Assessment of Dioxin Contamination in the Environment and Human Population in the Vicinity of Da Nang Airbase, Viet Nam

Report 3: Study Summary

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Summary of Findings

The impact of exposure to Agent Orange and other herbicides on human health remains a contentious issue. However, dioxin (particularly 2,3,7,8-tetrachlorodibenzo-p-dioxin; also referred to as 2,3,7,8-TCDD or TCDD), a known component of the Agent Orange mixture, is known to cause an increased risk of cancers, immunodeficiencies, reproductive and developmental changes, nervous system and other health problems. Countries around the world have implemented strict guidelines and criteria for the control and release of dioxins into the environment, in order to protect human health. Dioxins in soil can pose a lingering threat to human health; Paustenbach *et al.* (1992) has indicated that the half-life of dioxins in subsurface soils can extend to 100 years.

TCDD is lipid soluble and accumulates in organs with a high lipid or fat content (e.g., body fat, liver, mother's milk). Human exposure can occur through ingestion, absorption through the skin, or inhalation of dioxin-contaminated materials. Once in the human body, the half-life is estimated at approximately 7 to 11 years.

Agent Orange has been described as the last remaining vestige of the war to be resolved between the US and Viet Nam. Since the US-Viet Nam war, Vietnamese living in the vicinity of key Ranch Hand sites (Bien Hoa, Da Nang, Phu Cat and others) have been exposed to contaminated soils, sediments and foods; these areas are referred to as dioxin 'hot spots' (Dwernychuk *et al*. 2002). Due to the chemical stability of dioxins, contaminated lands have the potential to expose the general population to dioxin for many decades, well beyond the initial aerial applications and spillages that occurred during the war-time Ranch Hand operation.

The presence of dioxin in the environment in and around former US military sites in Viet Nam is a direct result of storage and use of herbicides by the US and Army of the Republic of Viet Nam (ARVN) forces, and spillage which occurred from improper disposal of empty herbicide barrels. Despite the fact that dioxins are known to be a significant environmental hazard, to date there have not been adequate measures taken to properly assess the extent and impact of contamination around known hot spots in Viet Nam. Protection of human health in the vicinity of these dioxin hot spots is of key concern.

The Da Nang Dioxin Assessment and Mitigation Project was conducted by Hatfield Consultants (West Vancouver, Canada) in association with the Ministry of Natural Resources and Environment (MONRE) Office of the National Steering Committee 33 (Ha Noi, Viet Nam) between October 2006 and April 2007. The project objective was to investigate the issue of residual dioxin contamination on the Da Nang Airbase and in the surrounding environment (Figure 1.1), and to develop mitigation measures to help prevent the local population from future exposure. Results of the study are as follows:

- Agent Orange and other herbicides were stored in large quantities at Da Nang Airbase during the US-Viet Nam war; more than 100,000 45-gallon (208-litre) barrels of herbicide were used on the Da Nang Airbase. These herbicides were loaded primarily onto C-123 aircraft for aerial spraying in central Viet Nam and Lao PDR; herbicides were also dispensed by truck, backpack spray devices and helicopter. Significant spillage occurred from improper handling and disposal of herbicides; this is well documented in US military records from the war period.

- Significant quantities of TCDD, a contaminant in Agent Orange, were detected in samples analyzed from the Da Nang Airbase in December 2006. To this day, dioxin continues to enter the aquatic ecosystem, the general environment, the food chain and the human population living in close proximity to the contaminated site on the Da Nang Airbase. Dioxin levels recorded in this study exceeded all international standards and guidelines for these toxic chemicals.

- There is no doubt that historical use of the Da Nang Airbase by the US military and their Operation Ranch Hand has resulted in significant dioxin contamination in the environment and human population of Da Nang. Contamination was widespread during the US-Viet Nam war period, particularly in waterbodies and agricultural areas north of the Airbase (Figure 1.2).

- Chemical analyses performed in this study confirm that the main source of dioxin contamination at Da Nang Airbase was Agent Orange and other dioxin-contaminated herbicides. The analytical chemistry undertaken at AXYS, a WHO-tested and approved dioxin laboratory, shows that TCDD contributed to over 90% of the TEQ (i.e., total sample toxicity) in samples collected from the former Agent Orange Mixing and Loading Area, former Storage Area and Sen Lake, all of which are located on Da Nang Airbase. Samples collected downstream of the Airbase in Da Nang City contained lower levels of Agent Orange dioxin. Other contaminants (including polychlorinated biphenyls [PCBs], organochlorine pesticides and hydrocarbons) were also shown to be present in the environment, both inside and outside the perimeter of Da Nang Airbase (Figure 1.3).

- The maximum soil TEQ concentration recorded in this study was 365,000 ppt, from samples collected from the former Mixing and Loading area (Figures 3.1, 3.2, 3.3). This is 365 times the globally acceptable maximum standard of 1,000 ppt (ATSDR 1997). Over 99% of the TEQ in the sample was TCDD (361,000 ppt). This dioxin level represents extremely high contamination, and confirms Da Nang Airbase as a significant 'hot spot'.

- Soil dioxin levels recorded in this study are the second highest reported in Viet Nam to date (the highest being >1 million ppt TEQ in soils at Bien Hoa Airbase by Schecter *et al.* [2001], although the exact geographical position, origin, and method of extraction of this

Bien Hoa Airbase soil sample is unknown, and has never been reported). Soil dioxin levels from this study confirm contamination data previously obtained by the Vietnamese Government and US EPA (unpublished data).

- The present study (and previous work by Hatfield/10-80 Division of the Ministry of Health [1998, 2000, 2003, 2005]) has verified that the highest concentrations of Agent Orange dioxin in soils/sediments in Viet Nam are found in the top 10 cm layer; some contamination is found at deeper strata (e.g., >30 cm), but only in limited areas on the former Mixing and Loading Area and former Storage Area at Da Nang Airbase (Figures 3.4, 3.5, 3.6).

- Dioxin from the former Mixing and Loading Area and the former Storage Area is adsorbed onto particulate matter and is transported via rainwater to downstream waterbodies, including Sen Lake. Fish and other aquatic animals (such as frogs, snails, ducks, etc.) continue to be contaminated to this day (Figure 3.7). The human population of Da Nang is therefore exposed to dioxin from contaminated food, and likely also absorbs dioxin through the skin as a result of direct exposure to contaminated soils and sediments (and possibly contaminated dust).

- The movement of dioxin from the contaminated Da Nang Airbase lands, into Sen Lake, and ultimately into humans (via ingestion of contaminated fish and direct contact with soils and sediments) is without doubt, and is directly linked to historical Agent Orange use at the Airbase. The resulting high dioxin levels in the environment and food chain pose an unacceptable health risk to exposed populations.

- Dioxin-contaminated sediments (and likely fish and other aquatic organisms) have migrated out of the Airbase through the city drainage system into neighboring wetland and agricultural areas for decades. Run-off from the dioxin hot spots on Da Nang Airbase drains from Sen Lake through a large underground culvert serving as a general storm sewer, and ultimately empties into the Phu Loc River and Da Nang Bay. Tests for dioxin at the culvert's outflow into the Phu Loc River in 2005 indicated low levels of dioxin (6.46 ppt TCDD; 11.9 ppt TEQ; Hatfield/10-80 2005). Therefore, except during massive floods, the major run-off from the Da Nang Airbase hot spots appears to settle

in Sen Lake, and likely does not adversely impact the environment outside the northern end of the Airbase.

- Maximum TCDD levels recorded in fish fat samples in this study were 3,000 ppt, which is 100 times the acceptable level established by Health Canada. Fish contaminated with dioxins are consumed by fishermen (and likely some members of the general public) at considerable distances from the point of herbicide release to the environment; there is a direct connection between Sen Lake and areas outside the Da Nang Airbase through the local drainage system.

- Blood dioxin levels recorded in this study (N=55 patients sampled) for some Da Nang residents were the highest reported for Viet Nam to date, and exceed all international standards for these chemicals. Those individuals who work on the Da Nang Airbase in Sen Lake (harvesting fish and lotus) and in the surrounding gardens (which are often flooded) were found to have dioxin concentrations in their blood more than 100 times globally acceptable levels. The highest TCDD level was recorded in a 42-year-old male who has lived and consumed fish from the Sen Lakes since 1990. His TCDD level was 1,150 ppt TCDD (1,220 ppt TEQ; 94% TCDD), indicating Agent Orange as the source of the TCDD contamination. Two other individuals who were fishing and farming inside the Da Nang Airbase perimeter had >500 ppt TEQ. A number of other contaminants, including PCBs, were also recorded in blood samples analyzed.

- One breast milk sample analyzed contained elevated levels of dioxins and PCBs, which exceeded World Health Organization and Canadian standards. Mothers who become contaminated with dioxin have the potential to transport the contaminant to their milk glands, and ultimately to their children. Breast-feeding essentially 'off loads' some of a mother's dioxin to her children, thus contaminating her child. Additional data are required to determine the extent of the problem at Da Nang, given the small sample size in this study.

- People most affected by direct exposure to dioxins from the Da Nang hot spot are members of an extended family fishing and harvesting lotus from Sen Lake and gardening along its banks. Those living near the West Airbase fishponds are also potentially highly exposed. In terms of current high dioxin exposure, approximately 50 people involved in harvesting fish and aquatic organisms from Airbase lakes (and their families) are likely most directly affected by dioxin contamination. Others in the general population are potentially also affected, through consumption of contaminated fish, other aquatic animals and vegetables originating from the contaminated lakes on Da Nang Airbase. At present, it is believed that only a small proportion of the general population of Da Nang City is adversely affected. Others may also be affected by eating fish and other aquatic animals harvested from the Airbase lakes, although exact numbers are presently unknown. Exact numbers of highly exposed people needs to be verified and monitored.

- Results from this Da Nang study support those from previous Hatfield/10-80 Division studies (1998, 2000, 2003, 2005, Dwernychuk *et al*. 2002), namely that dioxins are transported from soils to aquatic sediments to fish and other aquatic organism tissues, and ultimately into humans, as shown by blood and breast milk analyses. The high levels of TCDD contributed almost all of the total toxicity of the samples analyzed, indicating that Agent Orange was the principal source of this dioxin congener.

Immediate action is therefore necessary at Da Nang and other former Ranch Hand sites to prevent further human health risks from exposure to dioxins.

It is important to distinguish between historical and current dioxin contamination at Da Nang. Equally, it is important to realize that contamination has likely been ongoing for decades. For example, during the U.S.-Viet Nam War, empty herbicide barrels were sold to residents of Da Nang (for use as water containers and for other domestic purposes), and these barrels are known to have contained residual dioxin contamination. Use of these barrels by residents resulted in widespread death of vegetation outside the Da Nang Airbase during the war. Wind-blown dioxin molecules attached to soil particles may also have traveled out of the immediate areas of the Airbase following loading of herbicide onto C-123 aircraft, from the former Storage Area, and from local spray application. Erosion due to rains also transported the contaminant to other areas of the Airbase or other water bodies outside the Airbase. Fish in lakes and wetlands on Da Nang Airbase and in perimeter waterbodies accumulated high levels of contamination in their bodies, and ultimately entered the human food chain through bioaccumulation.

Therefore, dioxin residues from Da Nang Airbase are not restricted to a finite location on the Airbase itself. Some dioxin-contaminated residues have a high potential to be transported out of the immediate area of release, and into the human food chain in Da Nang City. Results from this study strongly indicate that exposure of Da Nang residents to dioxins originating from the Airbase is ongoing.

It is logical to assume that people on Da Nang Airbase and in Da Nang City who handled the herbicides during the US-Viet Nam war introduced dioxin into their bodies. The main exposure routes would have been: direct physical contact with the herbicides themselves or contaminated soils; breathing spray mist and/or contaminated dust; and/or ingestion of contaminated food items from the Sen Lakes and from other waterbodies downstream of the dioxin hot spots on the Airbase. There could also have been other sources of contamination, such as from the discarded herbicide barrels. People who have been living on or near the Sen Lake ecosystem are likely the ones most at risk, although some people living distant from the Airbase could also have been exposed through consumption of foods produced on the Airbase, and marketed off the base.

Determining health affects related to Agent Orange dioxin exposure is a contentious issue, as evidenced by court cases launched by US, Korean, Australian, New Zealand, Canadian and Vietnamese veterans, and by concerns expressed by Vietnamese in general. The health impacts of dioxin exposure can take decades to manifest and are highly variable between individuals. Proving exposure, and eliminating other possible causes of cancers or other health effects from a person's diagnosis, remains a challenge.

It is clear that certain health effects are linked to Agent Orange exposure, and that the precautionary principle should apply when dealing with dioxin contamination in the environment and human food chain. This is particularly true at Da Nang Airbase, where concentrations of dioxins in excess of 300,000 ppt have been recorded in soils, and where levels greater than 3,000 ppt are known to occur in fish tissues taken from Sen Lake. Blood dioxin levels in people known to consume fish and other aquatic organisms from the Airbase were the highest dioxin level recorded in Viet Nam to date. Protection of the local residents known to work on Airbase lakes harvesting fish and other aquatic organisms is therefore paramount, and mitigation measures need to be adopted immediately at Da Nang Airbase.

More than 40 years have elapsed since Agent Orange was introduced to the environment of Viet Nam, and the resultant chemical contamination continues to affect a number of residents of Da Nang City to this day. Similar situations can be expected at other major Ranch Hand sites in Viet Nam, in particular, Bien Hoa. Time is of the essence to move forward with this issue, to protect Vietnamese living in the vicinity of such hot spots from further contamination and associated health impacts. These circumstances pose a significant public health threat, particularly when considering elevated dioxin levels in relation to global guidelines for protection of the environment and human health.

Proposed Mitigation Measures

Given the high levels of dioxin on Da Nang Airbase and in the human population recorded in this study, the following mitigation measures should be implemented immediately. (Note that physical remediation measures are being dealt with separately, and therefore the activities listed below focus on human health protection, livelihoods, and socio-economic considerations).

1. Further research, health studies, community education programs and exposure studies are required at Da Nang to verify the extent of the exposure, and to protect populations from further dioxin contamination. Similar studies should be conducted at other dioxin hot spots in Viet Nam, in particular Bien Hoa. This is consistent with the recommendations of ATSDR (1997) for areas where soil levels are ≥1,000 ppt TEQ.

2. Fishing activities and lotus harvesting on all natural waterbodies on Da Nang Airbase (Sen Lake, Lake B, and Lake C) should be terminated immediately. Fishponds on the West Airbase should no longer be used, and no further excavation of fishponds should be permitted on the Da Nang Airbase. Cultivation of vegetables should be prohibited on

the Airbase. Fish consumption in Xuan Lake and March 29 Lake (waterbodies adjacent to the Da Nang Airbase, and connected by drainage canals) should also be prohibited as a precautionary measure.

3. A secure, more permanent fence around the perimeter of the Airbase, particularly at the northern border, is required to prevent access. Some sections of the current brick fence are in disrepair, and therefore the general public can easily enter the Airbase.

4. Individuals sampled for blood and breast milk in this study should be provided with a report on the results of dioxin analyses performed (all donors requested that their results be reported to them). These consultations should be one-on-one, and be conducted by qualified medical professionals. Educational materials related to preventing further exposure to dioxins and furans should be provided (similar to those prepared by Hatfield/10-80 [2000]).

5. Alternate livelihoods need to be developed for those individuals who currently earn their living from harvesting fish, lotus and other aquatic organisms and vegetables from Da Nang Airbase. These need to be developed in consultation with Vietnamese authorities to ensure that individuals are able to maintain similar standards of living, and that their new livelihoods do not result in increased risk of exposure to dioxin or other hazardous chemicals on Da Nang Airbase. Consideration should be given to relocating individuals currently residing on or near the West Airbase fishponds, the Viet Nam Airlines residence northeast of the former Storage Area, and other areas near identified hot spots.

6. Detailed human health assessments should be considered in selected areas of Da Nang City, to assess the extent of past exposure to herbicides, and to ensure no long-term effects of exposure occurs. Individuals who presently work or worked in the past on the Airbase may be particularly vulnerable to dioxin contamination from direct or indirect exposure to the Mixing and Loading Area, Storage Area, and the Sen Lakes (A, B and possibly C). Military personnel who resided in barracks adjacent to the Mixing and Loading Area, and those who have harvested and/or consumed fish and lotus from Sen Lakes and West Airbase ponds should be considered for further investigations of possible health consequences of high exposure to dioxins at the Airbase. Further study of breast milk dioxin levels in the Da Nang population should be undertaken.

7. Engineered solutions for hot spots identified at the former Mixing and Loading Area and Storage area need to be refined and implemented as soon as possible to prevent further transport of contaminated soil and sediment into the general environment at Da Nang. Funding for undertaking these activities needs to be secured immediately.

8. Long-term monitoring of the environment and human population of Da Nang City is recommended, including Thanh Khe District and possibly other Districts adjacent to the Airbase. It will be important to annually monitor soil, sediment and food items for dioxin contamination; monitoring should also be conducted during and after physical remediation measures are implemented, for a period of at least 5-7 years after completion (at a minimum, until dioxins are not detected for a 3-year continuous period in environmental samples). Results of monitoring should be provided to local residents.

9. A systematic review should be undertaken at Bien Hoa, Phu Cat and other Ranch Hand sites in southern Viet Nam, where Agent Orange was used on site. In addition, a full investigation needs to be carried out of ARVN bases where Agent Orange spray planes and helicopters were loaded and serviced. TCDD measurements should be made in these areas if evidence suggests contamination. Soils, food chain elements and the human population should be assessed during such investigations. We suspect that, as seen at Da Nang Airbase and in A So (in the A Luoi District of Thua-Thien Hue Province), some former firebases, airbases and other former US and South Vietnamese military facilities may have significant levels of TCDD in their subsurface soils. Crash sites and load-jettison sites of Agent Orange spray planes should also be investigated.

10. Detailed impact mitigation plans for Da Nang Airbase must be implemented immediately, as well as in other areas where dioxin contamination exceeds international guidelines for protection of human health, including Bien Hoa, Phu Cat and other hot spots listed in Hatfield/10-80 (2005).

Proposed mitigation measures are summarized in the table below.

Summary of Proposed Mitigation Strategies to Reduce Exposure of the Human Population to Dioxin Contamination from Historical Use of Agent Orange on the Da Nang Airbase.

Location	Recommended Mitigation Strategy
Sen Lake, Lake B, Lake C, West Base Fishponds, Xuan Lake and March 29 Lake	Institute an immediate ban on fishing, aquaculture, and consumption of aquatic organisms harvested. Ban the harvest and consumption of lotus and other vegetables raised in soils/sediments from Da Nang Airbase aquatic ecosystems. Ban fishing in waterbodies on the perimeter of the Airbase (Xuan Lake and March 29 Lake).
Da Nang Airbase perimeter	Install a new 'secure', permanent fence around the perimeter of the Airbase to prevent public access.
Da Nang City	One-on-one consultations should be held with all individuals who provided blood/milk samples under the current study. Educational materials related to preventing further exposure to dioxins and furans should be provided (similar to those prepared by Hatfield/10-80 [2000]).
Sen Lake Workers, West Airbase Fishpond Workers, Airbase Workers potentially exposed to contaminated soils and sediments	Development of alternate livelihoods for individuals currently earning their living from harvesting fish, lotus and other aquatic organisms and vegetables from Da Nang Airbase. These strategies require development by Vietnamese authorities in a manner that is appropriate to local culture and regulations.
Long-term monitoring	Monitoring of dioxin contamination in soils, sediments, food and residents should be implemented on an annual basis for a period of 5-7 years, at a minimum, to verify effectiveness of mitigation measures. Further sampling and health studies may be required to verify the extent of contamination and exposure. Results of these studies should be used to develop and implement strategies to minimize or avoid exposure to dioxins. Detailed assessment and monitoring should be undertaken at Bien Hoa, Phu Cat, and other identified hot spots.
Mixing and Loading Area, Storage Area, Drainage Canals: Clean up and/or ecologically isolate Airbase hot spots	Appropriate engineered solutions require refining and rapid implementation to prevent further spread of dioxin-contaminated soils and sediments into Sen Lake, and, ultimately, into the human population of Da Nang. Funding for undertaking these activities, and removing dioxin residues from the local ecosystem, needs to be secured as soon as possible.

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Figure 1.1 Overview map of Da Nang City and Airbase Study Area, December 2006.

Figure 1.2 Land use changes in Da Nang City and Airbase between 1969 and 2002, Viet Nam.

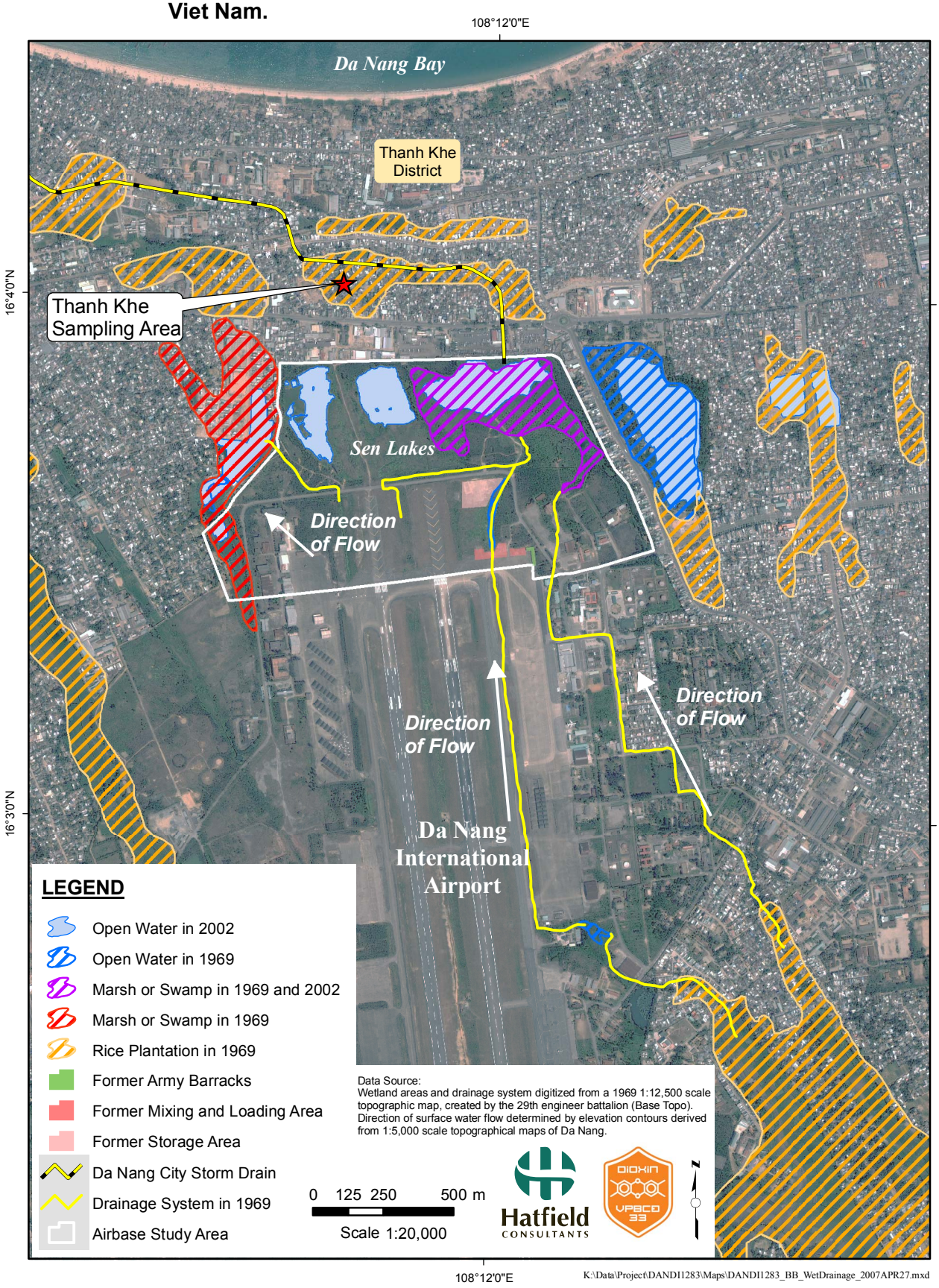
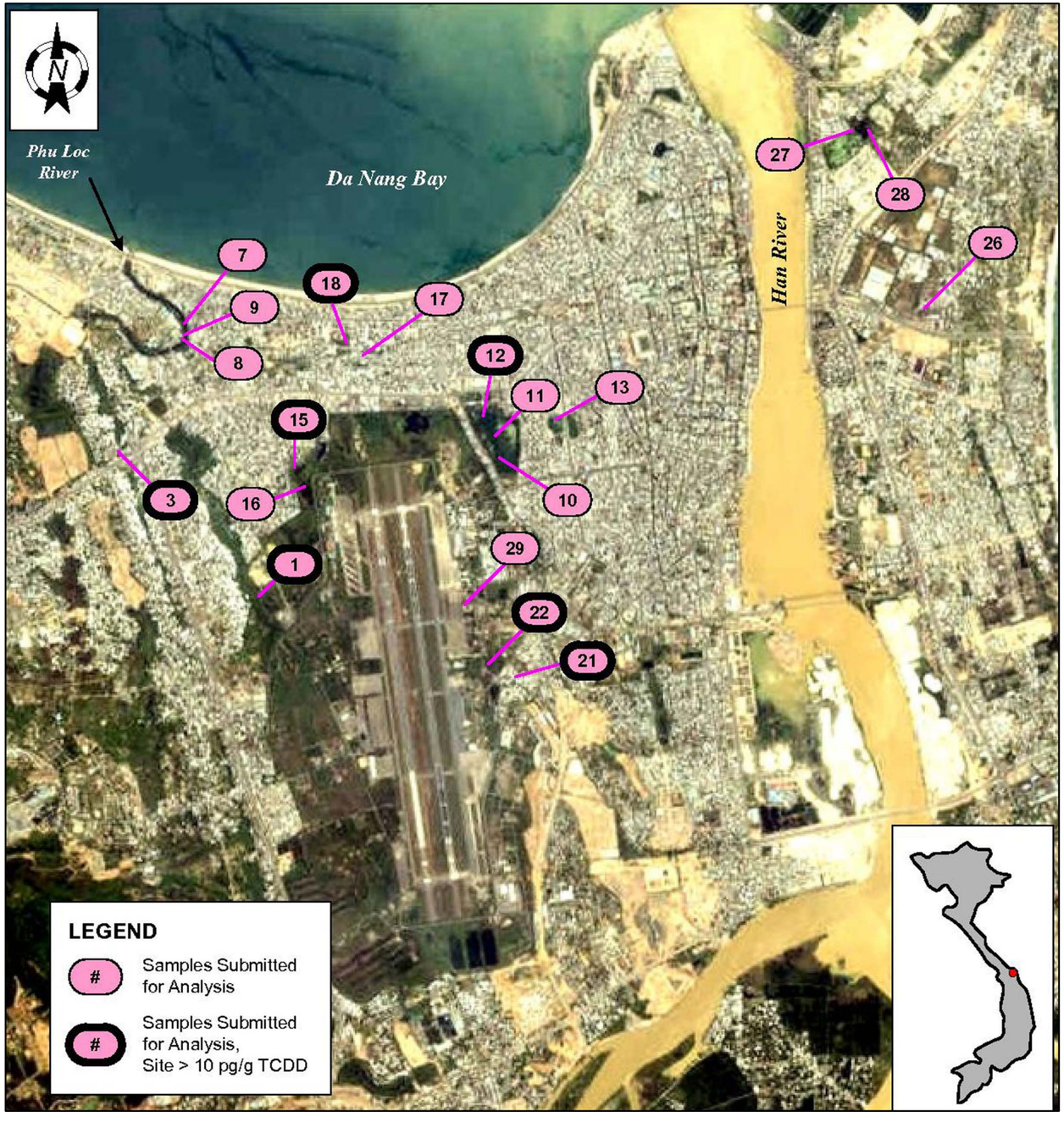


Figure 1.3 Location of soil/sediment sample collection sites, and 2,3,7,8-TCDD data (pg/g, dry weight), Total TEQ, and percent TCDD of Total TEQ, Da Nang, Viet Nam, 2005



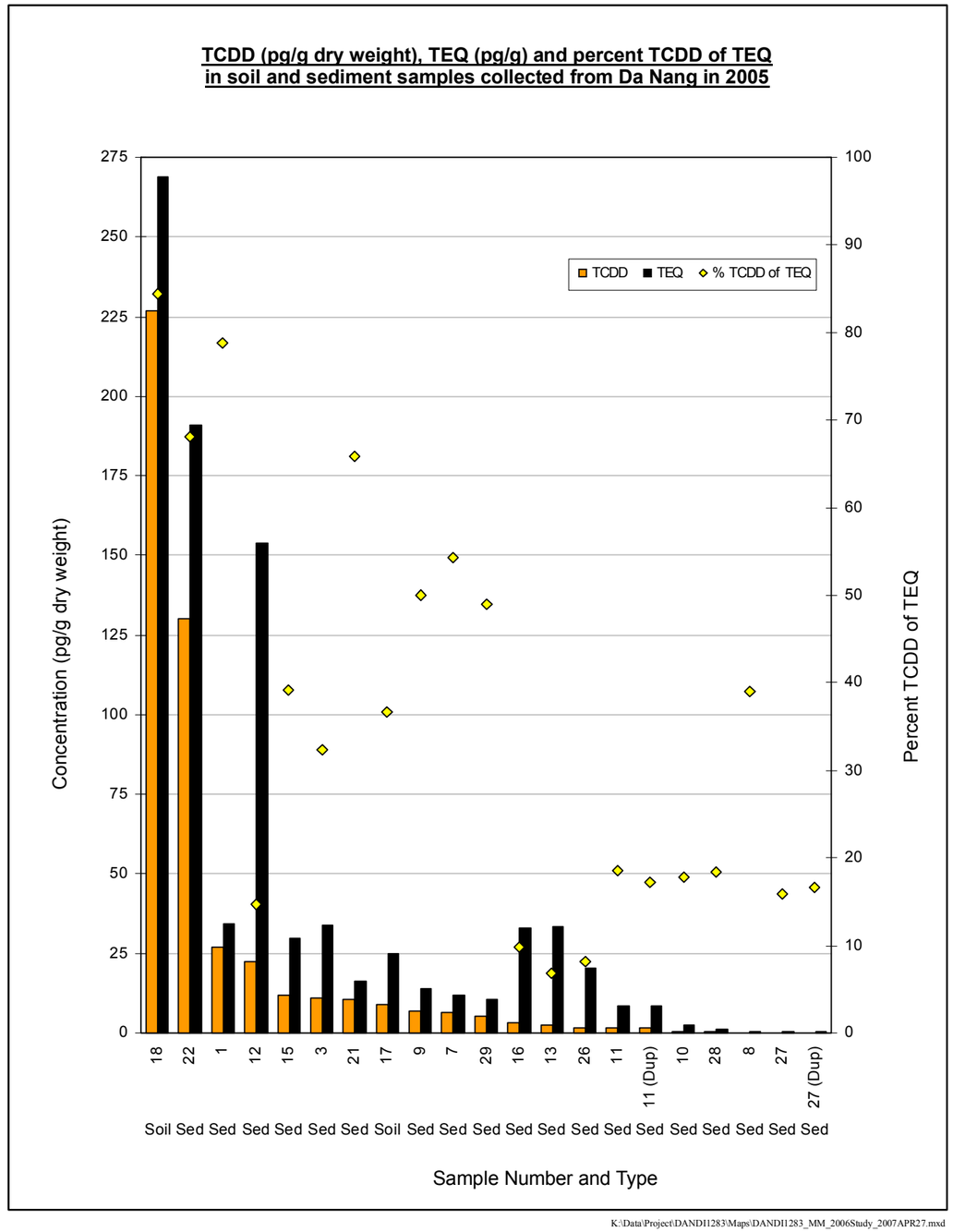


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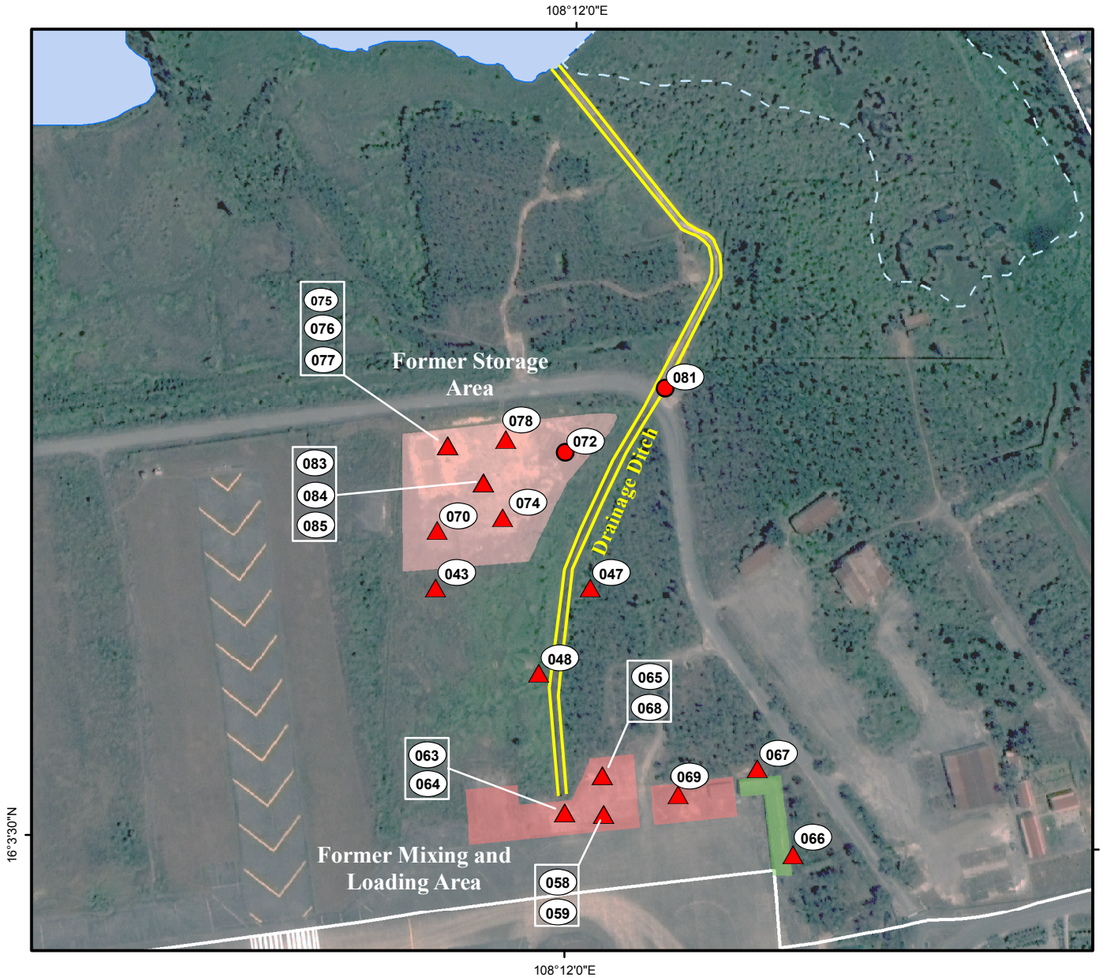
Figure 3.1 TCDD and TEQ (pg/g dry weight) in Da Nang Airbase soil and sediment samples, Viet Nam, December 2006.



LEGEND

- Open Water
- Wetted Extent
- Drainage Ditch
- Airport Study Area
- Former Army Barracks
- Former Mixing and Loading Area
- Former Storage Area

Soil & Sediment Sample Sites

- Sediment Sample
- Soil Sample

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0 100 200 m

Scale 1:4,000

Data Source: QuickBird (April 21, 2002)
Projection: UTM Zone 49 North
Datum: WGS 84

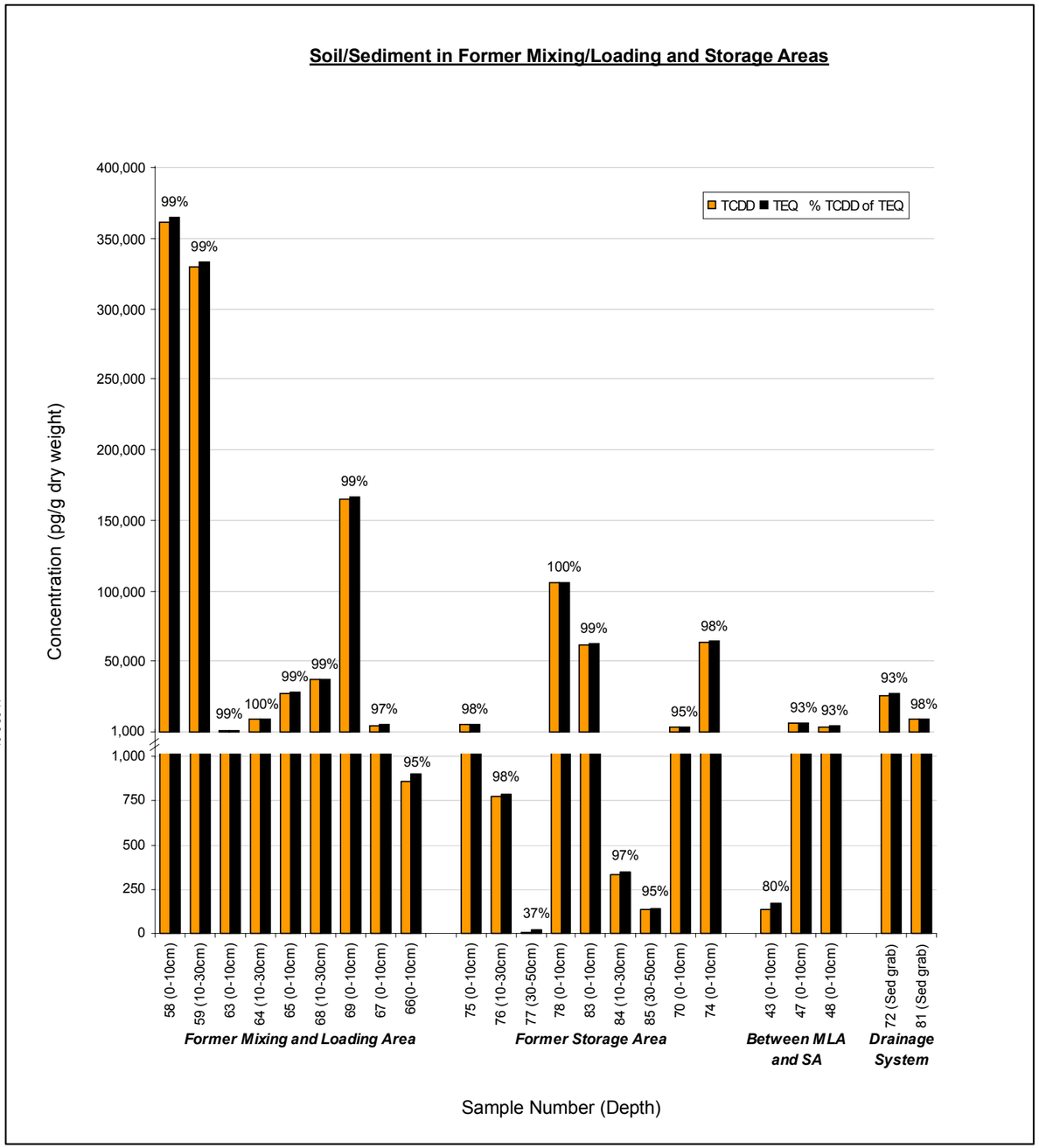

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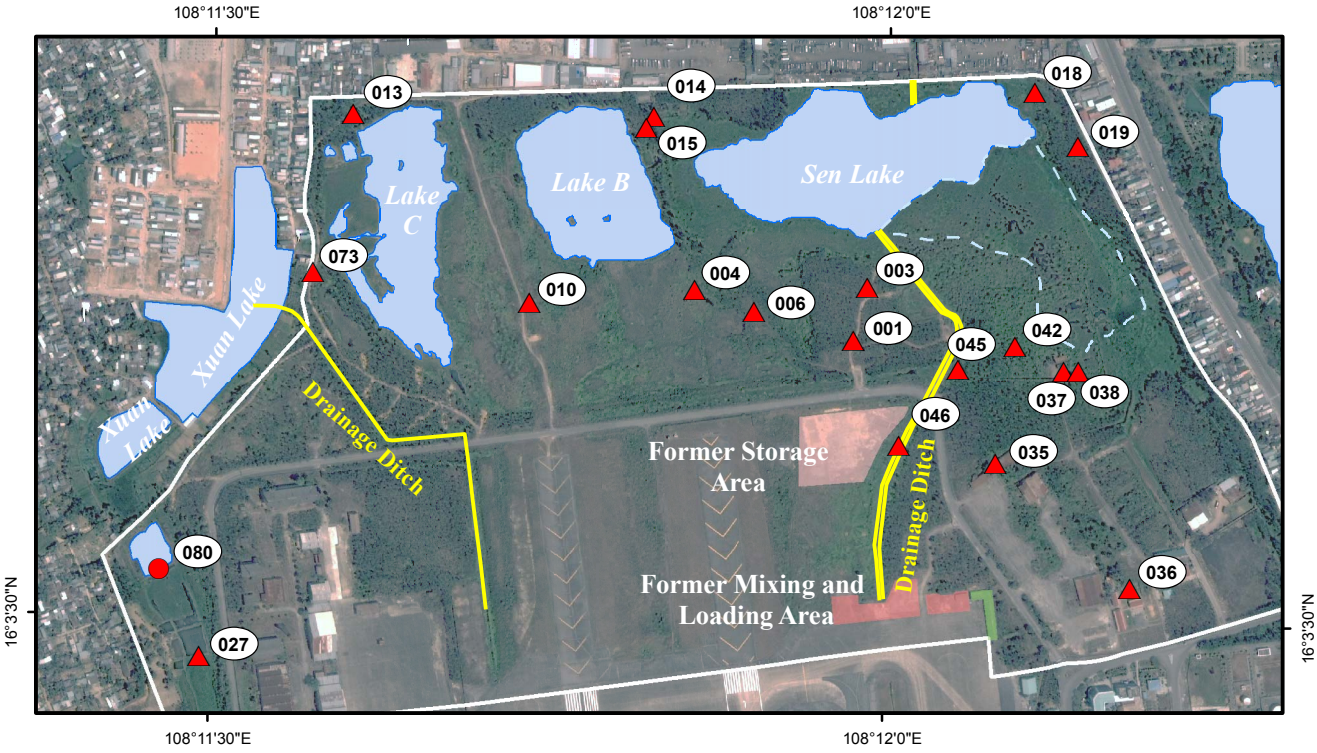
Figure 3.2 TCDD and TEQ (pg/g dry weight) in Da Nang Airbase perimeter soil and sediment samples, Viet Nam, December 2006.



LEGEND

Open Water
Wetted Extent

Soil & Sediment Sample Sites
Sediment Sample
Soil Sample

0 150 300 m
Scale 1:10,000

Data Source: QuickBird (April 21, 2002)
Projection: UTM Zone 49 North
Datum: WGS 84

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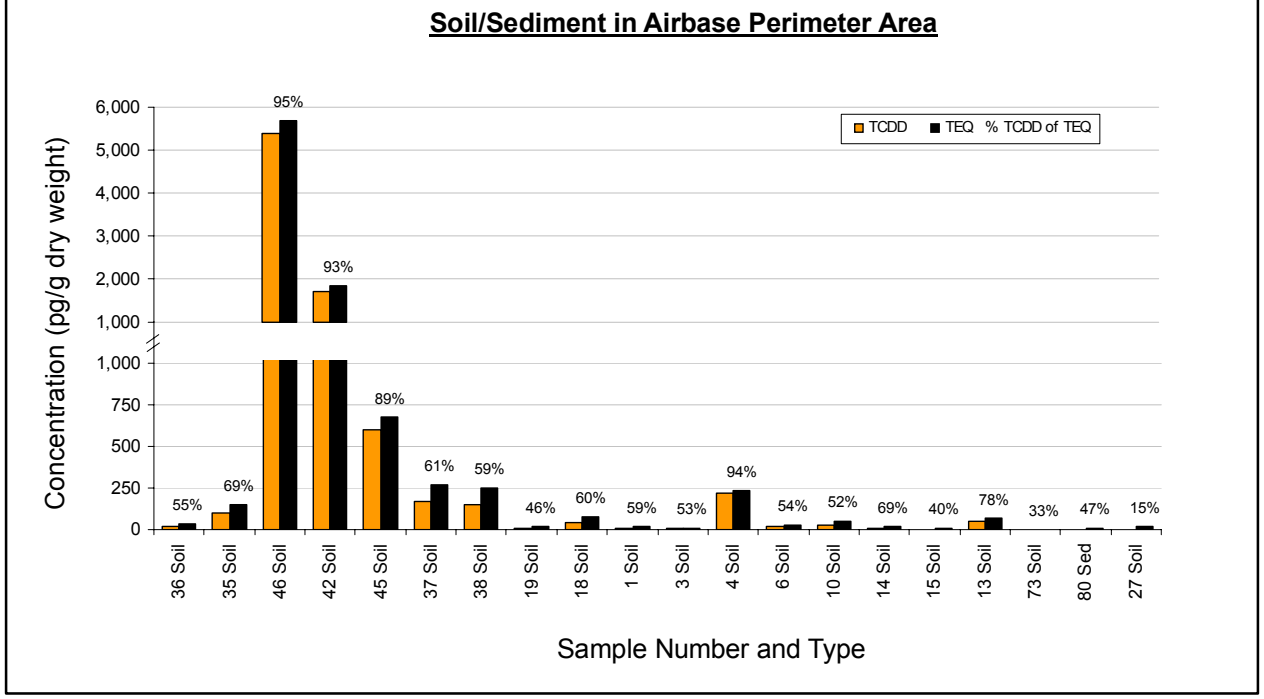

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Figure 3.3 TCDD and TEQ (pg/g dry weight) in Da Nang City soil and sediment samples, Viet Nam, December 2006.

LEGEND

Open-Water
Wetted Extent

Soil & Sediment Sample Sites
Sediment Sample
Soil Sample

0 200 400 m
Scale 1:13,000

Data Source: QuickBird (April 21, 2002)
Projection: UTM Zone 49 North
Datum: WGS 84

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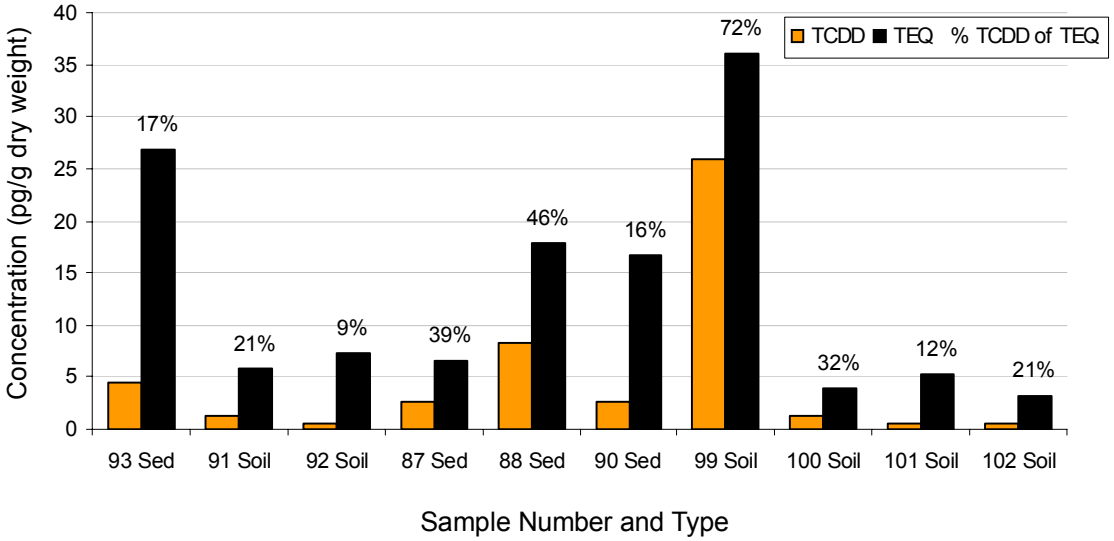

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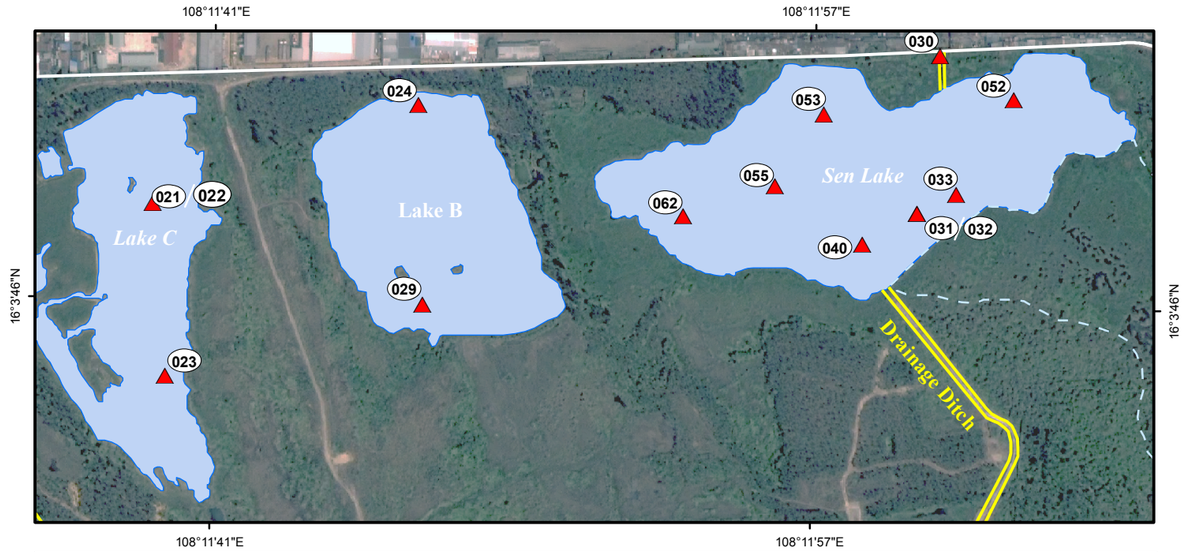
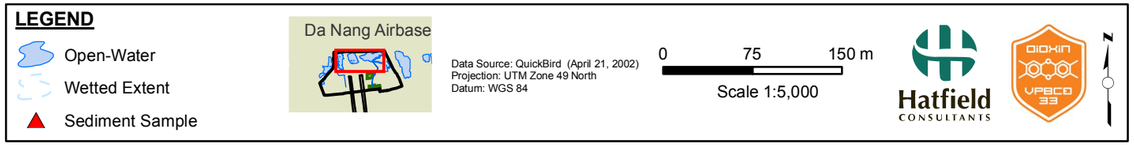
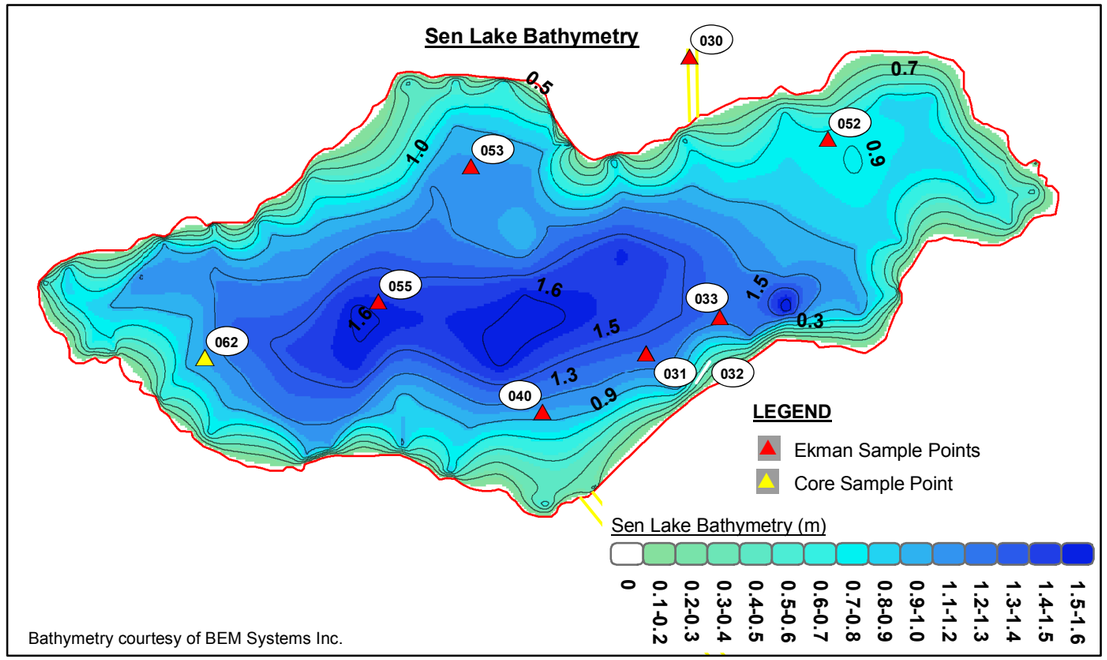
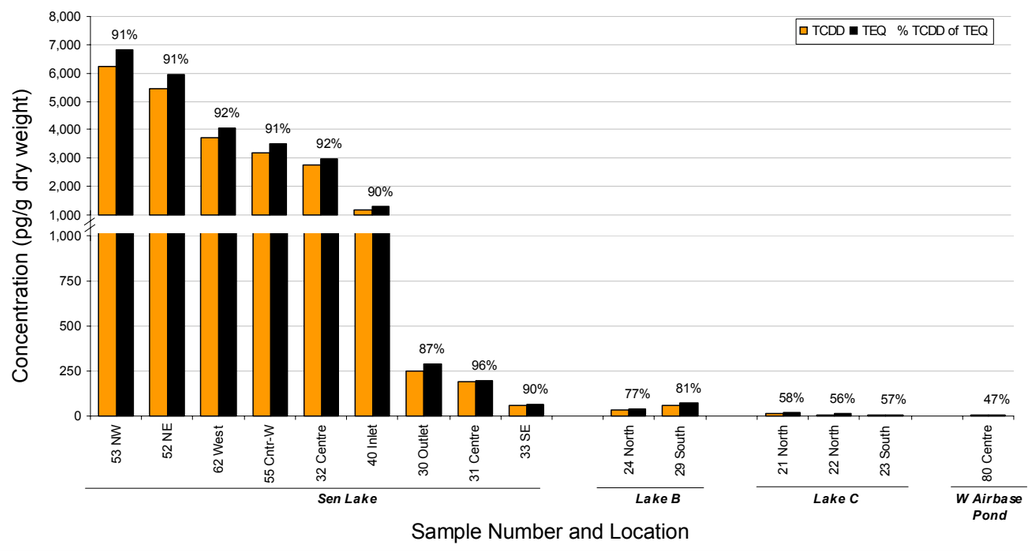
Figure 3.4 TCDD and TEQ (pg/g dry weight) in Sen Lake, Lake B and Lake C sediment samples, Viet Nam, December 2006.









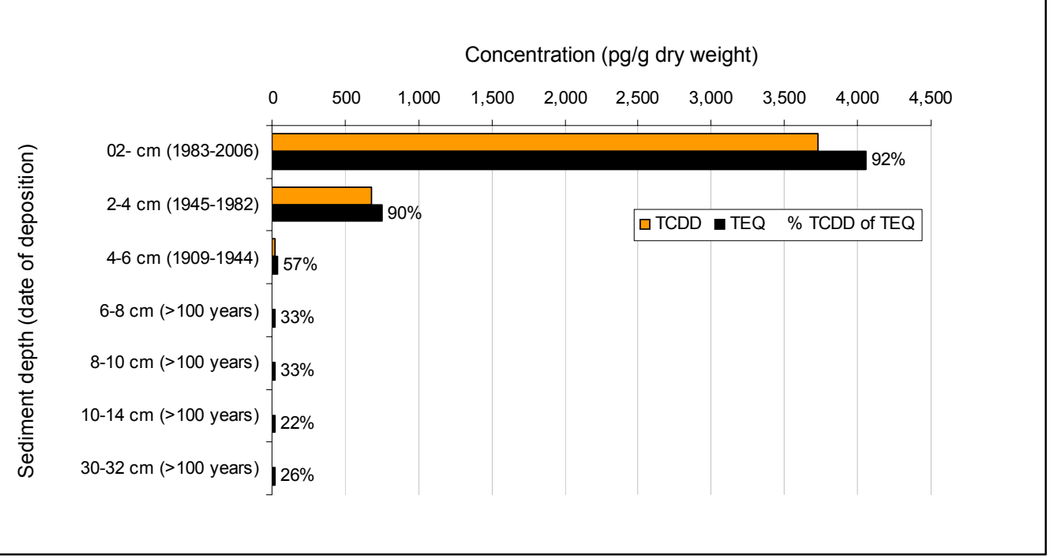


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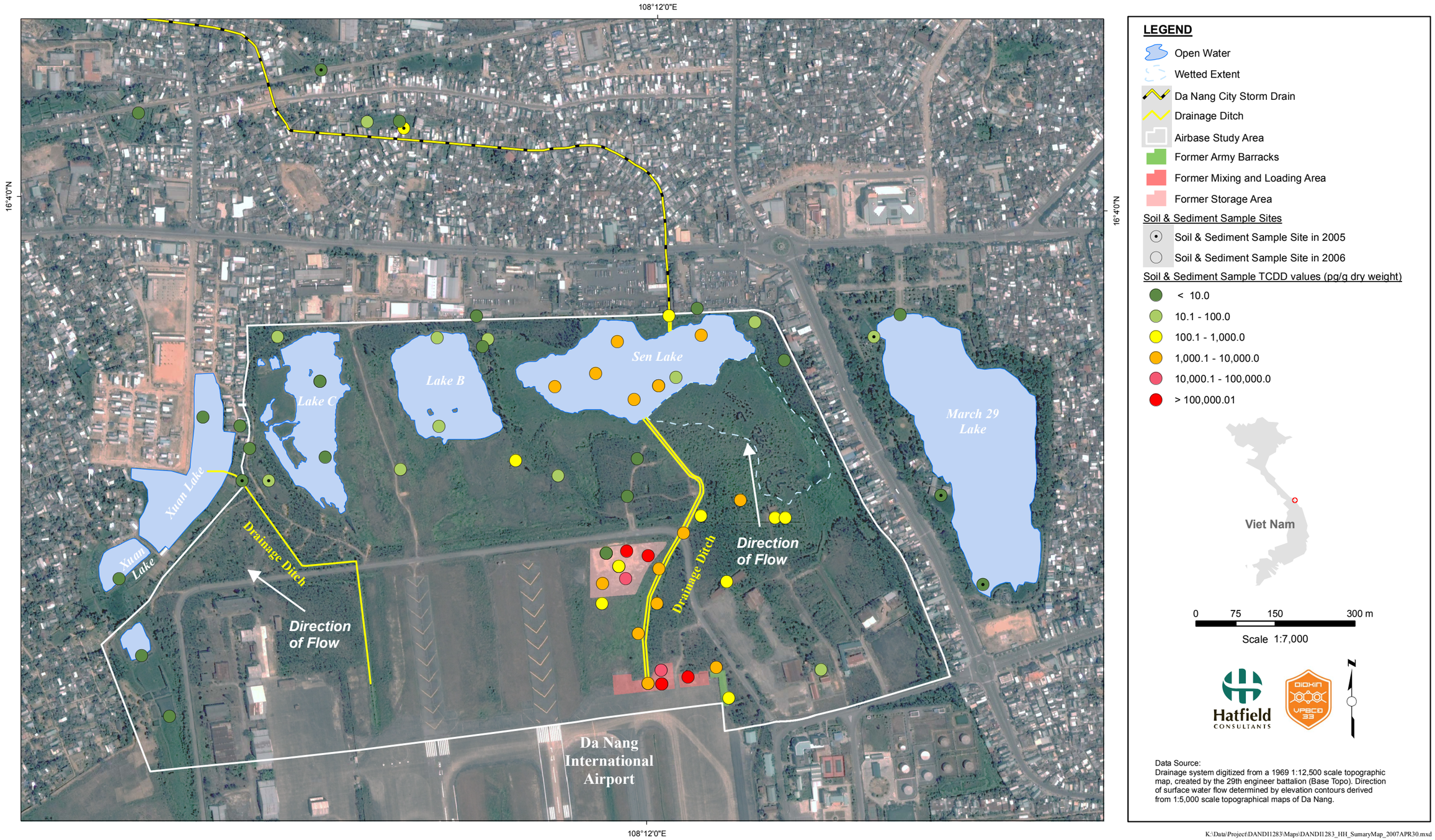
Figure 3.5 Summary of TCDD values (pg/g dry weight) for soil and sediment samples analyzed in Da Nang, Viet Nam, 2005 and 2006.



Data Source:
Drainage system digitized from a 1969 1:12,500 scale topographic map, created by the 29th engineer battalion (Base Topo). Direction of surface water flow determined by elevation contours derived from 1:5,000 scale topographical maps of Da Nang.

K:\Data\Project\DAND11283\Maps\DAND11283_HH_SumaryMap_2007APR30.mxd

Figure 3.6 Summary of interpolated TCDD values (pg/g dry weight) for the Da Nang Airbase study area, Viet Nam, 2006.

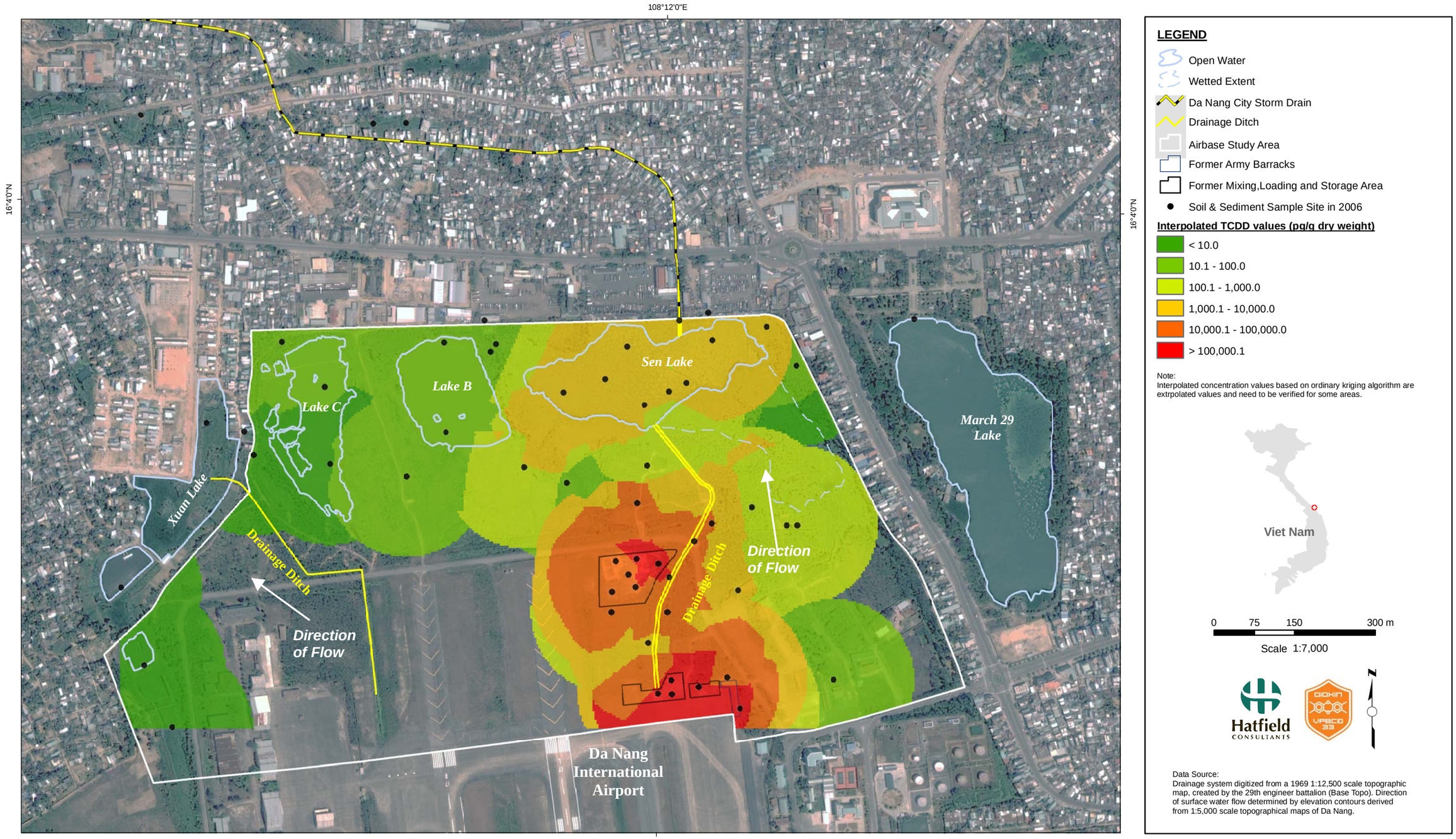
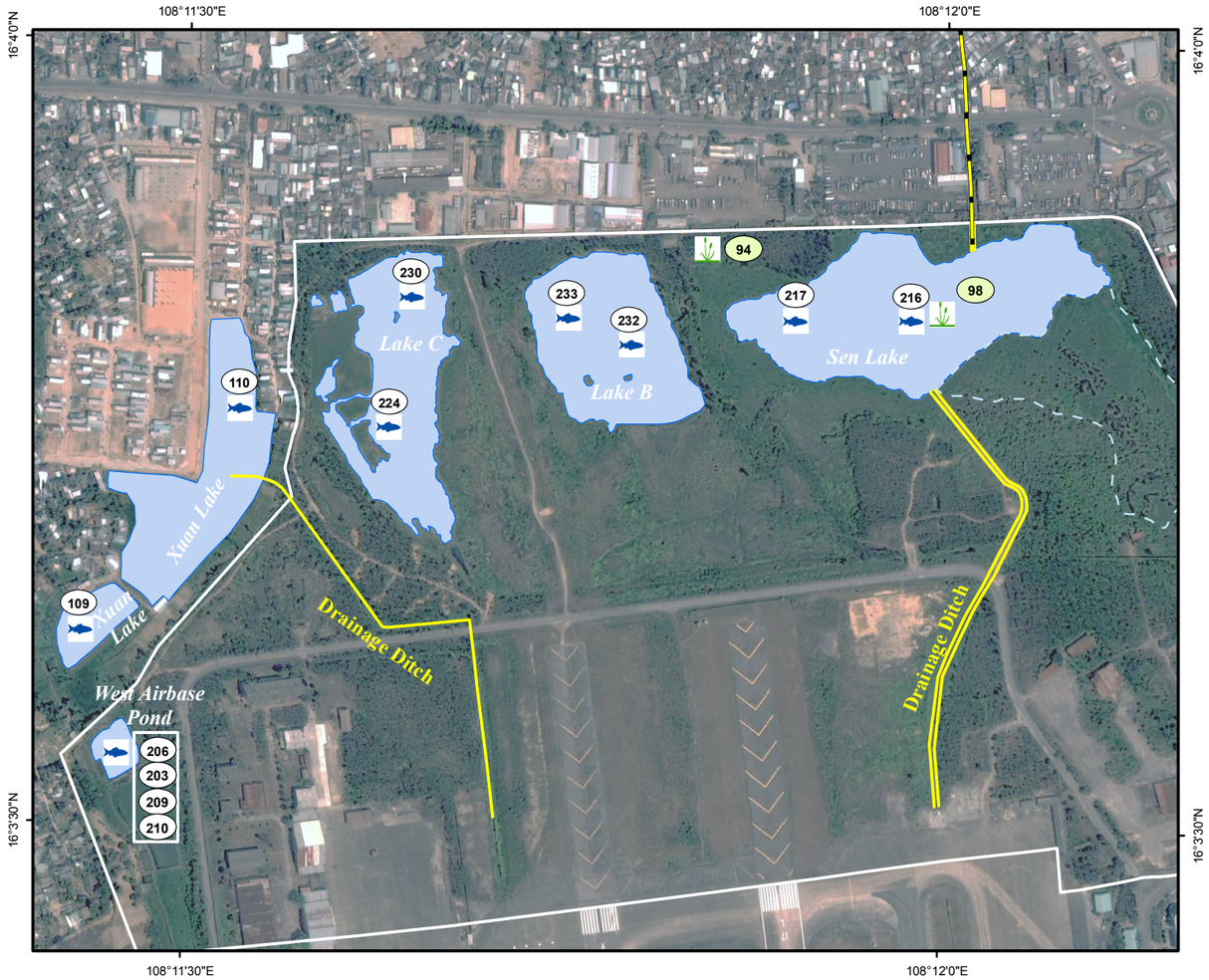


Figure 3.7 TCDD and TEQ (pg/g wet weight) in fish and vegetation samples, analyzed in Da Nang, Viet Nam, December 2006.



LEGEND

- Open Water
- Wetted Extent
- Da Nang City Storm Drain
- Drainage Ditch
- Airbase Study Area

Sample Sites

- Vegetation Sampling Site
- Fish Sampling Site

Hatfield CONSULTANTS

DIOXIN VPBCD 33

N

0 130 260 m

Scale 1:7,000

Data Source: QuickBird (April 21, 2002)
Projection: UTM Zone 49 North
Datum: WGS 84

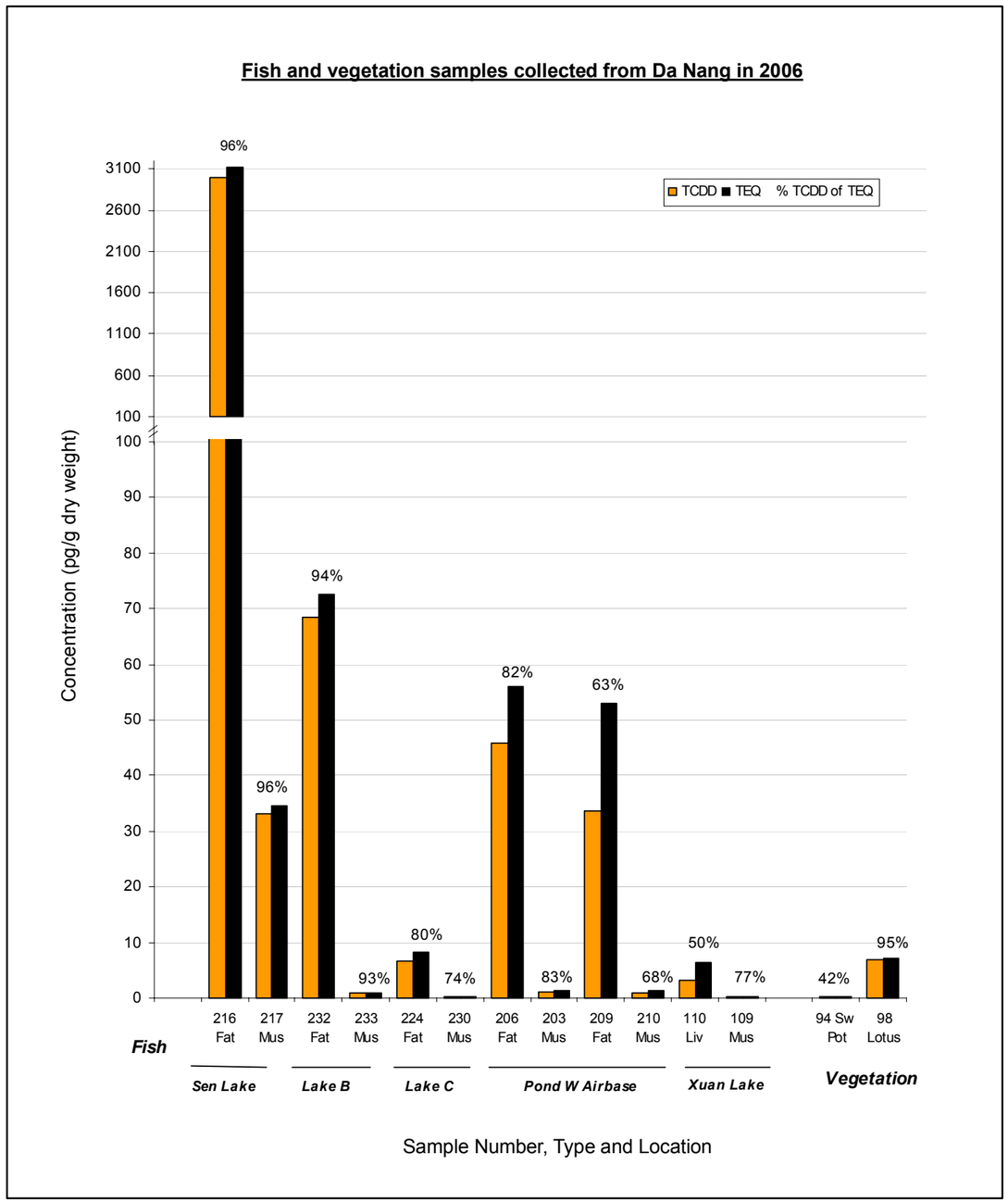


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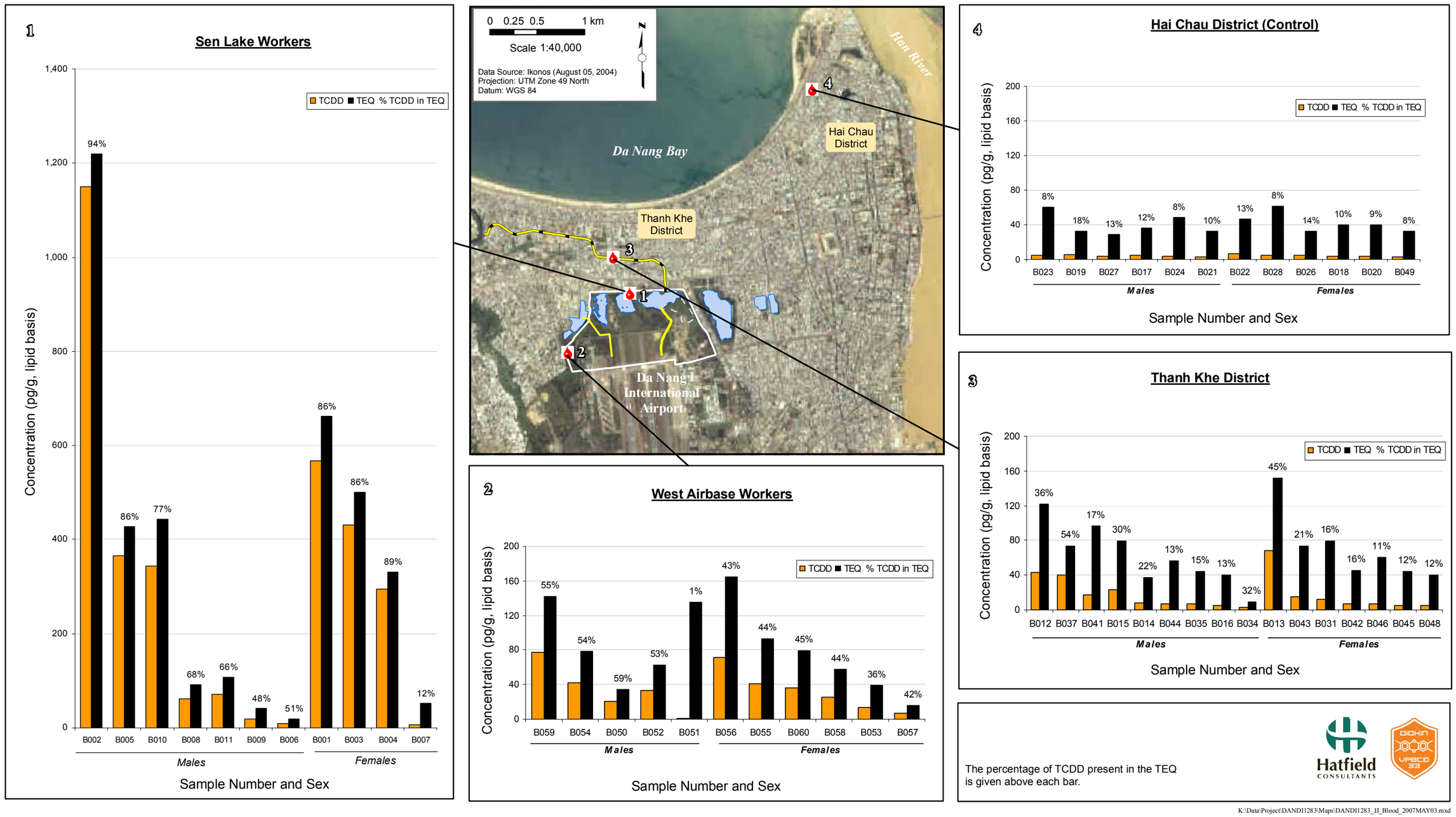
Figure 3.8 TCDD and Total TEQ (pg/g [ppt], lipid basis) for individual human blood, Da Nang, Viet Nam, December 2006.



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