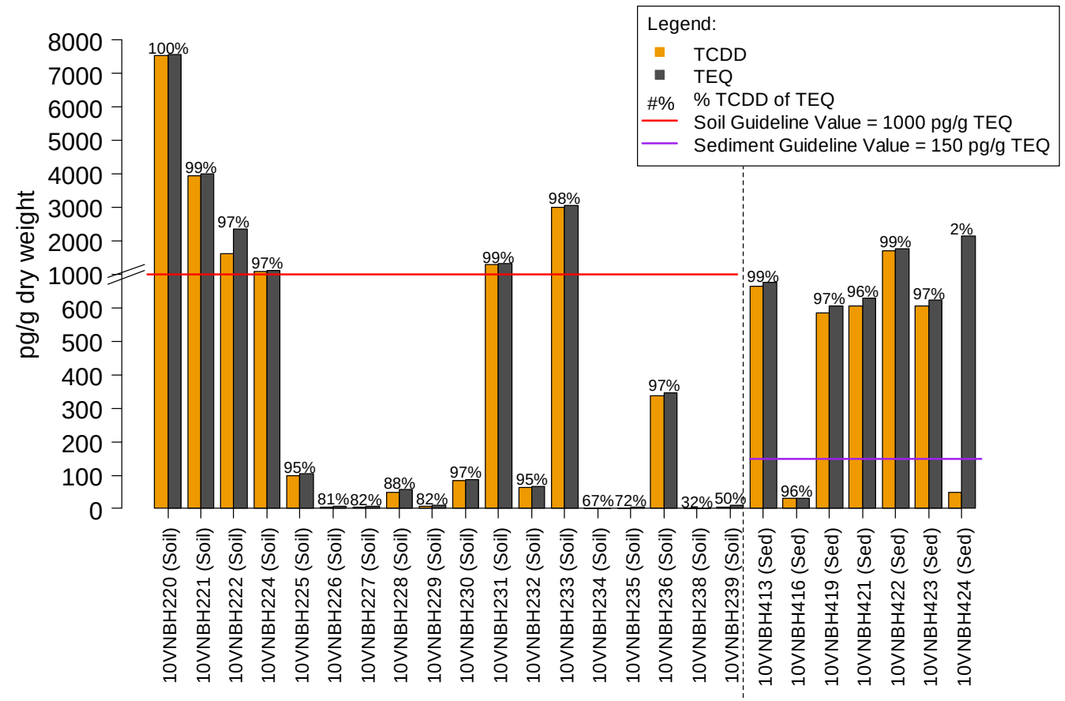

Figure 3 **Southwest corner of Bien Hoa Airbase: soil and sediment sampling locations, 2008 and 2010.**

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Southwest corner of Bien Hoa Airbase: Dioxin concentrations (TCDD and TEQ; pg/g) in soil and sediment samples, 2008 and 2010.

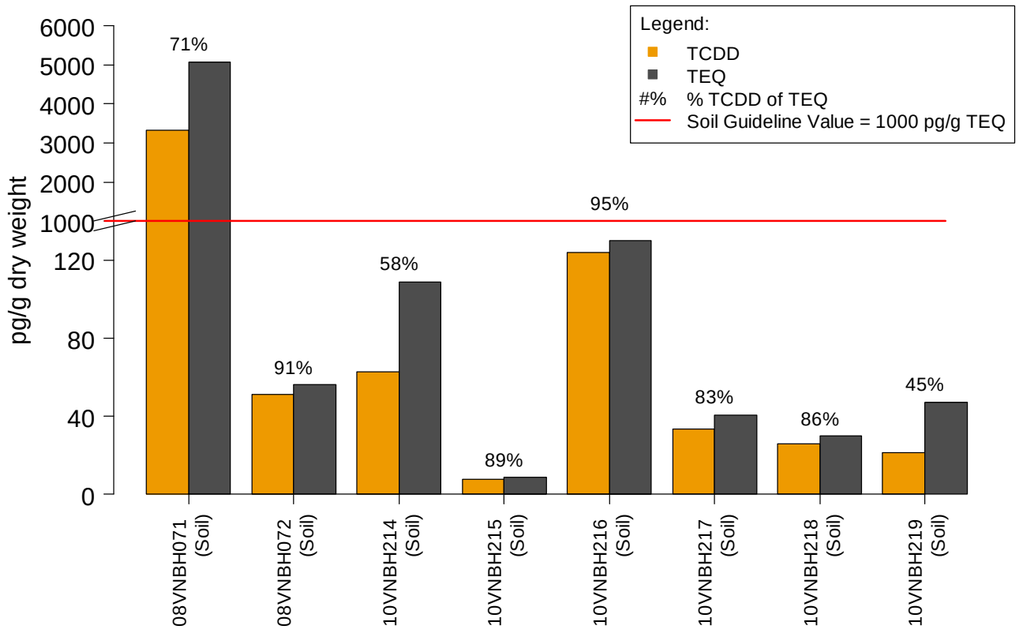
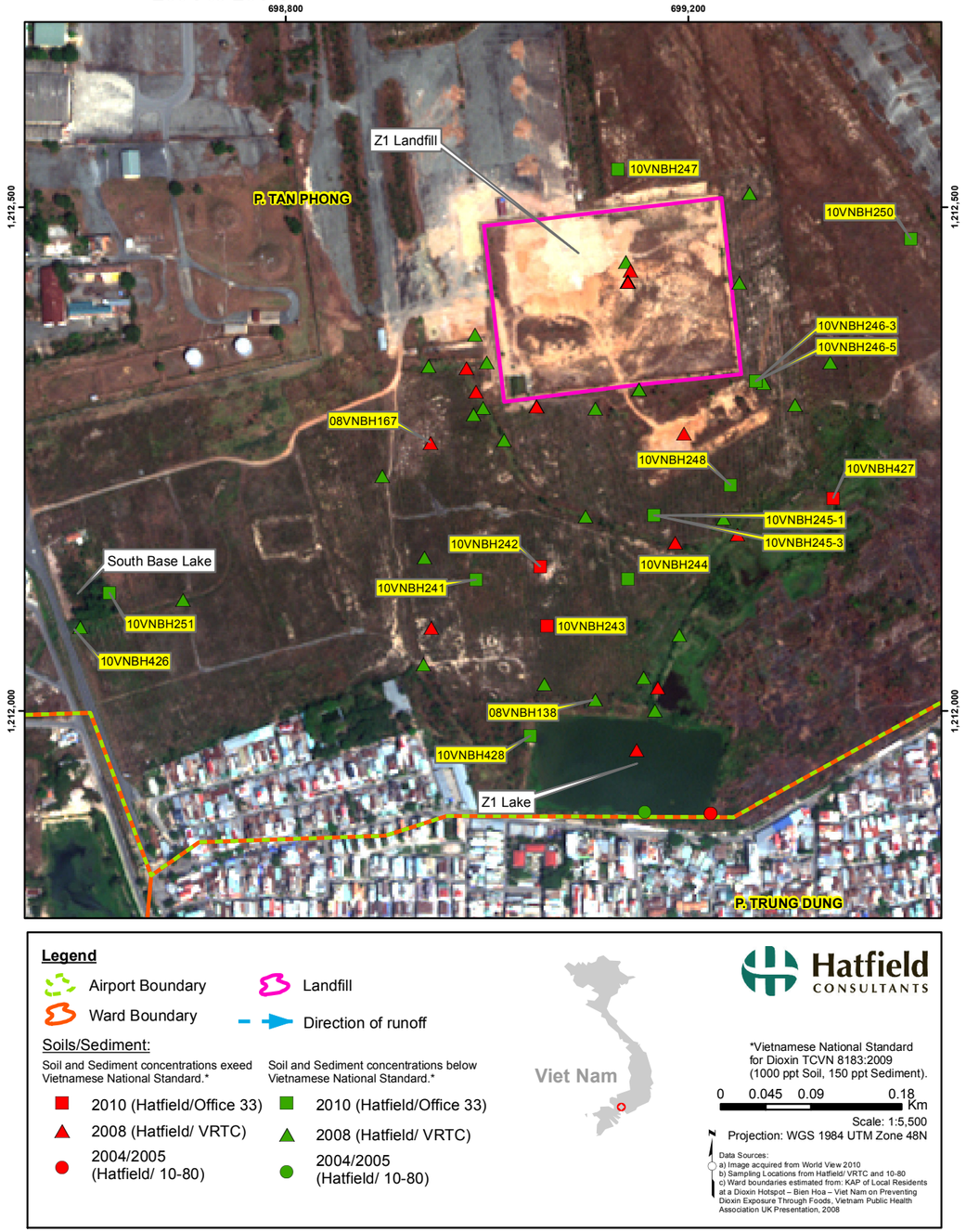


Figure 4 **Z1 area of Bien Hoa Airbase: soil and sediment sampling locations, 2004 to 2010.**



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Z1 Area of Bien Hoa Airbase: Dioxin concentrations (TCDD and TEQ; pg/g) in soil and sediment samples, 2008 and 2010.

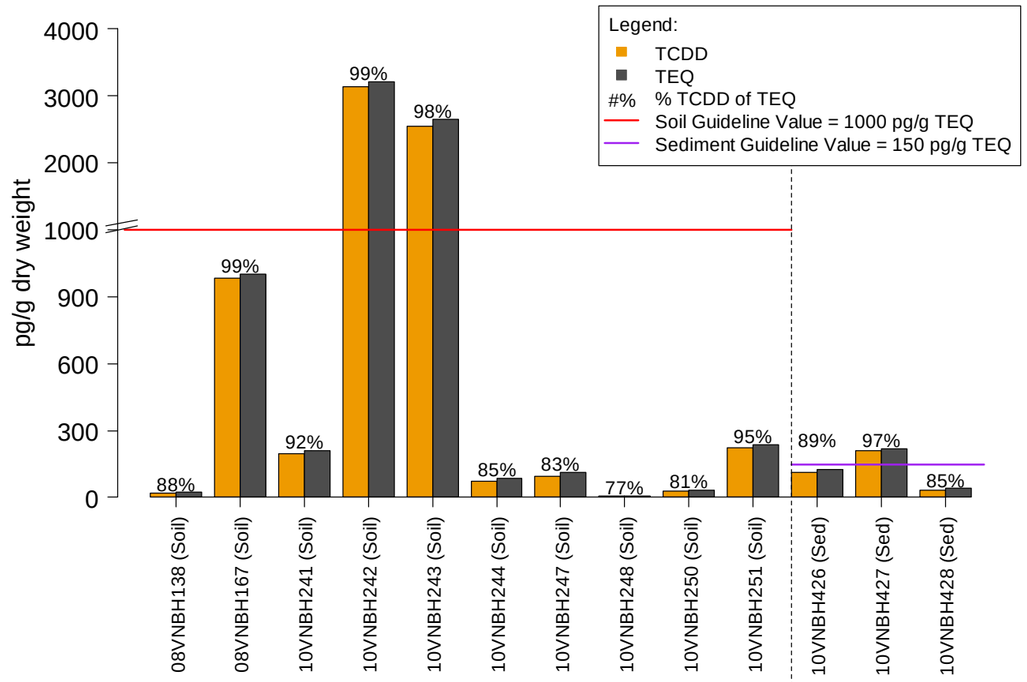
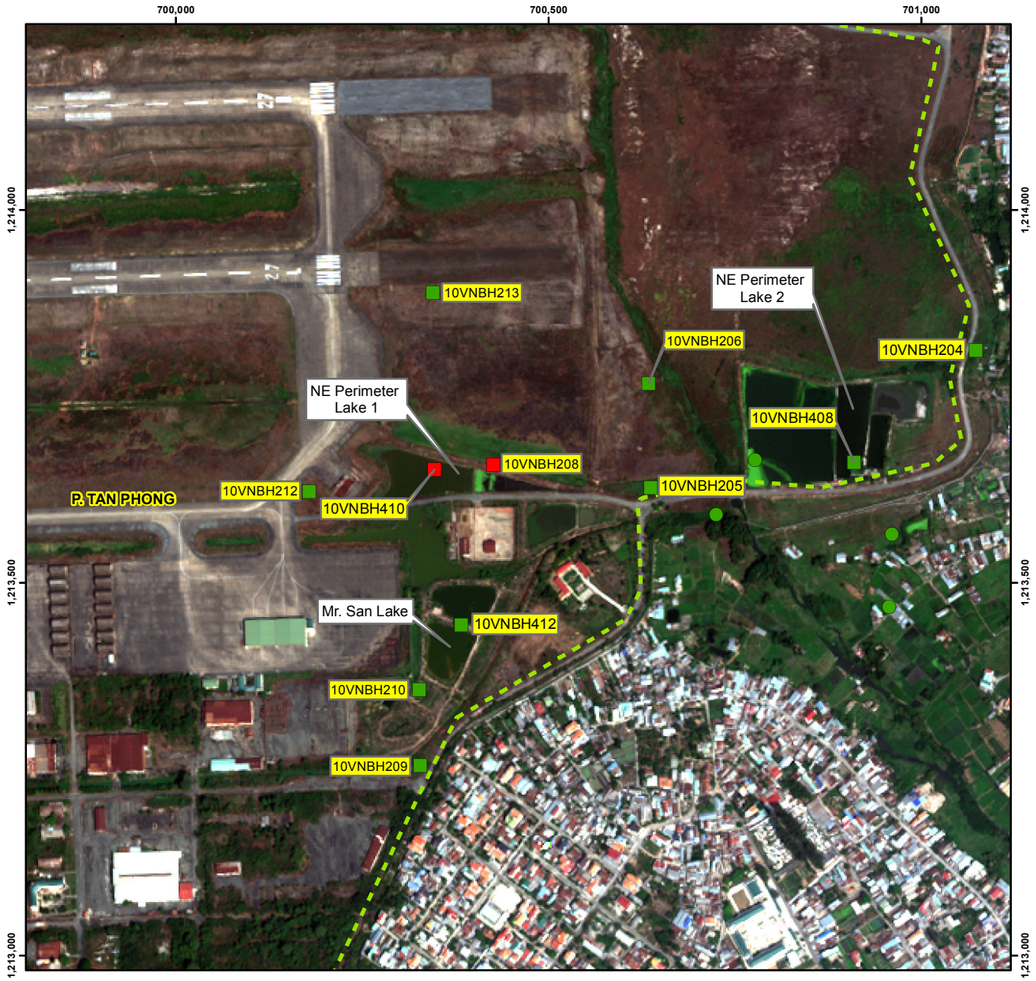


Figure 5 **Northeastern perimeter of Bien Hoa Airbase soil and sediment sampling locations, 2004 to 2010.**



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Northeastern perimeter of Bien Hoa Airbase: Dioxin concentrations (TCDD and TEQ; pg/g) in soil and sediment samples, 2010.

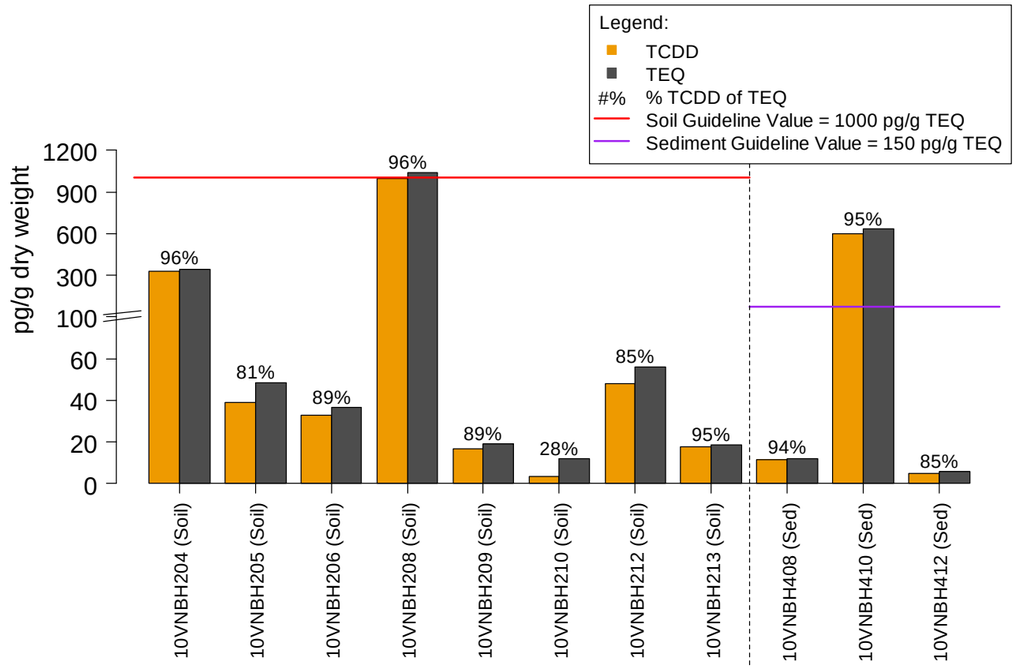

Figure 6 **Perimeter of Bien Hoa Airbase soil and sediment sampling locations, 2004 to 2010.**

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Perimeter of Bien Hoa Airbase and Bien Hoa City: Dioxin concentrations (TCDD and TEQ; pg/g) in soil and sediment samples, 2010.

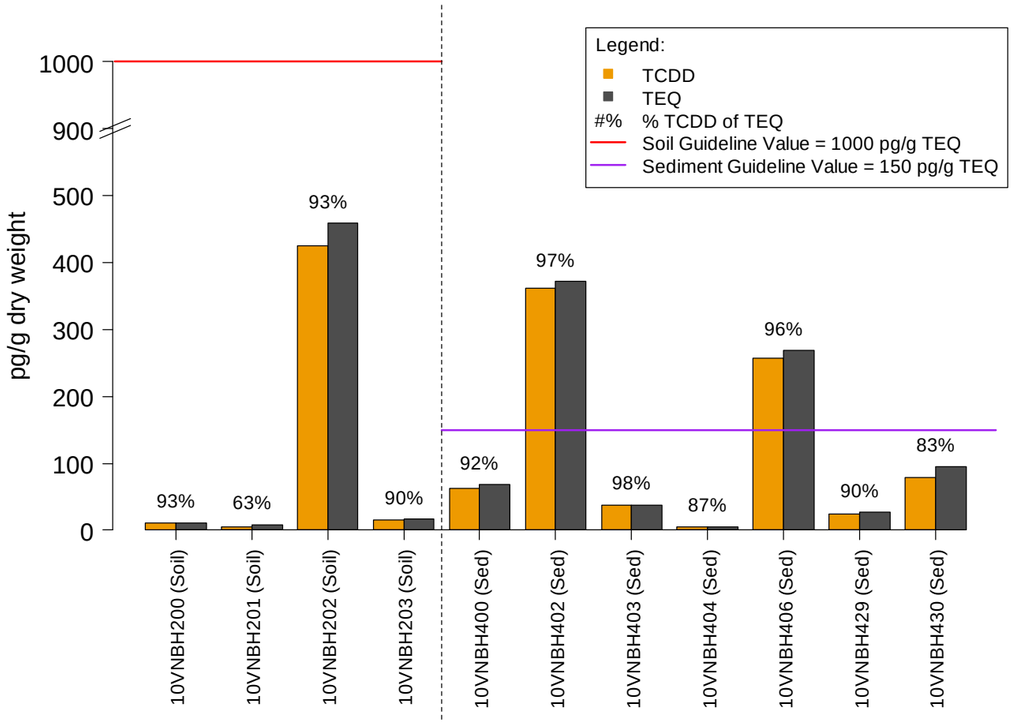
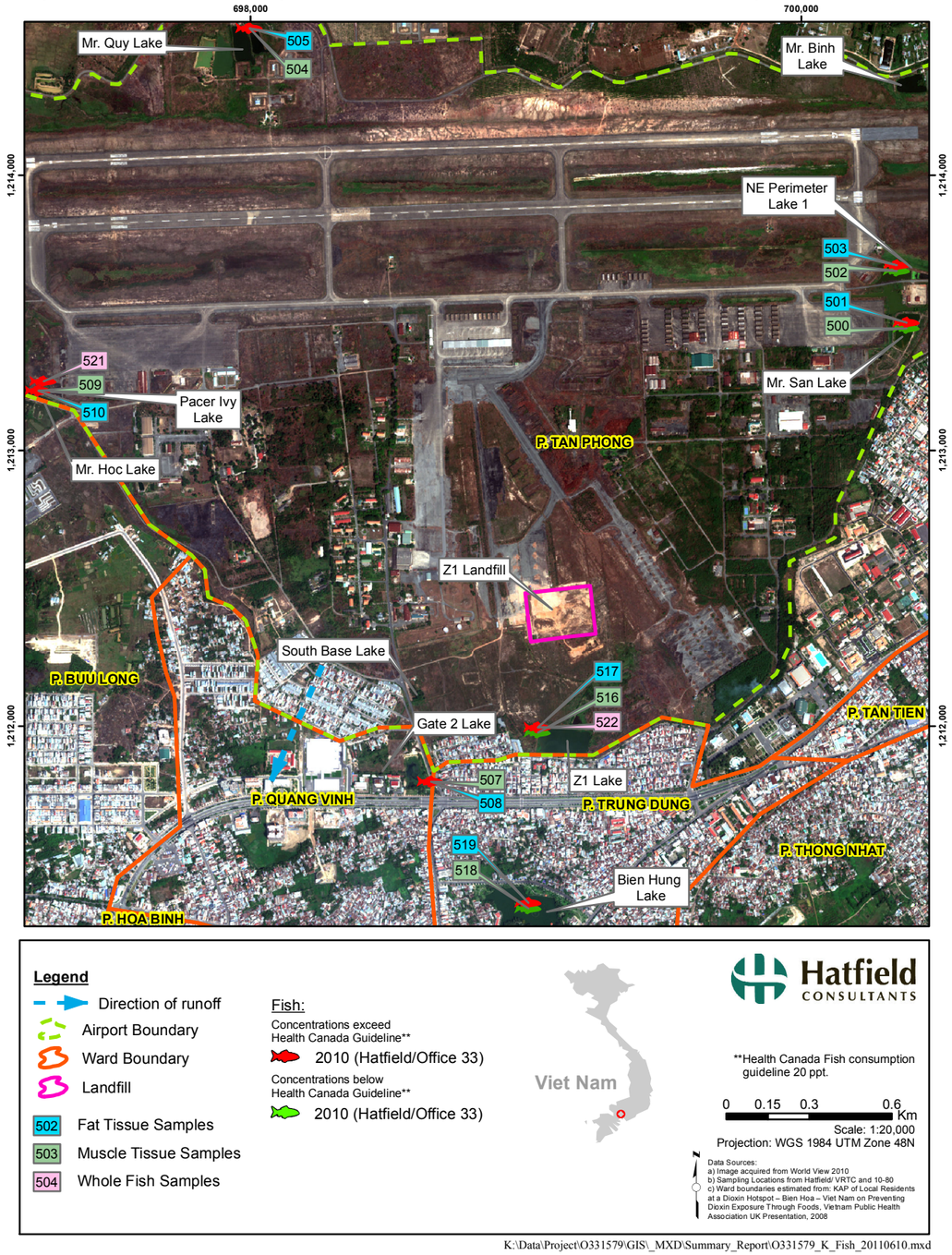


Figure 7 Fish sampling locations, Bien Hoa Airbase and Bien Hoa City, 2010.



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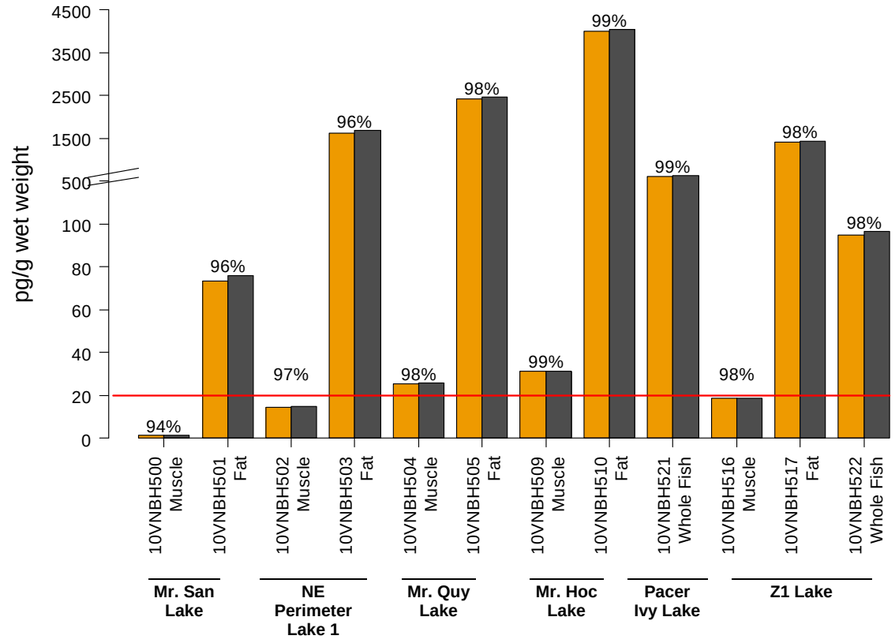
Dioxin concentrations (TCDD and TEQ; pg/g) in fish sampled inside the Bien Hoa Airbase, 2010.



Dioxin concentrations (TCDD and TEQ; pg/g) in fish sampled from Bien Hoa City, 2010.

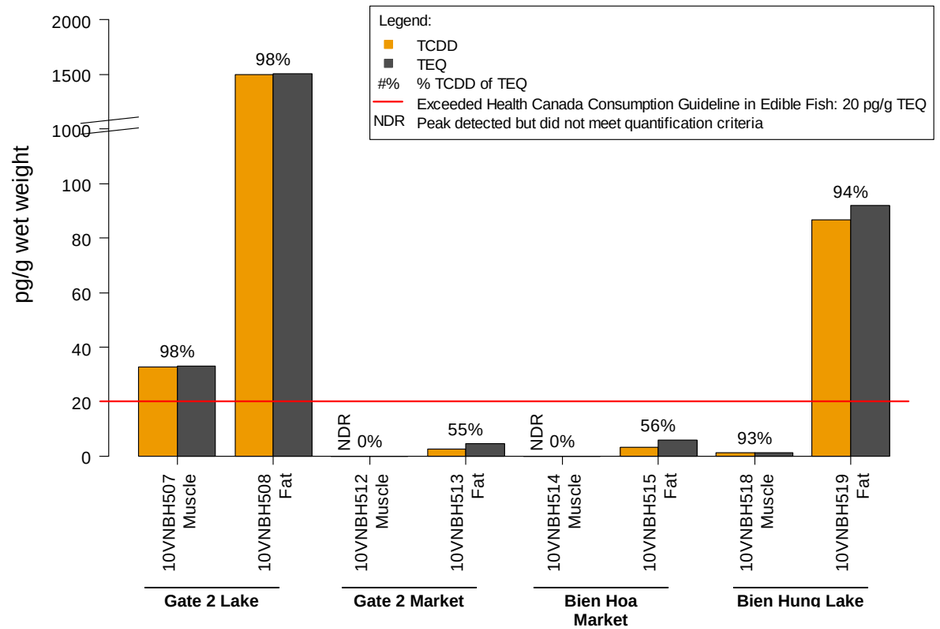


Figure 8 TCDD and total TEQ (pg/g [ppt], lipid basis) for human blood serum, Bien Hoa, Viet Nam, November 2010.

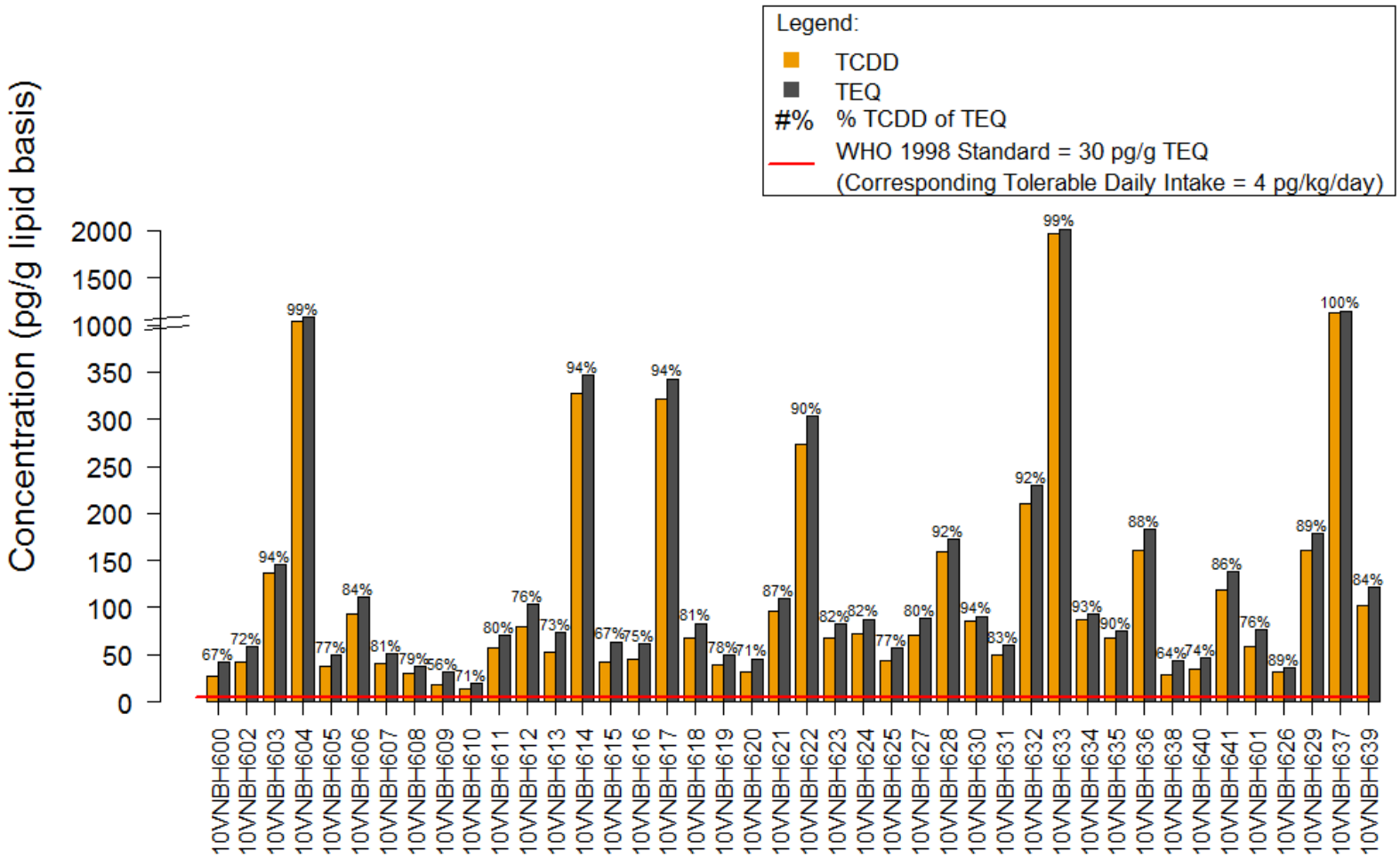


Figure 9 **TCDD and total TEQ (pg/g [ppt], lipid basis) in human breast milk for Bien Hoa Airbase and Bien Hoa City, November 2010.**