Metals Concentrations in Soils Below Decks Made of CCA-Treated Wood

This report is an excerpt from the report titled:
New Lines of CCA-Treated Wood Research,
In-Service and Disposal Issues
Which was finalized on March 19, 2001

This excerpt was prepared in response to the overwhelming number of requests for the deck study that was included within Chapter 2 of the March 19, 2001 report.

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LIST OF ABBREVIATIONS AND ACRONYMS

AAS	Atomic Absorption Spectrometry
ACQ	Alkaline Copper Quat
AES	Atomic Emission Spectrometry
AFS	Atomic Fluorescence Spectrometry
APDC	Ammonium Pyrrolidine Dithiocarbamate
As	Arsenic
As(III)	Arsenite
As(V)	Arsenate
AsB	Arsenobetaine
AsC	Arsenocholine
AsH_3	Arsine
Ave.	Average
AWPA	American Wood Preservers Association
AWPI	American Wood Preservers' Institute
BDL	Below Detection Limit
CBA	Copper Boron Azole
CC	Copper Citrate
CCA	Chromated Copper Arsenate
CDDC	Copper Dimethyldithiocarbamate
C&D	Construction and Demolition
CHG	Chemical Hydride Generation
Cr	Chromium
Cr(III)	Trivalent Chromium
Cr(VI)	Hexavalent Chromium
Cu	Copper
CZE	Capillary Zone Electrophoresis
DDAC	Didecyldimethyl Ammonium Chloride
DDC	Dimethyldithiocarbamate
DEP	Department of Environmental Protection

LIST OF ABBREVIATIONS AND ACRONYMS (Con'd)

DI	De-ionized
DMAA	Dimethylarsinic Acid
EHG	Electrochemical Hydride Generation
EPA	Environmental Protection Agency
EP Tox	U.S. Environmental Agency Toxicity Test
FID	Flame Ionization Detector
GC	Gas Chromatography
GF	Graphite Furnace
GWCTL	Groundwater Cleanup Target Level
GWGC	Groundwater Guidance Concentrations
HCl	Hydrochloric Acid
HG	Hydride Generation
HPLC	High Performance Liquid Chromatography
IC	Ion Chromatography
ICP	Inductively Coupled Plasma
LD_{50}	Lethal Dose Where 50% of the Population Dies
LMAC	Listed Metals Advisory Council
MEP	Multiple Extraction Procedure
MIBK	Methyl Isobutyl Ketone
MMAA	Monomethylarsonic Acid
MPCA	Minnesota Pollution Control Agency
MS	Mass Spectrometry
MSW	Municipal Solid Waste
MW	Molecular Weight
$NaBH_4$	Sodium tetraborohydride
NM	Not Measured
pcf	Pounds per Cubic Foot
PTFE	Polytetrafluoroethylene
RCRA	Resource Conservation and Recovery Act
SCTL	Soil Cleanup Target Level
SDDC	Sodium Dimethyldithiocarbamate or Silver Diethyldithiocarbamate

LIST OF ABBREVIATIONS AND ACRONYMS (Con'd)

SFPA	Southern Forest Products Association
SPLP	Synthetic Precipitation Leaching Procedure
SSL	Soil Screening Level
Std. dev.	Standard Deviation
TAG	Technical Advisory Group
TC	Toxicity Characteristic
TCLP	Toxicity Characteristic Leaching Procedure
THF	Tetrahydrofuran
TSD	Thermionic Specific Detector
TMAO	Trimethylarsine Oxide
UF	University of Florida
UM	University of Miami
USEPA	U.S. Environmental Protection Agency
UV	Ultra Violet
UV/Vis	Ultra Violet – Visible Light Region
WET	Waste Extraction Test

UNITS OF MEASURE

%	parts per hundred
Φg	microgram
Φg/l	micrograms per liter
Φl	microliter
Φm	micron (1 millionth of a meter)
atm	atmospheres
^{o}C	degrees Celcius
Eh	measure of electron activity
ft^3	cubic feet
g	grams
lb/ft^3	pounds per cubic foot
lbs.	pounds
mg	milligrams
mg/kg	milligrams of chemical per kilogram of wood or soil
mg/kg/day	milligrams of chemical per kilogram of body weight per day
mg/l	milligrams per liter
ml	milliliter
mm	millimeter
ng	nanogram
nl	nanoliter
nm	nanometer
M	Molar concentration units
mM	Millimolar
N	normality (equivalents per liter)
pcf	pounds of chemical per cubic foot of wood
pH	measure of the hydrogen ion activity
ppb	parts per billion
ppm	parts per million
ppt	parts per trillion
V	Volts or Volume

ABSTRACT

This research was initiated in response to a series of perceived data gaps that were identified during the deliberations for a potential ban on chromated copper arsenate (CCA) during the 1999 hearings held in Minnesota. This project was designed to answer some of these data gaps through a set of three short-term studies and by conducting a set of literature reviews in areas that should be evaluated over a longer term. The three short-term projects focused on a) evaluating the impacts of CCA-treated decks on the soils located below them, b) developing an inventory of CCA-treated products within Florida, and c) evaluating leaching characteristics of unburned CCA-treated wood and construction and demolition (C&D) debris wood mulch. The literature reviews focused on identifying laboratory methods for arsenic speciation analysis, chromium speciation analysis, and for analysis of leachates from alternative-chemical treated wood products.

The impacts of CCA-treated decks on soils were evaluated by collecting surface soil samples and cores from below nine decks located within three cities in Florida. Results showed that the average arsenic concentration in the “below deck” soils was 28 mg/kg whereas the average arsenic concentration of the control samples was 1.5 mg/kg. For chromium and copper, the average of the “below deck” soils was 34 and 40 mg/kg, respectively, whereas the average of the controls was less than 10 mg/kg for both metals. The depth of the impact was observed to a depth of 3 inches for chromium and copper and to a depth of 8 inches for arsenic. The arsenic concentration in “below deck” soils exceeded Florida’s residential Soil Clean-up Target Level of 0.8 mg/kg for all samples collected below confirmed CCA-treated decks. The volume of the impact for all CCA-treated decks located throughout Florida is estimated at 25,000 acres or 60 million tons of soil.

The amount of arsenic associated with CCA-treated wood currently in service in Florida is estimated at 26,800 tons. This quantity is enough to increase the arsenic concentration of a volume of water equal to 650 times the size of Lake Okeechobee by 10 ug/L, which is the proposed federal drinking water limit. Given the potential for significant environmental impacts, efforts should focus on recovering as much of this arsenic as possible. Approximately 1500 tons or 5% of the total amount of arsenic in products currently in service can be recovered from utility poles. Approximately 4,100 tons or 15% of the arsenic are associated with marine and fresh water applications. Recapturing the arsenic from these use sectors will require coordination with major Florida utilities and marine and fresh water contractors.

Results of standardized leaching tests show that new CCA-treated wood leaches enough arsenic to routinely fail the U.S. EPA’s TCLP. If a regulatory exemption were not in place, discarded CCA-treated wood would frequently require management as a hazardous waste. Leaching of arsenic occurs at similar levels in tests using synthetic rainwater indicating that leaching is a concern in environments besides landfills. If new CCA-treated wood were managed with the same restrictions as other types of wastes, the disposal in unlined landfills would not be allowed. This also corroborates the fact that metals leach from CCA-treated wood decks (and other similar structures) to the underlying soil. The leaching of all three metals increases as the size of the wood decreases. Previous experience showing that CCA-treated wood occurs in recycled wood from C&D debris was again demonstrated in leaching tests. Nearly all of the C&D debris wood mulch samples tested leached arsenic at concentrations greater than drinking water standards, indicating that these mulch samples should not be land

applied.

As a result of the literature review, analytical methods have been identified for the analysis of chromium species, arsenic species, and for the analysis of the organic co-biocides associated with alternative waterborne preservatives. These methods will be implemented in future studies focusing on characterizing the leachates from CCA-treated wood and alternative-chemical treated wood.

The overall results of this study indicate that CCA-treated wood does impact the environment during its service life by increasing the metal concentrations of soil. The potential impacts of these releases on human and ecological health, however, are open to interpretation. This study also emphasizes the need to better manage CCA-treated wood upon disposal. Due to the large quantity of metals and the leaching characteristics of CCA-treated wood, as much of the arsenic should be recovered prior to disposal as mulch or in unlined landfills. Future research should focus on identifying cost effective means of ultimate disposal for CCA-treated wood waste.

CHAPTER I

MOTIVATION, OBJECTIVES, AND BACKGROUND

I.1 MOTIVATION

During August 18 and 19, 1999, four individuals involved in Florida's CCA-treated wood research (William Hinkley, John Schert, Helena Solo-Gabriele, and Timothy Townsend) were invited by the Minnesota Pollution Control Agency (MPCA) located in St. Paul, Minnesota, to participate in the deliberations of Minnesota's Listed Metals Advisory Council (LMAC). The research team was invited for the purpose of sharing their research on the disposal aspects of CCA-treated wood. Minnesota's LMAC has the authority to make recommendations to MPCA's Commissioner concerning the following four listed metals: cadmium, lead, mercury, and hexavalent chromium. The Council specifically evaluates whether or not products containing these metals should be banned from the State. Since the CCA chemical (and not necessarily CCA-treated wood[1]) contains hexavalent chromium, the focus of deliberations was on the use and sale of the CCA <u>chemical</u>. Although Minnesota's Listed Advisory Council did not vote for a ban on the CCA chemical, the Council did recognize the significant disposal issues associated with CCA-treated wood and therefore concluded that disposal of CCA-treated wood requires "prompt, thorough consideration, and possible action to protect the environment from the deposition of large volumes of arsenic…... We do not have the authority to recommend banning CCA-treated wood because the treated wood is not a specified product.... Therefore, we strongly urge that treated wood be disposed of by methods which safeguard the environment and our citizens." (Listed Metals Advisory Council, personal communication to the Commissioner of MPCA 2000)

During the deliberations, many issues were highlighted concerning CCA-treated wood that were not the focus of earlier research conducted by the Florida CCA-treated wood research team. Specific issues discussed during the meeting included: 1) the impacts of CCA-treated wood during its service life, 2) the amounts of CCA-treated wood used by major industries, 3) the availability of alternative chemicals and their potential impacts on the environment and, 4) chromium and arsenic speciation of the leachates from CCA-treated wood. Many deliberations were marred by lack of scientific data. The Florida research team, recognizing the gap in information, thereby embarked to address these issues through a request for supplemental funds to the "year 3" study. The request was approved in September 1999 by the Florida Center for Solid and Hazardous Waste. This report focuses solely on the research funded through the supplemental funds.

I.2 OBJECTIVES

The overall goal of this study was to address some of the issues that were debated during the Minnesota hearings through a set of three short-term studies and by conducting a set of literature reviews in areas that will be evaluated over a longer term. Specifically, the objectives of the short-term studies were to: a) document metals concentrations in soils located in the

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[1] The chromium in CCA-treated wood is added in its hexavalent form. After a waiting period (which is temperature dependent) the chromium is converted to its trivalent form and thereby becomes "fixed" into the wood.

vicinity of decks made of CCA-treated wood, b) identify the quantity of CCA-treated wood used by major industries, and c) conduct TCLP and SPLP tests on unburned CCA-treated wood and construction and demolition (C&D) debris mulch.

Currently there is huge reservoir of CCA-treated wood in use within Florida today (540 million cubic feet, estimated) and a large fraction of this wood, roughly 36%, is associated with outdoor decks (SFPA, personal communication). Given this large reservoir, it was of interest to determine the impacts of CCA treated decks on the surrounding environment. The purpose of the first short-term study was to evaluate whether or not enough metals leach from CCA-treated decks to increase the concentrations of the soil above background levels. In this particular study soils below decks were sampled and analyzed for arsenic, chromium, and copper concentrations. These results were then compared to background concentrations for the site and to Florida regulatory guidelines.

One of the goals of disposal-end management is to recapture as much of the CCA chemical before it is mixed with other components of the solid waste stream. Knowledge concerning where the current CCA reservoirs reside will help to prioritize which products to recapture so that the treated wood is not commingled with other solid wastes. The purpose of the second short-term project was to determine the distribution of the arsenic associated with CCA-treated wood within different use sectors. In particular statistics are provided for U.S. production (by product type) and two use sectors in Florida (utility poles and fresh/marine water applications). Statistics were used to estimate the total amount of arsenic associated with CCA-treated wood currently in service.

The last short-term project was intended to complete the analysis of CCA-treated wood and C&D debris mulch using standardized leaching tests. All of the earlier leaching tests conducted through the UM/UF research program utilized CCA-treated wood ash. Given that the wood waste market is now shifting towards the production of mulch it is likely that CCA-treated wood is inadvertently mixed with this disposal stream. Therefore in order to assess this disposal route, it is important to evaluate the leaching characteristics of the unburned CCA-treated wood and C&D debris mulch. In this study, CCA-treated wood samples were subjected to a set of 5 different leaching tests. Twenty samples of C&D debris mulch were evaluated using the standard SPLP. Results were then compared to regulatory guidelines.

It was envisioned at the outset of the “year 3 supplemental” study that a long-term research plan could be established for evaluating chromium and arsenic speciation in leachates from CCA-treated wood and that non-arsenical treated wood products should also be included within a leaching study. A literature review to evaluate the most suitable analytical methods for arsenic and chromium speciation as well as alternative wood treatment preservatives was therefore incorporated as part of the “year 3 supplemental” study.

The organization of this report is consistent with the “year 3 supplemental” objectives and is

- Metals Concentrations in Soils Below Decks Made of CCA-Treated Wood (Chapter II)
- Inventory of CCA-Treated Wood in Florida (Chapter III)
- Leaching of Chromium, Copper, and Arsenic from New CCA-Treated Wood and

C&D Debris Mulch (Chapter IV)

- Literature Reviews for Future Research (Chapter V)
  - Analytical Methods for Chromium Speciation (Section V.1)
  - Analytical Methods for Arsenic Speciation (Section V.2)
  - Laboratory Methods for the Analysis of Alternative Chemicals (Section V.3)

Given the diverse nature of the research tasks, conclusions corresponding to each task are provided within the each chapter rather than having one concluding chapter for all the work presented. The report ends with a chapter which provides a summary of the primary conclusions and recommendations for future work (Chapter VI) .

I.3 BACKGROUND

Wood is treated with chemical preservatives so it can resist biological degradation. Chromated copper arsenate (CCA) treated wood contains copper which serves as a fungicide, arsenic which serves as an insecticide, and chromium which is used to “fix” the copper and arsenic into the wood. CCA-treated wood is the most widely used type of treated wood (AWPI 1999) representing about 80% of the wood preservation market today. Although the production of CCA-treated wood was commercialized in the 1960s, it was not until the 1980s that CCA-treated wood dominated the market due to large increases in the demand for the product. Given that CCA-treated wood generally maintains its structural integrity for 20 to 40 years, disposal quantities of CCA-treated wood will increase significantly in the near future (Solo-Gabriele and Townsend 1999).

There are three types of CCA-treated wood: Type A, Type B, and Type C. The most common type is CCA-Type C, which is composed of 34.0% As_2O_5, 47.5% CrO_3, and 18.5% CuO, by weight. The amount of CCA utilized to treat the wood or “retention level” depends upon the particular application for the wood product. Typical retention levels utilized by the industry are 0.25 pcf, 0.40 pcf, 0.60 pcf, 0.8 pcf, and 2.50 pcf. (Note: pcf = pounds of chemical per cubic foot of wood). Low retention values (0.25 pcf) are permissible for plywood, lumber, and timbers if the wood is used for above ground applications. Higher retention values are required for load bearing wood components such as pilings, structural poles, and columns. The highest retention levels (0.8 and 2.5 pcf) are required for wood components that are used for foundations or saltwater applications.

CHAPTER II

METALS CONCENTRATIONS IN SOILS BELOW DECKS MADE OF CCA-TREATED WOOD

CHAPTER II, METALS CONCENTRATIONS IN SOILS BELOW DECKS MADE OF CCA-TREATED WOOD

This chapter begins by describing the motivation and objectives of the study (section II.1) and the methods used for soil sampling (section II.2) and soil analysis (section II.3). Results are separated into three sections. The first of these sections (section II.4) focuses on the metals concentrations of the surface soil samples collected through this study. Section II.5 focuses on the results of physical measurements performed on the soil samples and section II.6 focuses on the results from the soil core analysis. The chapter closes with a summary and conclusion (section II.7).

II.1 MOTIVATION AND OBJECTIVES

Earlier studies have found elevated levels of metals in the vicinity of CCA-treated wood structures. Arsenic concentrations observed in soils below decks in Connecticut, for example, averaged 76 mg/kg (3 to 350 mg/kg range) whereas the background soil values averaged 3.7 mg/kg (1.3 to 8.3 mg/kg range) (Stilwell and Gorney 1997). For chromium, the average concentration below the decks was 43 mg/kg whereas background samples averaged 20 mg/kg; and copper concentrations of 75 mg/kg were reported on average below the decks, whereas background concentrations were 17 mg/kg. In Canada, elevated metals concentrations were observed in the immediate vicinity of CCA-treated utility poles. Arsenic concentrations as high as 550 mg/kg were observed in the soil in the immediate vicinity of the poles; chromium concentrations were as high as 200 mg/kg whereas copper was as high as 1000 mg/kg. In general metal concentrations were higher for older poles and concentrations generally dropped-off considerably within 4 inches from the pole (Cooper 1997). Among the three metals evaluated in these studies, arsenic appears to exceed risk-based regulatory guidelines by the largest margin. For example, the U.S. EPA soil screening level (SSL) is 0.4 mg/kg for arsenic (direct exposure) whereas Florida's soil clean-up target levels for arsenic is 0.8 mg/kg for residential areas and 3.7 mg/kg for industrial areas. The U.S. soil screening guidance concentration for chromium is 390 mg/kg and there is no SSL for copper. Florida's clean-up target levels for chromium (as chromium VI) and copper are 210 and 110 mg/kg respectively for residential areas and 420 and 76,000 mg/kg for industrial areas. The objective of the work summarized in this chapter was to evaluate the impacts of CCA-treated wood decks on surrounding soils located within the State of Florida. Soils below decks were sampled and compared to background concentrations to determine the additional load of metals due to the presence of CCA-treated decks. To provide a point of reference, the concentration of metals in the soils below the decks were also compared to Florida's clean-up target levels. All three metals (chromium, copper, and arsenic) were evaluated through this study. However, a particular focus was provided on the arsenic results.

II.2 METHODS OF SOIL SAMPLING

Nine structures were sampled throughout Florida to evaluate the impacts of CCA-treated decks on the underlying soil. Three decks were sampled in Gainesville on November 18, 1999, three in Miami on November 27, 1999 and three in Tallahassee on December 6, 1999. The sites were revisited during June and July 2000 in order to collect additional soil control samples and to confirm that the decks were indeed CCA treated.

Immediately prior to sample collection, a grid was set up below the decks using rope. This provided a uniform distribution of sampling points below each deck. At each site, eight surface samples were taken with the exception of the first site (site BR, the 34th Street footbridge in Gainesville) where nine surface samples were collected. A diagram of the grid along with the location where each sample was collected is provided in appendix A. The surface samples were collected within the top one inch of the ground. After thorough mixing, each sample was split; one for the University of Florida for metals analysis and the other for archiving at the University of Miami. Extra surface soil was collected in a plastic bag at each site in order to analyze the soil for moisture content, volatile solids, and grain size distribution. During the first visit to each deck two control samples (a.k.a. background samples) were also collected at each site, again with the exception of the first site where five controls were collected. Additional controls were collected during the second visit to each deck so that the total number of controls equaled the number of samples collected below the corresponding deck. In other words, after the second sampling effort the total number of controls collected for all the decks was 8 (2 from the first trip and 6 from the second) except for site BR where a total of 9 controls (5 from the first trip and 4 from the second) were collected. The sites for the controls were determined by their location with respect to the grid. Locations upstream of the grid were preferred, ranging from 50-100 feet away. In addition, at each site, a soil core sample of approximately seven inches in depth was collected in order to determine the vertical distribution of Cr, Cu, and As. Each core was taken approximately in the center of the grid that was set up below each structure. The samples were collected using a 1 and 1/8” diameter unslotted stainless steel probe fitted with a plastic liner (Forestry Suppliers, Inc., Jackson, MS). A different plastic liner was utilized for each site. After collection, all sample containers were placed in plastic bags and put in a cooler with ice for transportation to the laboratory.

II.2.a Site Description

The Gainesville sites were at the 34th Street footbridge, the main walkway at Paynes Prairie, and the deck at Bivens Arm Park. The three in Miami were a deck at Oleta River Park, a playground at A.D. Barnes Park, and a lifeguard tower at Tropical Park. The three sites at Tallahassee were a deck at Lake Talquin, a deck at Maclay Gardens, and a footbridge at Tom Brown City Park. Each site was given a two letter abbreviation for sample tracking. A listing of these abbreviations is provided in table II.1.

Decks identified for soil sampling varied in age between 2 years (Tom Brown City Park) to 19 years (Lake Talquin) (table II.1). All decks used in this study were confirmed as CCA treated except for the deck at Lake Talquin. CCA treatment was confirmed by applying a chemical stain and by using x-ray fluorescence to quantify the retention level of CCA within either wood bores or sawdust samples collected from each deck. Sawdust and wood bores utilized for analysis corresponded to the outer 6/10 inch of wood as specified by AWPA standards. The stain utilized was PAN indicator which when applied to the surface of the deck resulted in a distinctive color change when metals were present (See Blassino et al. 2000 for more details concerning this stain). X-ray fluorescence was conducted by Javaro Johnson of Robbins Manufacturing, Tampa, FL, using an ASOMA Model #1503. As shown from the data, all decks stained positive for CCA except for the Lake Talquin deck in Tallahassee. The deck at the 34th Street Bridge in Gainesville was characterized by a generally high CCA retention level (0.755 pcf) whereas extremely low retention values were obtained for the Lake Talquin deck in Tallahassee. The

XRF results for the deck at Oleta River Park were variable. The hand rail portion of the deck was characterized by a retention level of 0.005 pcf. The joists below the deck tested at 0.54 and 0.50 pcf and the support columns tested at 0.15 pcf. The general descriptions of each site are provided below.

City	Description of deck	Site Abbre-viation	Year deck constructed	Age of deck when sampled	Results from Stain	CCA Ret. Level (pcf)
Gainesville	34th Street Footbridge	BR	1994	5 years	Positive	0.755
	Deck at Paynes Prairie	PP	1983-1984	~15 years	Positive	0.206
	Walkway at Bivens Arm Park	BP	1985	14 years	Positive	0.477
Miami	Deck at Oleta River Park	OP	1985	14 years	Positive	Variable (0.005-0.54)
	Playground at A.D. Barnes Park	AD	1990	9 years	Positive	0.261
	Lifeguard station at Tropical Park	TP	1993	6 years	Positive	0.206
Tallahassee	Footbridge at Lake Talquin	LT	1980	19 years	Negative	0.008
	Deck at Maclay Gardens	MG	1995	4 years	Positive	0.412
	Footbridge at Tom Brown City Park	TB	1998	2 years	Positive	0.247

Table II.1: Site Abbreviations and Ages of Decks Sampled

Gainesville

34th Street Bridge: The 34th Street deck is a footbridge that runs parallel to NW 34th Street, between NW 30th Blvd and NW 33 Lane. It was built by the Florida Department of Transportation within the past decade. The plans for the original construction of the bridge indicate that the pilings were treated at 2.5 pcf and the handrails, decking, and stringers were treated at 1.2 pcf. These retention levels are exceptionally high and support the high retention level measurement (0.755 pcf) obtained for this particular deck. The surface soil samples were collected from below the bridge, where the soil was somewhat rocky. The land was sloped beneath the bridge, from a high at NW 34th Street toward a low at control sample location C01 (figure A.2 in appendix A). Six of the nine control samples (C02, C03, C04, C06, C07, and C08) were collected upstream of the grid and three downstream (C01, C05, and C09). One of the core samples was taken in the center of the "below deck" sampling grid, while the other was taken at a downstream location near CO1, the farthest downstream control.

Paynes Prairie: The deck at Paynes Prairie leads out to an expanse of wetland. The soil sample corresponded to the portion of the deck that is used as a walkway for pedestrians who wish to view the prairies. During the first sampling trip the area was dry. To the west of the walkway stood a CCA-treated wood fence. A few months after the first sampling trip, construction began at the site. A concrete barrier was put in place of the fence and the area below the deck became waterlogged. This proved to make further sample collection somewhat difficult.

Bivens Arm Park: Bivens Arm Park is maintained by the City of Gainesville and contains a treated wood pedestrian walkway through the park. The walkway at Bivens Arm Park is covered with trees limiting the amount of direct sunlight to the area. This particular deck was pressure washed shortly before sample collection.

Miami

Oleta River Park: The deck at Oleta River Park serves as a walkway for a bathroom facility. Dense vegetation surrounded the deck at the location sampled. From the original plans obtained for this particular site, it was noted that only some of the structure was pressure treated, while the rest of the structure was made of Cedar. Constructions drawings indicate that the floor and roof decking of the bathroom facility, for example, were to be built with Alaskan Yellow Cedar, while the interior of the structure was to be built with Western Red Cedar. Originally, it was not clear whether or not the deck that led to the bathroom facility was CCA treated. Stains and analysis of the decks using XRF confirmed that the handrail portion of the deck was not CCA treated. CCA treatment was confirmed within the support columns (0.15 pcf) and joists (0.54 pcf and 0.50 pcf) below the decks. The original plans for the deck indicated that the deck boards were to be constructed of Alaskan Yellow Cedar; however, inspection of the deck indicates that some of the deck boards (especially those closer to the bathroom facility) may have been replaced with CCA-treated wood. Several of the deck boards closest to the bathroom facility tested positive using the chemical stains.

A.D. Barnes Park: The playground at A.D. Barnes Park is a combined playground and walkway characterized by various levels. Samples were collected at a portion of the deck that was a few feet off of the ground. Martha MacDonald from Miami-Dade Parks and Recreation indicated that this deck was constructed of 0.4 pcf CCA-treated wood. XRF analysis confirmed CCA treatment. Upon inspection of the structure it was noted that part of the structure included small vertical bars between the deck and handrails. These bars consisted of painted metal.

Tropical Park: The lifeguard station at Tropical Park is located adjacent to a lake. This tower consists of a shaded enclosure for the lifeguard and a ramp that leads up to the enclosure. The station was rebuilt shortly after Hurricane Andrew in 1993, possibly on the same site as a previous tower. The area below the tower was characterized by two levels that were separated by a concrete wall. The portion below the lifeguard enclosure was grassy and flat; the portion below the ramp was sandy and beach-like in appearance and sloped away from the lifeguard enclosure toward the lake. Samples were collected below each portion of the lifeguard station.

Tallahassee

Maclay Gardens: The deck at Maclay Gardens leads into a portable office building. The siding of the office building appeared to be composed of vinyl. The soil was very loose and easy to collect.

Tom Brown City Park: The footbridge at Tom Brown City Park sits around the perimeter of a lake. Sometimes, the area sampled below the deck can get flooded at times of heavy rain. The structure was originally built in 1978. The original pilings were left in place when the deck and handrails were replaced in January of 1998. Ashley Edwards from Tom Brown Park indicated that most of the wood for this deck was treated with either 0.4 or 0.25 pcf. Furthermore an end tag was found below the deck during sampling. The end tag came from wood rated at 0.25 pcf. This deck was confirmed positive for CCA treatment through XRF analysis.

Lake Talquin: Soils were collected from below a footbridge located at River Bluff State Park, which is immediately adjacent to the lake. The area is covered with trees that limit the amount of direct sunlight to the area. Moss was observed growing on the surface of this particular deck. This deck tested negative for CCA-treated wood and pentachlorophenol using chemical stains. The presence of pentachlorophenol was tested using Penta-Check provided by Wood Protection Products, Inc. from Charlotte, North Carolina. Sawdust samples collected from the handrails confirmed that this portion of the deck was not CCA treated. Construction drawings obtained for the deck, however, indicated that the support columns for the deck may be pressure treated. Whether or not these support columns were in fact treated with CCA-treated wood has not been confirmed. The minimum distance between the closest surface sample and support column was 1 foot.

II.3 METHODS OF SOIL ANALYSIS

Soils were analyzed for their physical characteristics and for their metals content. Physical characteristics measured included volatile solids content and grain size distribution. Measurement of metals concentrations required sample pre-processing, digestion, and analysis.

II.3.a Physical Characteristics

Volatile Solids Analysis

Volatile solids are an indirect measure of the bulk organic content of a soil. The method used to measure the volatile solids concentration of the soil samples was a modification of method 2540E *Standard Methods* (APHA 1995). The analysis began by weighing between 5 and 10 grams of moist soil and placing this soil in a drying oven at 100 ºC for 24 hours. The soil samples were removed from the oven, cooled, and weighed. After weighing they were immediately placed in a furnace at 450 ºC for 5 hours. During this step it is presumed that all of the volatile solids present in the soil sample were lost. The samples were then reweighed and the volatile solids content was computed on a % weight basis

Grain Size Analysis

Sieve analysis was run to determine the grain size distribution of the soil samples. Prior to sieve analysis, a sub-sample from each of the surface soil sampling sites collected below each deck was combined to form one large representative sample for each deck. The samples were oven-dried, weighed, and placed through a series of sieves. The sieves used were #4 (4.75 mm), #10 (2.0 mm), #20 (0.85 mm), #40 (0.425 mm), #60 (0.25 mm), #140 (0.106 mm), #200 (0.075mm). The sieve with the largest opening was placed on the top with the collection pan on the bottom. The entire stack was run through a shaker for approximately 10 minutes. Each sieve was then re-weighed and the grain size distribution was computed.

II.3.b Metals Concentrations

Sample Preparation

All soil samples were stored at 4 ^{o}C prior to digestion and analysis. The soil core samples were separated into either 0.5 or 1.0 inch long sections. The first two inches were separated into 0.5 inch increments. The remainder of the core was separated into 1 inch increments. Immediately prior to digestion, soil samples (both surface soils and cores) were dried at 105 ^{o}C for 24 hours and the moisture content was computed.

It is important to note that all scoops, glassware, plastic containers etc. that came in contact with a sample were first acid rinsed to remove metal contamination as per standard quality control procedures.

Sample Digestion

Each dried soil sample was digested following EPA Method 3050B (USEPA 1996). Method 3050B is an open vessel method requiring the use of acid and oxidizing agents to reflux a sample on a hot plate for a period of 2 to 8 hours. This method provides a slightly different procedure depending on whether the digestate is being analyzed by flame aspiration or graphite furnace. The digestion procedure calls for weighing 2.0 g of sample into an Erlenmeyer flask, then adding 10 ml of 1:1 nitric acid and heating on a hotplate. After 15 minutes, the Erlenmeyer flask was removed from the hotplate and an additional 5 ml of concentrated nitric acid was added. The Erlenmeyer flask was then placed back onto the hotplate for an additional 30 minutes. If brown fumes were generated, 5 ml of concentrated nitric acid was added sequentially, until no more fumes were formed. When brown fumes ceased, the Erlenmeyer flask was heated for an additional 2 hours or until the final volume of the mixture was 5 ml. The Erlenmeyer flask was then removed from the hotplate and 3 ml of 30% hydrogen peroxide (H_2O_2) was added and the solution was placed back onto the hotplate for 2 hours. Samples being digested for analysis using GF-AAS were then filtered through a Whatman 41 filter into a 100 ml volumetric flask. The sample in the volumetric flask was then diluted to volume with deionized water, at which point the sample was ready for analysis. Samples digested for analysis using Flame-AAS were subjected to an additional step. Ten ml of concentrated HCl was added and the samples were allowed to reflux for 15 minutes. The digestate was filtered through a Whatman 41 filter into a 100 ml volumetric flask. The sample was then diluted to volume with deionized water, at which point, the sample was ready for analysis.

Metals Analysis

Metals analysis of the digestates was performed using a Perkin Elmer model 5100 atomic absorption spectrophotometer. This instrument was equipped with both a flame aspiration system and a graphite furnace with Zeeman background correction. Arsenic concentrations were measured using the graphite furnace technique. The graphite furnace was also used to measure the concentration of copper and chromium in the control samples. The Flame-AAS technique was employed for all other measurements of Cu and Cr. The graphite furnace was used to measure copper and chromium for the control samples due to the lower concentrations contained in the samples. The detection limit for the flame technique was 1 mg/L for both copper and chromium, whereas the detection limit for the graphite furnace was 5 μg/L for chromium and 10 μg/L for copper. Appropriate quality control and quality assurance procedures were followed in accordance with Florida Department of Environmental Protection Comprehensive Quality Assurance Plan # 960216.

II.4 RESULTS OF METALS ANALYSES ON SURFACE SOILS

A total of 73 surface soil samples were collected under the nine decks and board walks in Gainesville, Miami, and Tallahassee. Among the 73 surface soils samples, 65 were collected from below decks that were confirmed to be treated with CCA. The remaining 8 samples were collected from below the Lake Talquin deck which is the only deck that did not show a positive measurement for CCA using either the stains or XRF. Stains and XRF samples were collected from the upper portions of the Lake Talquin deck. However, it is important to note that construction drawings for the Lake Talquin deck specify the use of pressure treated support columns. Whether or not these support columns were in fact CCA treated was not confirmed.

In addition to the surface samples collected below the decks, a total of 73 control soil samples were collected. Control samples were located at a distance removed from the deck and results from these samples are expected to represent background metals concentrations.

A summary of the results of arsenic, chromium, and copper analyses are provided in the following sub-sections. Due to the fact that the metals concentrations in some samples were found below the detection limit (BDL), two sets of statistics are reported. One set only includes the results that were above the detection limit. For the second set of statistics, the samples that were below the detection limit were set to zero and averaged with the data that were above the detection limit. The first set of statistics will be biased toward the high side and the second set will be biased toward the low side. The range of values from each set of statistics will include the true average of the samples. As observed from the subsequent data, the results from each computation method are very close to one another. Please refer to appendix A for details concerning the results for each individual deck.

II.4.a Arsenic Results for Surface Soils

Arsenic was detected in all the surface soil samples collected from below decks. The arsenic concentrations for surface soils collected from underneath the decks ranged from 1.2 mg/kg (Miami site TP) to 217 mg/kg (Miami site OP) with an average of 28.5 mg/kg (table II.2). This average includes the results from all decks except for those from Lake Talquin. The average arsenic concentration of the control samples (without Lake Talquin) varied between 1.3 and 1.5 mg/kg depending upon how the non-detects were handled. Figure II.1 provides a plot of the average deck soil sample arsenic concentrations in relation to the average control sample arsenic concentration for each site. The average arsenic concentrations for surface soils collected below the decks are higher than the control samples at 95% confidence for 8 of the 9 decks. The only deck soils that were not elevated in concentration were those collected from below the Lake Talquin deck.

Of interest is the large variability of arsenic concentrations observed in the Oleta River Park deck samples (figure II.2). For this particular deck, surface soil samples ranged from 32 to 217 mg/kg of arsenic. The highest concentrations were measured at site S02 (112 mg/kg) and S07 (217 mg/kg). These sites line up along one particular horizontal line (See figure A.9 in appendix A for sample locations). To evaluate the possible reasons for this particular pattern in arsenic concentrations, the grid was re-created during a subsequent field trip to the site (after the metals data were available). It was found during this subsequent field trip that the joists supporting the deck intersect immediately above S02 and S07 forming a "T" pattern. The deck was visited shortly after a storm event and dampness along the "T" portion of the joists was noticeable whereas at other portions of the joists it was not. It is likely that runoff from upper portions of the deck drip along the joists resulting in a concentrated input of rainwater at the point where the two joists intersect and thus causing the elevated arsenic concentrations at S02 and S07.

Location		**Surface Soil Samples Collected Below Decks (all analyses above detection limit)**					**Controls (above detection limit)**		**Controls (BDL[1] = 0)**	
		N	**Average (mg/kg)**	**Std. Dev. (mg/kg)**	**Max. (mg/kg)**	**Min. (mg/kg)**	**N**	**Average (mg/kg)**	**N**	**Average (mg/kg)**
Gainesville	BP	8	41.6	22.8	87.9	15.6	8	2.61	8	2.61
	BR	9	10.7	9.15	33.2	4.05	5	0.46	9	0.26
	PP	8	9.56	4.50	18.1	3.54	4	1.03	8	0.52
total samples		25	20.2	20.2	87.9	3.54	17	1.61	25	1.09
Tallahassee	TB	8	17.2	7.72	31.0	8.59	8	2.31	8	2.31
	MG	8	34.0	13.7	48.8	5.09	8	1.42	8	1.42
	LT	8	0.48	0.14	0.62	0.25	8	0.47	8	0.47
total samples[2]		16	25.6	13.8	48.8	5.09	16	1.86	16	1.86
Miami	AD	8	33.9	20.7	81.2	15.5	8	1.98	8	1.98
	TP	8	4.30	2.32	7.47	1.18	8	1.13	8	1.13
	OP	8	79.1	60.7	217	31.7	8	0.66	8	0.66
total samples		24	39.1	47.3	217	1.18	24	1.26	24	1.26
All Sites[2]		65	28.5	32.8	217	1.18	57	1.53	65	1.34

[1] BDL=Below Detection Limit. Detection limit is 0.25 mg/kg based on sample dry mass of 2.0 g

[2] Does not include results from Lake Talquin, LT, deck

Table II.2: Arsenic Results for Surface Soils

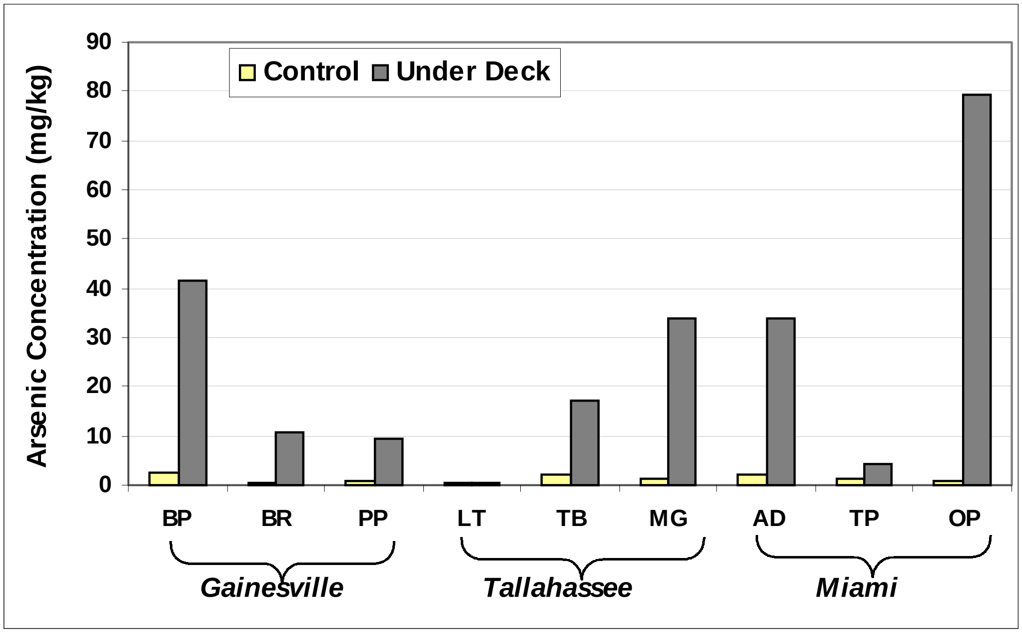

Figure II.1: Comparison of Mean Deck Arsenic Soil Concentration Versus Control Soil Concentrations

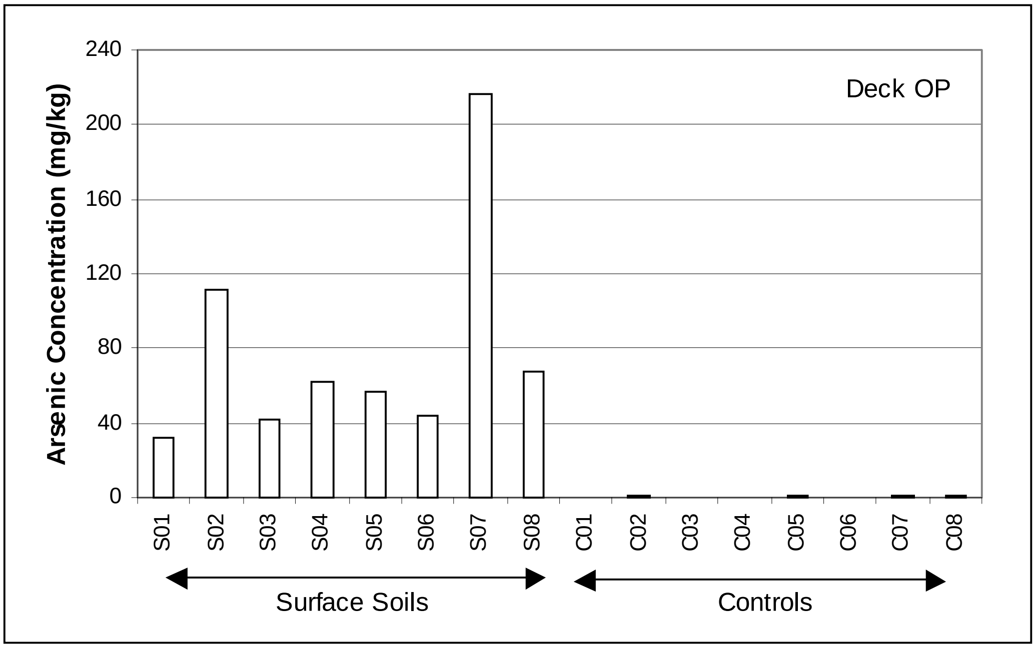

Figure II.2: Arsenic Concentration in Surface Soil Samples from the Oleta River Park Deck, Miami

II.4.b Chromium Results for Surface Soils

Of the 65 soil samples collected from below confirmed CCA-treated decks, 59 were above the detection limit for chromium. For the samples above the detection limit, the surface soil chromium concentrations ranged from a maximum of 198 mg/kg (site OP in Miami) to a minimum of 5.4 mg/kg (site TP in Miami) with an average of 34 mg/kg (table II.3). It is noted that the average, maximum, and minimum do not include site LT. The average of the corresponding controls varied from 8.6 to 9.8 mg/kg depending upon how the below detection limit samples were evaluated.

The average below deck soil chromium concentration is plotted in relation to the average control chromium concentration for each site in figure II.3. It is readily observed from this figure that the average of the deck soils were higher than the average of the controls for 6 of the 9 decks. Three decks (PP, LT, and TP) had higher chromium concentrations in the controls than in the deck soils. Statistically at 95% confidence limits, the soils below 3 of the 9 decks were elevated in chromium concentrations above that for the controls (BP, MG, and OP). At 80% confidence, 6 of the 9 deck soils (BP, MG, OP, BR, TB, AD) were elevated above background concentrations. As mentioned earlier, the average chromium concentration of the controls for three of the sites (PP, LT, and TP) was higher than that for the deck soils. Statistical significance was tested for this observation for 2 of the 3 decks. One deck (LT) could not be evaluated given that the results for all the deck soils were below detection limit. For PP, the higher average concentration of the control over the deck soil was not statistically significant at either 95% or 80% confidence limits. For the TP deck, the average of the control samples was elevated above the average of the deck soils at 80% confidence limits but not at 95% confidence limits.

Of interest is that within a site characterized by elevated chromium concentrations in the deck soils, the deck soil chromium concentrations are generally correlated with arsenic concentrations. This correlation generally corresponds to the stoichiometric ratio of CCA type C, thereby supporting the hypothesis that the cause of the elevated chromium and arsenic concentrations below the decks is due to the deck treatment with CCA. A representative plot illustrating the correlation is provided in figure II.4.

Location		**Surface Soil Samples Collected Below Decks (all analyses above detection limit except for PP, LT & TP)**					**Controls (above detection limit)**		**Controls (BDL[1] = 0)**	
		N[3]	**Average[4] (mg/kg)**	**Std. Dev.[4] (mg/kg)**	**Max. (mg/kg)**	**Min.[5] (mg/kg)**	**N**	**Average (mg/kg)**	**N**	**Average (mg/kg)**
Gainesville	BP	8	59.7	25.6	113.5	30.8	7	3.53	8	3.09
	BR	9	23.4	13.8	48.6	10.6	7	10.1	9	7.87
	PP	6(8)	15.3(11.5)	9.05(10.4)	28.6	7.80	8	19.2	8	19.2
total samples		23(25)	33.9(31.2)	26.0(26.6)	113.5	7.80	22	11.3	25	9.96
Tallahassee	TB	8	16.4	9.4	32.4	6.90	8	8.80	8	8.80
	MG	8	22.9	10.1	44.3	14.3	7	7.95	8	6.96
	LT	8	BDL[1]	---	BDL	BDL	6	4.58	8	3.43
total samples[2]		16	19.7	10.0	44.3	6.90	15	8.40	16	7.88
Miami	AD	8	39.5	31.5	113.6	13.8	8	12.7	8	12.7
	TP	4 (8)	6.19(3.09)	0.71(3.34)	6.85	5.35	6	9.01	8	6.76
	OP	8	71.1	56.6	198.5	32.0	6	4.82	8	3.61
total samples		20 (24)	45.5(37.9)	46.5(45.7)	198.5	5.35	20	9.22	24	7.68
All Sites		59 (65)	34.0 (30.8)	33.1 (33.0)	198.5	5.35	57	9.82	65	8.61

[1] BDL=Below Detection Limit. The detection limit for samples collected below the decks was 5 mg/kg based on a sample dry mass of 2.0 g. The detection limit for the control samples was 0.25 mg/kg based on sample dry mass of 2.0 g. The difference in the detection limits is due to the use of a flame AAS for the analysis of deck soils and graphite furnace AAS for the analysis of control soils.

[2] Does not include results from Lake Talquin, LT, deck

[3] Numbers in parentheses correspond to the total number of samples, including those below detection.

[4] Numbers in parentheses assumes a value of zero for samples that were BDL.

[5] Minimum excluding samples that were BDL.

Table II.3: Chromium Results for Surface Soils

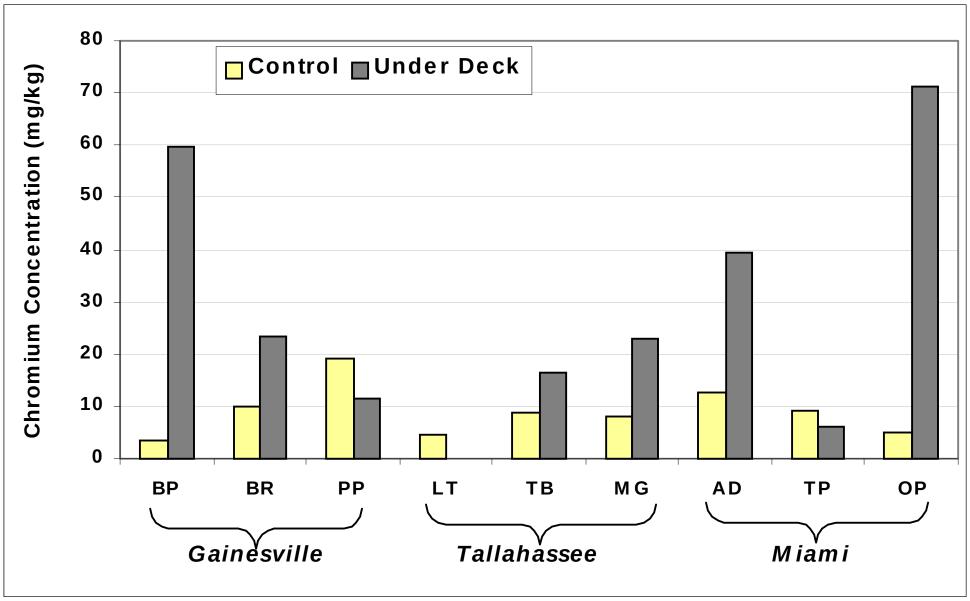

Figure II.3: Comparison of Mean Deck Soil Chromium Concentration Versus Control Soil Concentrations

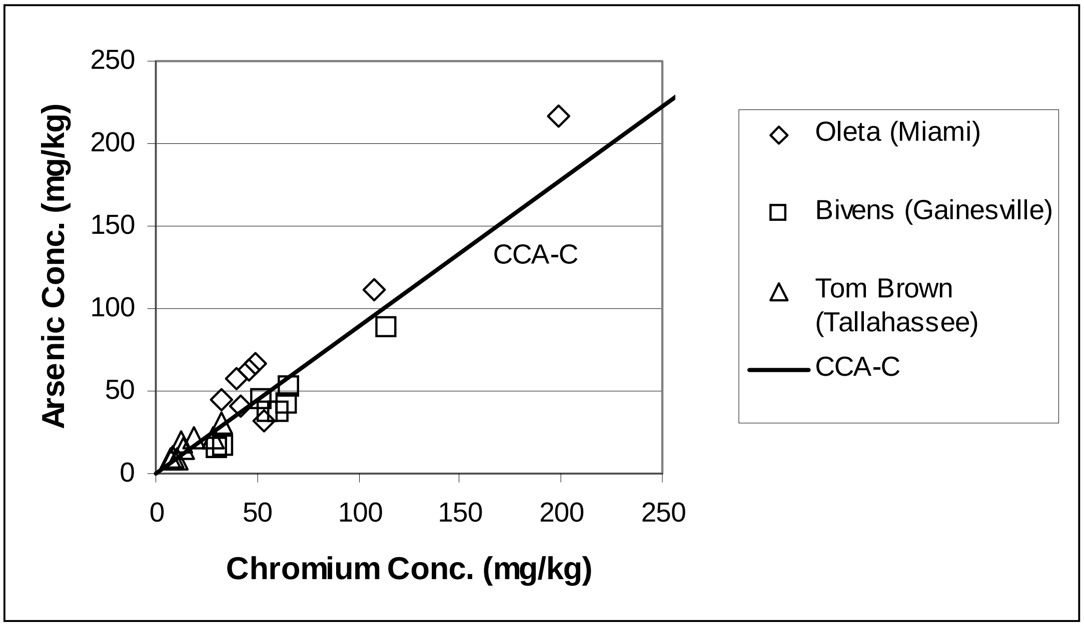

Figure II.4: Chromium Versus Arsenic Concentration for Surface Soils Collected From Three Decks

II.4.c Copper Results for Surface Soils

Of the 65 soil samples collected from below confirmed CCA-treated decks, 60 were above the detection limit for copper. For the samples above the detection limit, the surface soil copper concentrations ranged from a maximum of 216 mg/kg (site OP in Miami) to a minimum of 7.5 mg/kg (site BR in Gainesville) with an average of 40 mg/kg (table II.4). It is noted that the average, maximum, and minimum do not include site LT. The average of the corresponding controls varied from 6.1 to 6.7 mg/kg depending upon how the below detection limit samples were evaluated.

The average below deck soil copper concentration is plotted in relation to the average control sample copper concentration for each site in figure II.5. It is readily observed from this figure that the average of the deck soils were higher than the average of the controls for all of the sites sampled except for Lake Talquin. Statistically at 95% confidence limits, the soils below 6 of the 9 decks were elevated in copper concentrations above that for the controls (BP, BR, PP, MG, AD, OP). The three decks that did not show the elevated concentrations at 95% confidence were TB, LT, and TP. However it is important to note that TB deck soils were statistically elevated at 80% confidence. The TP soils were not significantly elevated at either 95% nor 80%. LT could not be tested statistically since all of the deck samples were below detection.

Of interest is that the copper concentrations appear to be correlated with arsenic concentrations within a particular site (figure II.6). However this correlation does not correspond to the stoichiometric relationship between arsenic and copper within CCA type C. Rather it appears as though there is more copper in the soil relative to arsenic. There are two potential explanations for this trend. The first is that the copper is preferentially leached from the CCA-treated decks. The second is that the copper leached from the CCA-treated decks is more tightly bound to the soil so that with subsequent washing it is not leached as readily from the soil as arsenic. This second hypothesis implies that there is some arsenic (and potentially chromium) that has been lost from the soils below the deck area and not accounted for.

Location		Surface Soil Samples Collected Below Decks (all analyses above detection limit except for LT & TP)					Controls (above detection limit)		Controls (BDL[1]` = 0)	
		N[3]	Average (mg/kg)	Std. Dev. (mg/kg)	Max. (mg/kg)	Min. (mg/kg)	N	Average (mg/kg)	N	Average (mg/kg)
Gainesville	BP	8	106.3	32.4	155.5	53.0	5	9.46	8	5.91
	BR	9	20.1	10.1	37.0	7.50	7	8.58	9	6.67
	PP	7 (8)	15.2(13.3)	6.14 (7.83)	26.00	9.0	8	4.60	8	4.60
total samples		24(25)	47.4(45.5)	46.7 (46.7)	155.50	7.50	20	7.21	25	5.77
Tallahassee	TB	8	18.9	10.0	34.0	10.0	8	7.30	8	7.30
	MG	8	21.8	8.91	36.0	12.0	8	3.95	8	3.95
	LT	8	BDL[1]	---	BDL	BDL	5	3.31	8	2.48
total samples[2]		16	20.3	9.29	36.0	10.0	16	5.63	16	4.92
Miami	AD	8	44.5	36.2	128.5	16.5	8	7.92	8	7.92
	TP	4 (8)	9.75(4.88)	1.19(5.27)	11.00	8.50	7	8.38	8	7.33
	OP	8	68.1	64.5	216.0	18.5	8	4.63	8	4.63
total samples		20 (24)	47.0(39.2)	50.0 (48.8)	216.0	8.50	23	6.91	24	6.63
All Sites[2]		60 (65)	40.0 (37.0)	42.6(42.3)	216.0	7.50	59	6.66	65	6.05

[1] BDL=Below Detection Limit. The detection limit for samples collected below the decks was 5 mg/kg based on a sample dry mass of 2.0 g. The detection limit for the control samples was 0.5 mg/kg based on sample dry mass of 2.0 g. The difference in the detection limits is due to the use of a flame AAS for the analysis of deck soils and graphite furnace AAS for the analysis of control soils.

[2] Does not include results from Lake Talquin, LT, deck

[3] Numbers in parentheses correspond to the total number of samples, including those below detection.

[4] Numbers in parentheses assumes a value of zero for samples that were BDL.

[5] Minimum excluding samples that were BDL.

Table II.4: Copper Results for Surface Soils

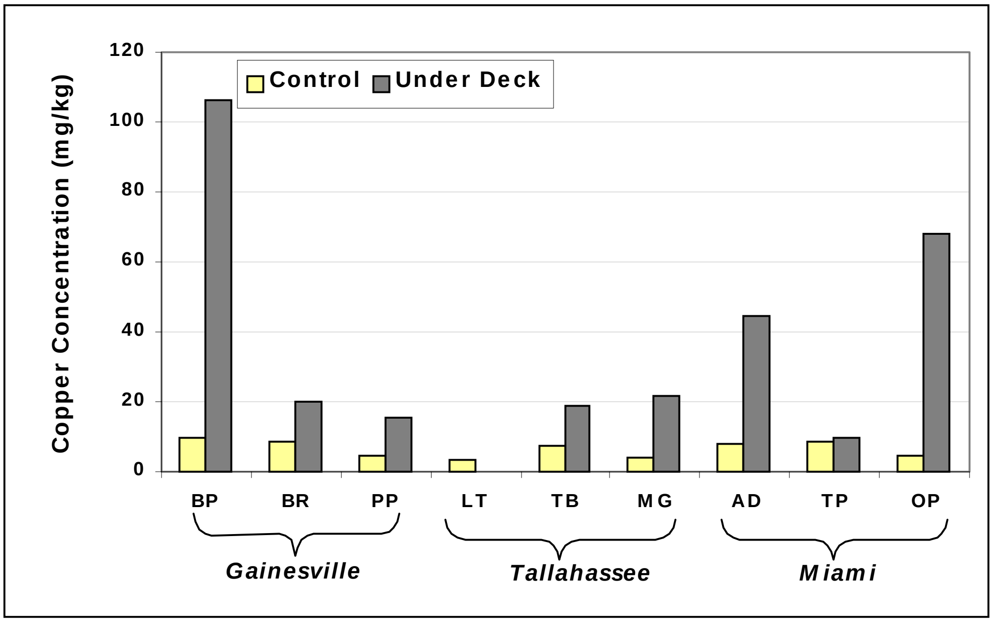

Figure II.5: Comparison of Mean Deck Soil Copper Concentration Versus Control Soil Concentrations

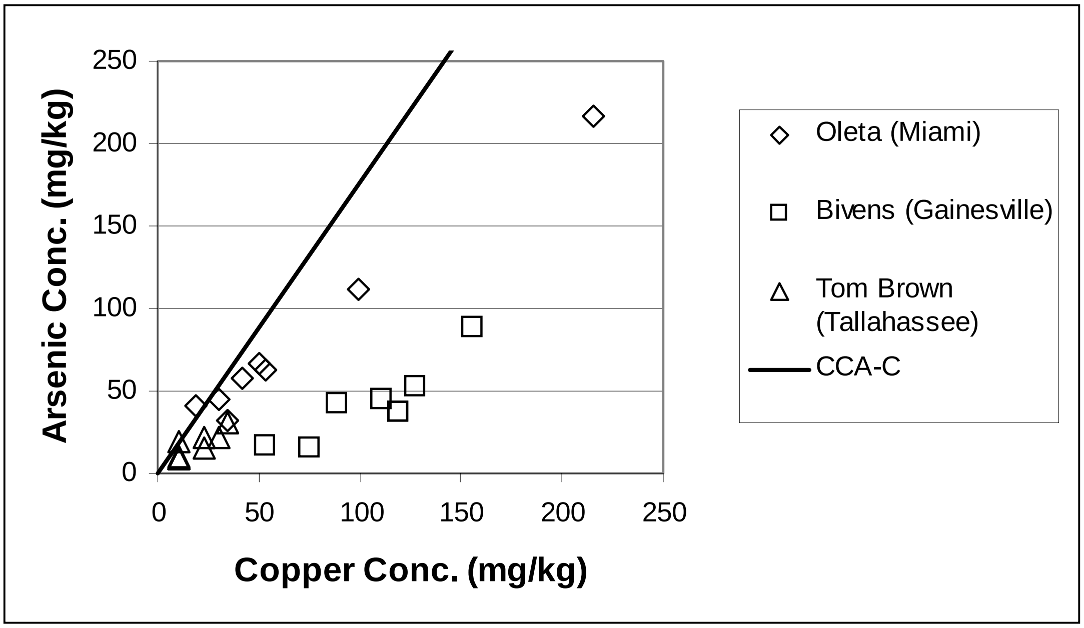

Figure II.6: Chromium Versus Arsenic Concentration for Surface Soils Collected From Three Decks

II.5 RESULTS OF PHYSICAL MEASUREMENTS

Two sets of physical measurements were performed on the surface soil samples: volatile solids content and grain size analyses.

II.5.a Volatile Solids Content

Results indicate that the volatile solids content of the surface soil samples varied from 2% to 26% (table II.5). The site characterized by the lowest volatile solids content was Tropical Park which had the consistency and appearance of a beach sand. The site characterized by the highest volatile solids content was Bivens Arm Park. Soils collected from Bivens Arm Park were dark brown in color and were characterized by a "sponge-like" consistency.

There appears to be a correlation between volatile solids content and soil metal concentrations. This correlation appears weak between sites but is very noticeable within a particular site. Between sites (figure II.7) it is noted that soils collected at Tropical Park had very low arsenic concentrations (4.3 mg/kg average) and also had a low volatile solids content (1.9%). Soils at Bivens Arm Park were characterized by the highest volatile solids content (26%) and the second highest average arsenic concentration (42 mg/kg). Exceptions to the general trend include the very low arsenic concentrations observed at Lake Talquin (0.48 mg/kg) even though the volatile content of the soils was at 12%. The low arsenic concentrations at Lake Talquin is likely due to the fact that this deck was not confirmed to be CCA-treated and was therefore not likely impacted by CCA. The second exception to the trend is noted at Oleta River Park which was characterized by the highest arsenic concentrations (79 mg/kg average) and relatively low volatile solids (4.4 %).

Correlations between volatile solids content and metals concentrations *within* a particular site were observed for 5 of the 9 decks. These decks included Bivens Arm Park, A.D. Barnes Park, Oleta River Park, Tropical Park, and Tom Brown Park. A representative plot of this relationship is provided in figure II.8, where it is observed that the highest arsenic concentration was observed for the deck soil site characterized by the highest volatile solids content. Similarly, the lowest arsenic concentrations where measured for sites characterized by low volatile solids. Due to the low arsenic concentrations observed for the control samples, no correlations were generally observed between arsenic concentrations and volatile solids content of the controls. The primary exception, however, was observed for control sample #2 (CO2) collected at Bivens Arm Park (figure II.8). This particular sample was characterized by a very high volatile solids concentration (75%) and for a control sample also had a relatively high arsenic concentration (13 mg/kg). The remaining control samples for this site were characterized by an average arsenic concentration of 1.1 mg/kg and average volatile solids concentration of 8%. The high arsenic concentration observed for sample C02 may be due to the extremely high volatile solids content.

City	Name/Description of deck	Site Abbre-viation	Volatile Solids (%)	Grain Size, 50% finer (mm)
Gainesville	34th Street Footbridge	BR	3.5	0.343
	Deck at Paynes Prairie	PP	5.0	0.370
	Walkway at Bivens Arm Park	BP	26.4	0.387
Miami	Deck at Oleta River Park	OP	4.4	0.293
	Playground at A.D. Barnes Park	AD	9.7	0.339
	Lifeguard station at Tropical Park	TP	1.9	0.284
Tallahassee	Footbridge at Lake Talquin	LT	11.7	0.393
	Deck at Maclay Gardens	MG	4.4	0.387
	Footbridge at Tom Brown City Park	TB	4.6	0.390

Table II.5: Volatile Solids and Grain Size Data for Soils Collected Below Decks

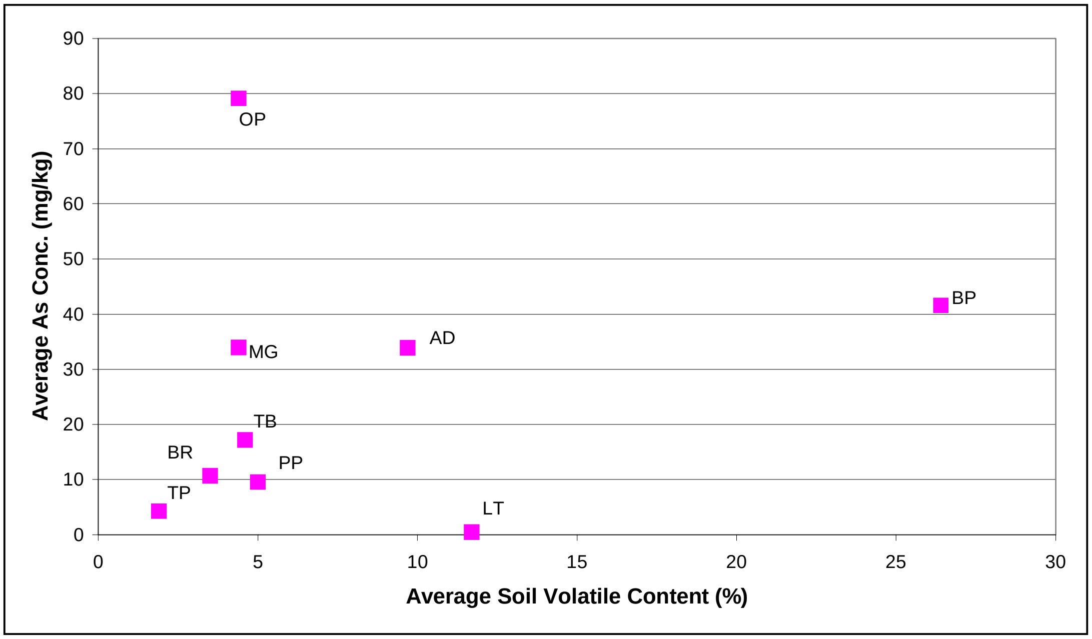

Figure II.7: Average Arsenic Concentration Versus Average Soil Volatile Content

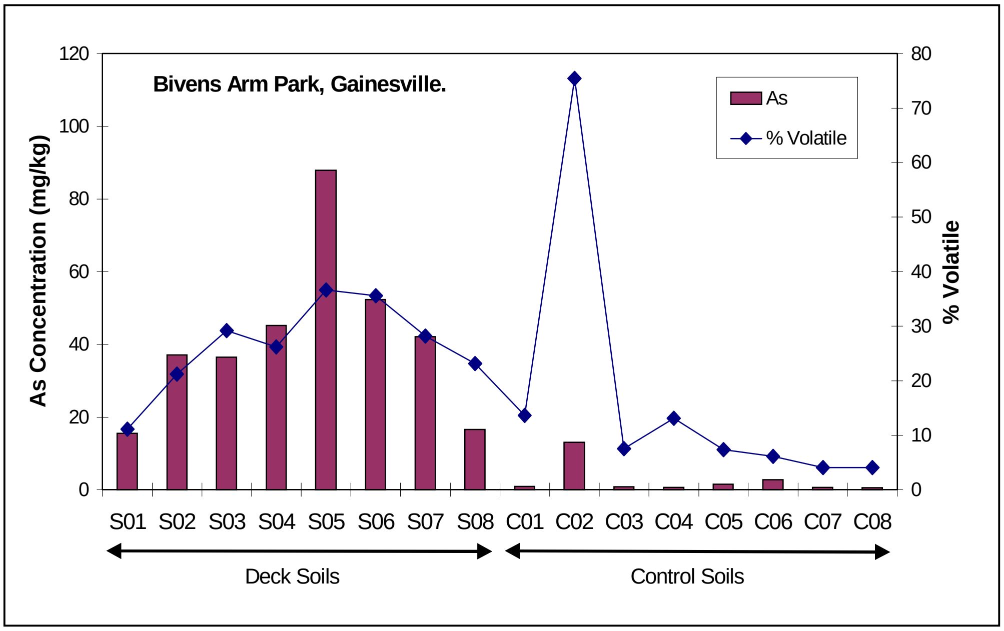

Figure II.8: Arsenic and % Volatile Concentration Per Sampling Station at Bivens Arm Park, Gainesville

II.5.b Grain Size Distribution

Results from grain size analysis indicate that the soils below each deck were characterized by a similar grain size distribution (figure II.9). All soils were generally uniformly graded with an average size (50% finer) between 0.28 to 0.39 mm. This range of grain sizes corresponds to a medium sandy soil (Das 1985).

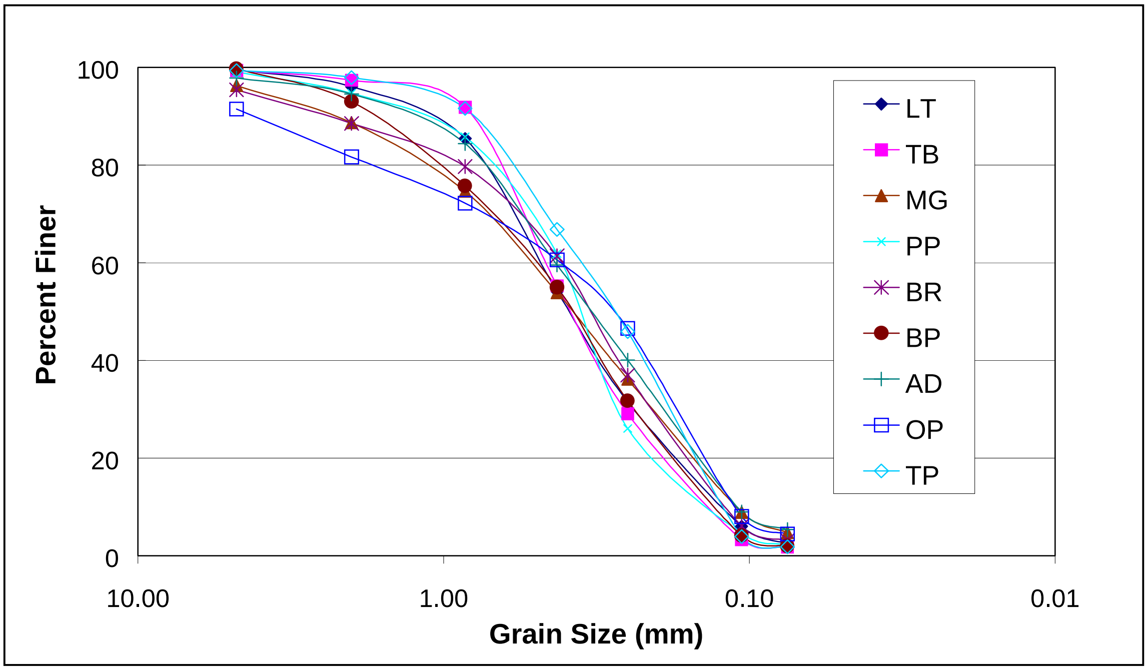

Figure II.9: Soil Grain Size Distribution

II.6 RESULTS FROM SOIL CORE SAMPLES

In addition to the surface soil samples a set of eight soil cores were collected under the nine decks and boardwalks in Gainesville, Miami, and Tallahassee. (See figures A.28 to A.36 in appendix A for details.) One control soil core sample was collected at the Gainesville 34th Street boardwalk. The results from the cores collected below the decks (except for the Lake Talquin core) were averaged and compared to the value obtained for the control core collected at the 34th St. boardwalk in Gainesville. Results (figure II.10 and tables II.6 and II.7) suggest that the CCA-treated decks impact at least the upper 3 inches of soil below the decks. The depth of the impact appears deeper for arsenic than for chromium or copper.

Statistics from the soil cores for each individual site are provided in table II.8. Data indicate that the maximum concentrations of arsenic were found within the first two inches of the soil within all cores. The majority of the minimum arsenic concentrations are shown to be confined mainly to depths greater than five inches, with the exception of the MG deck in Tallahassee which had a minimum arsenic concentration at a depth of 3.5 in. The trends in the chromium concentrations from the soil core samples were not as consistent as those observed for arsenic. Five of the 8 cores did show an overall trend (BP, TB, MG, TP, and OP) with the highest chromium concentrations near the soil surface and lower concentrations at deeper depths. Overall, the maximum chromium concentrations occurred from 0.75 to 11.5 inches from the ground surface and the minimum chromium concentrations were measured at depths ranging from 1.75 to 9.9 inches. As for the copper results, five of the 8 cores showed an overall trend (BP, BR, PP, TB, and TP) with the highest copper concentrations near the soil surface and lower concentrations at deeper depths. For all nine cores evaluated, the maximum copper concentrations occurred from 0.25 to 9.5 inches below the surface and the minimum copper concentrations were measured at depths ranging from 2.5 to 10.5 inches below the surface.

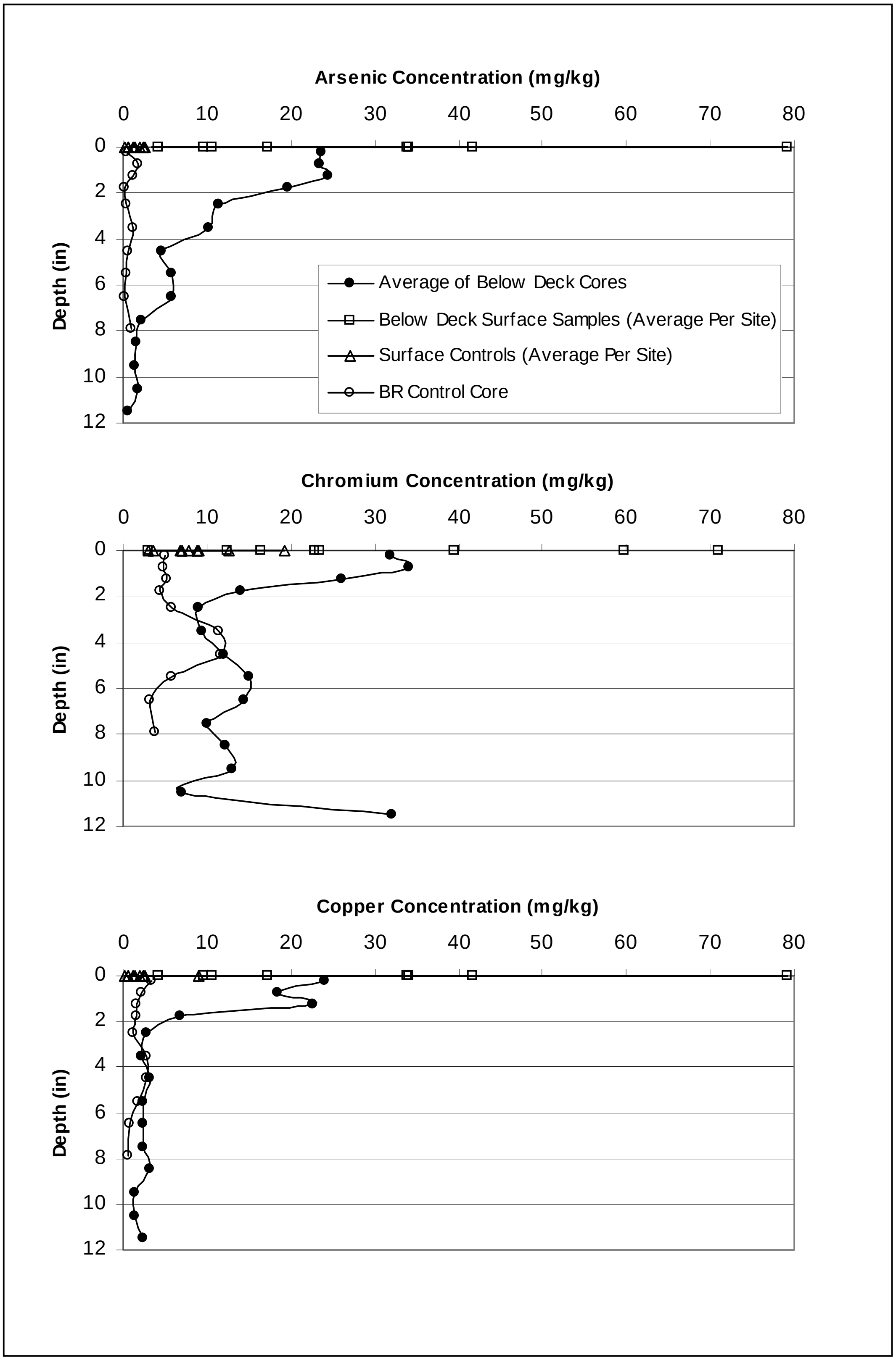

Figure II.10: Average of Soil Cores

Depth (in)	**N (At Given Depth)**	**Average Metal Concentration (mg/kg)**		
		As	**Cu**	**Cr**
0.25	8	23.66	24.01	31.89
0.75	8	23.40	18.48	34.01
1.25	8	24.45	22.64	26.13
1.75	8	19.70	6.79	14.12
2.5	8	11.33	2.75	9.06
3.5	8	10.27	2.29	9.34
4.5	8	4.70	3.26	11.99
5.5	8	5.87	2.37	15.11
6.5	7	5.84	2.50	14.47
7.5	7	2.16	2.43	9.95
8.5	6	1.54	3.23	12.16
9.5	6	1.46	1.47	13.03
10.5	3	1.79	1.49	6.92
11.5	1	0.58	2.32	32.08

Table II.6: Average Metal Concentration in Core Samples

Depth (in)	**Average Metal Concentration (mg/kg)**		
	As	**Cu**	**Cr**
0.25	0.32	3.32	4.97
0.75	1.76	2.20	4.84
1.25	1.10	1.63	5.29
1.75	0.12	1.57	4.43
2.5	0.30	1.28	5.80
3.5	1.28	2.85	11.46
4.5	0.60	2.84	11.70
5.5	0.33	1.71	5.90
6.5	0.16	0.76	3.25
7.9	0.96	0.62	3.80

Table II.7: Metal Concentration in BR Control Core Sample

Location		N	Average (mg/kg)	Standard Deviation (mg/kg)	Maximum		Minimum	
					Concentration (mg/kg)	Depth[1] (in)	Concentration (mg/kg)	Depth[1] (in)
Arsenic								
Gainesville	BP	13	10.2	14.8	35.29	1.25	0.25	9.5
	BR	14	5.85	6.66	25.34	0.25	0.38	10.5
	PP	12	4.58	4.75	16.02	0.25	0.98	7.5
Tallahassee	TB	11	8.09	5.27	19.55	0.25	1.35	8.5
	MG	13	3.94	2.55	11.19	0.25	1.34	3.5
Miami	AD	12	1.84	1.36	4.97	0.25	0.73	9.8
	TP	10	30.88	24.16	67.58	1.75	3.64	4.5
	OP	8	39.76	24.10	64.61	0.75	2.55	5.6
All Sites		93	11.35	16.84	67.58	1.75	0.25	9.5
Chromium								
Gainesville	BP	13	17.5	25.0	64.0	0.75	0.56	4.5
	BR	14	17.1	8.64	32.1	11.50	4.25	10.5
	PP	12	29.0	14.8	51.8	0.25	4.10	1.75
Tallahassee	TB	11	7.87	5.88	23.0	0.25	3.18	9.9
	MG	13	15.7	9.92	47.0	6.50	8.18	7.5
Miami	AD	12	6.67	4.49	16.9	0.75	0.93	2.5
	TP	10	25.0	19.5	65.1	0.75	8.35	2.5
	OP	8	18.1	14.6	41.5	0.75	6.02	5.6
All Sites		93	16.9	15.5	65.1	0.75	0.56	4.5
Copper								
Gainesville	BP	13	22.8	37.5	108.0	1.25	0.10	7.5
	BR	14	5.84	4.25	18.3	0.25	0.69	10.5
	PP	12	5.36	9.63	30.5	0.25	0.29	2.5
Tallahassee	TB	11	5.12	6.56	23.8	0.25	0.61	9.9
	MG	13	3.47	0.62	4.71	9.50	2.39	3.5
Miami	AD	12	2.57	2.36	6.41	0.25	0.55	8.5
	TP	10	9.17	10.9	30.6	1.25	0.76	7.9
	OP	8	7.41	6.80	21.5	1.25	1.70	5.6
All Sites		93	7.77	16.0	108.0	1.25	0.10	7.5

[1] Depths correspond to the mid-point of the core portion analyzed. The upper 2 inches were analyzed in ½ increments and 1 inch increments thereafter. The top of the core corresponds to 0.25 inches.

Table II.8: Summary of Arsenic, Chromium, and Copper Soil Core Results

II.7 SUMMARY AND CONCLUSIONS

This section focuses on summarizing the data from the preceding sections (II.7.a), computing theoretical arsenic concentrations below CCA-treated decks (II.7.b), computing the areal extent of the potential impacts of CCA-treated decks (II.7.c) ,and comparing the results of the arsenic analysis to clean soils standards (II.7.d).

II.7.a Summary

Results indicate that CCA-treated decks do in fact impact the soils below them. The average arsenic concentration of surface soils below the decks was 28.5 mg/kg whereas the average of the surface soil controls was between 1.3 and 1.5 mg/kg. The differences between the below deck soils and controls was statistically significant at 95% confidence for 8 of the 9 decks evaluated. The only "below deck" surface soil found not to be elevated was the Lake Talquin deck. The Lake Talquin deck was the only deck that was not confirmed for CCA treatment. The data suggest that CCA-treated decks impact the soil arsenic concentrations up to a depth of 4 to 8 inches, thus confirming that the impacts are not limited to CCA-treated sawdust that may have been deposited on the soil during the deck's construction. Within a particular site volatile solids content appears to be correlated with arsenic concentrations. This correlation is weak between sites.

The decks were also observed to impact soil chromium and copper concentrations. The average chromium and copper concentrations in the below deck soils were 34 and 40 mg/kg, respectively, for samples above detection limits. In comparison, the chromium and copper concentrations for the controls were 9.8 and 6.7 mg/kg, respectively, on average. The differences between below deck soils and controls was statistically significant at 95% confidence for 3 of the decks for chromium and for 6 of the decks for copper. The lack of statistical significance for the remaining decks may be due to the relatively higher background chromium and copper concentrations found at each site (versus that for arsenic). Chen et al., 1999, report that the geometric mean Florida soil concentration for arsenic, chromium and copper as 0.42 mg/kg, 8.45 mg/kg and 2.21 mg/kg respectively.

The ratio of the arsenic and chromium in the below deck surface soils was consistent with the stoichiometry of CCA type C, whereas the ratio of arsenic to copper in the below deck surface soils suggests preferential leaching of copper from the deck or preferential sorption of copper onto the below deck soils.

II.7.b Theoretical Concentrations of Arsenic Below CCA-Treated Decks

A set of computations were performed to estimate the resultant increase in soil arsenic concentrations assuming that a particular fraction of the CCA chemical were to leach from CCA-treated decks. These computations were performed in order to determine whether the amount of arsenic measured in the soil was reasonable. The computations assume that 12 ft^3 of treated wood covers a soil area of 64 ft^2. The concentration of arsenic in the deck wood is assumed to be 2000 mg/kg which is equivalent to a 0.3 pcf retention level. The density of the soil is assumed to be 2.65 g/cm^3 and the porosity is assumed at 0.33. The results from such a computation (figure II.11) indicate that in order to increase the soil concentrations by 25 mg/kg in the upper 8 inches, only 15% of the CCA chemical needs to leach. If the impact is assumed to be limited to the upper 2 inches, then less than 5% of the CCA chemical needs to leach in order to increase the soil concentration by 25 mg/kg. This analysis indicates that the results from the soil sampling study are consistent with a reasonable fraction of CCA chemical leached from the decks. The analysis also suggests that only a relatively small fraction of the CCA chemical needs to leach from CCA-treated decks in order to observe measurable impacts on the soil.

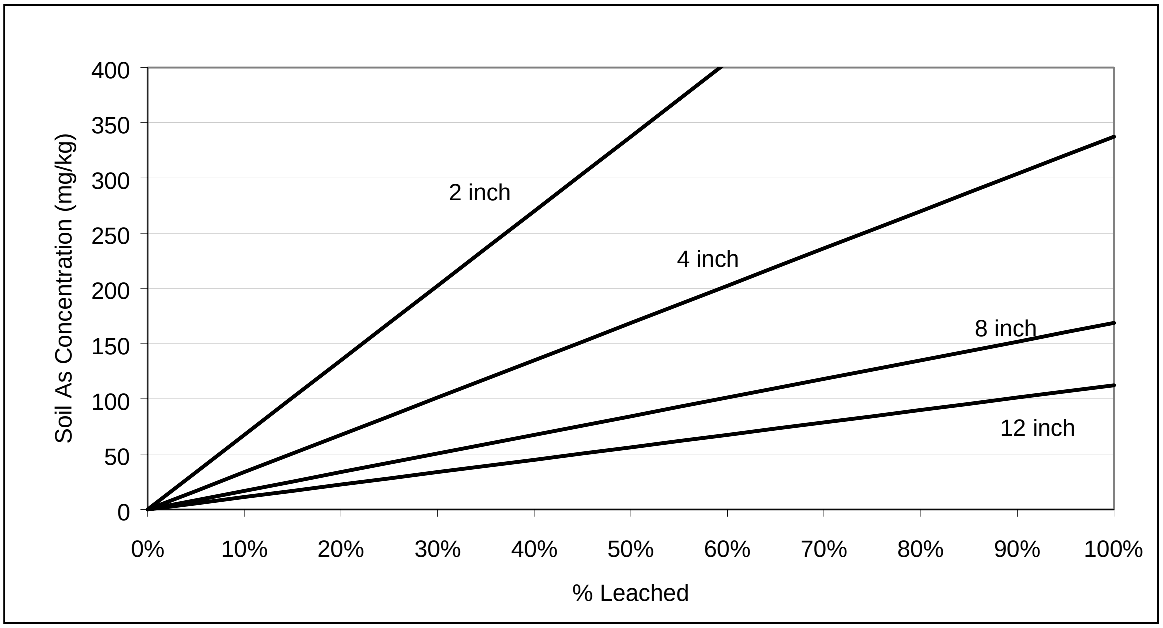

Figure II.11: Theoretical Soil Arsenic Concentration Versus % CCA Leached and Depth of Soil Impacted

II.7.c Areal Extent of Potential Impacts of CCA-Treated Decks

Approximately 565 million cubic feet of CCA-treated wood have been sold within Florida and of this quantity approximately 36% is used for decks (See chapter III for more information concerning these statistics). In order to convert from cubic feet of wood product to square feet of area, assumptions must be made about the typical construction of a deck. For this computation, it is assumed that an 8 foot by 8 foot deck is covered with 1.5 inch thick deck boards and that the deck is supported by 3 x 6 inch joists around the perimeter. Thus the amount of wood needed for a 64 square foot deck is 12 cubic feet [8x8x (1.5/12) + 4x8x(3/12)x(6/12)]. The equivalent surface area of soil in Florida covered by decks is therefore 25,000 acres [$565\text{x}10^6$ x 0.36 x (64/12) /43,560] or 39 square miles. If it is assumed that the effects are observed in the upper 8 inches, then it is estimated that 60 million tons of soil have been impacted by CCA-treated decks in Florida.

II.7.d Comparison of Arsenic Data to Clean Soil Standards

The deck soil sample arsenic concentrations were compared to Florida's Soil Cleanup Target Levels (SCTLs). The Florida SCTLs are risk-based soil concentrations that have been developed for a number of different pollutants, including arsenic. The SCTLS have been developed using a set of assumptions regarding the properties of the soil; the characteristics of the exposure; and specific chemical toxicity. A number of different SCTLs have been developed for application in various land use scenarios and for both direct exposure (ingestion, dermal contact, and inhalation) and leaching to groundwater. Although the SCTL may be modified for site-specific conditions, properties of a generic Florida soil were used in the SCTL development (e.g organic carbon content).

The residential SCTL for direct exposure is 0.8 mg/kg. The mean arsenic concentration exceeded 0.8 mg/kg at eight out of the nine sites studied. The one site that was below the 0.8 mg/kg SCTL was the Lake Talquin site in Tallahassee which was the only deck sampled that was not constructed of CCA-treated wood. Every sample collected under the Lake Talquin foot bridge was less than 0.8 mg/kg. All 65 of the remaining samples exceeded the residential SCTL for arsenic. The industrial SCTL for direct exposure is 3.7 mg/kg. As with the residential SCTL, the mean arsenic concentration for each site exceeded the industrial SCTL with the exception of Lake Talquin. Sixty two of the remaining 65 samples exceeded the industrial SCTL. Figure II.12 shows all soil samples compared to the SCTLs.

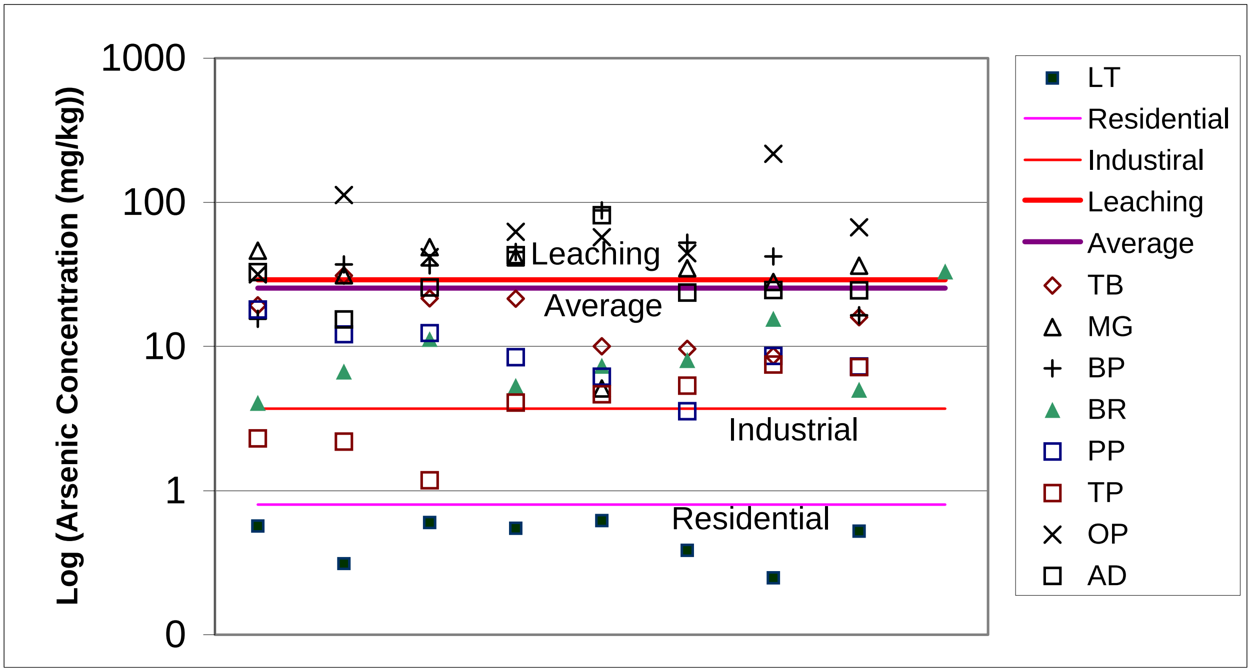

Figure II.12: Log of Arsenic Concentrations

The SCTL for leaching to groundwater (based on the groundwater standard of 50µg/l) is 29 mg/kg. The mean arsenic concentration was greater than 29 mg/kg at 4 of the 9 sites. Twenty-four of the 73 deck soil samples collected were above the leaching-to-groundwater SCTL. It is worth noting that since the leaching SCTL is based on the current primary drinking water standard of 50 µg/l, if this standard is lowered, the SCTL will be lowered accordingly. The U.S. EPA, 2001, has proposed lowering the standard for arsenic from 50 µg/l to 10 µg/l. If the proposed standard is finalized at 10 µg/l, the arsenic leaching SCTL would be lowered to 5.8 mg/kg, in which 7 of the 8 sites CCA-treated deck sites would exceed the level and 54 of the 65 surface soil samples (excluding site LT) would exceed.

Chapters III, IV, and V along with the corresponding appendices were omitted in this abbreviated version.

CHAPTER VI

SUMMARY, RECOMMENDATIONS, AND ACKNOWLEDGMENTS

CHAPTER VI,
SUMMARY, RECOMMENDATIONS, AND ACKNOWLEDGMENTS

VI.1 SUMMARY & RECOMMENDATIONS

A summary along with concluding remarks are provided for each of the investigative chapters (Chapter II through VI) of this report.

Chapter II, Metals Concentrations in Soils Below Decks Made of CCA-Treated Wood

Results from the deck soil study indicate that CCA-treated decks caused the surface soil arsenic concentrations below the decks to increase by over two orders of magnitude or 2000%, on average. Increases above background concentrations were also observed for chromium and copper. On average the concentrations of chromium in "below deck" soils was 3 and ½ times larger than the average of the control samples. For copper, the "below deck" soils were, on average, 6 times higher. Data also indicate that the impact of CCA-treated decks is not confined to the soil surface. Core data show that impacts are observed within the upper 3 inches for chromium and copper. For arsenic, the impacts are observed to a depth of roughly 8 inches of soil.

The increases in soil metal concentrations are significant. All of the surface soil samples collected from below decks (except those collected from Lake Talquin) exceeded the residential SCTL of 0.8 mg/kg of arsenic. Of these 65 samples, 62 also exceeded the industrial SCTL of 3.7 mg/kg. If it is assumed that all CCA-treated decks in Florida impact the surrounding soil it can be estimated that roughly 25,000 acres or 60 million tons of soil in Florida are impacted due to the use of CCA-treated decks.

Given the evidence in Chapters II and IV data indicate that the CCA chemical does in fact leach from the treated wood decks. There is the potential for an additional metal burden to the environment that has not been accounted for. This additional burden can be in the form of rainwater and runoff that has been contaminated and discharged into nearby surface water bodies and groundwater. It would be of interest to quantify the overall amount of metals discharged from CCA-treated products It is therefore recommended that a set of experimental decks be constructed that will permit all potential metal discharges to be captured. In particular, the experimental decks should be fitted with a drainage system designed to capture rainwater that has been in contact with the deck, surface runoff, and potential infiltration to the groundwater system. Given the high retention levels associated with marine and freshwater docks, it is also of interest to determine the quantities of CCA leached from such products. It is likely that the quantity of metals released is greater for these products than for decks. Further research should therefore focus on quantifying all releases from CCA-treated products. An emphasis should be placed on wood treated at high retention levels.

Production statistics indicate that the proportion of CCA-treated wood among all wood types used for construction can be as high as 40 to 50%. Such a high proportion of treated wood greatly limits recycling and reuse options for the waste. The disposal forecast model indicates that the majority of treated wood disposed in Florida is in the form of lumber, timbers, and fence posts. The disposal of these products is currently at roughly 4 million cubic feet per year. The peak in the disposal of these products (up to 32 million cubic feet per year) will be likely observed near the year 2020. Disposal of significant quantities of poles is yet to be observed given the longer service life of this product. Currently it is estimated that roughly 0.03 million cubic feet of utility poles are disposed per year. This disposal quantity is anticipated to increase by over a factor of 50 (to 1.55 million cubic feet per year) by the year 2040. The success of current utility pole re-use or “give-away” programs is therefore due, in part, to the relatively small amount of utility poles available and the fact that the poles that are discarded today have not yet reached their service life, thereby maintaining their structural integrity. It is likely that once major power lines are decommissioned that current “give-away” programs will not be able to handle the quantity nor the quality of the wood coming out of service.

The cumulative amount of arsenic imported into the State associated with CCA-treated wood is estimated at 28,600 tons. Of this quantity roughly 1,800 tons have been disposed and 26,800 tons are currently in service. The amount of arsenic associated with CCA-treated wood currently in service (26,800 tons) is enough to increase the arsenic concentration in the upper one inch of Florida soils by 4 mg/kg. The 4 mg/kg is 5 times greater than the residential soil clean-up target level of 0.8 mg/kg established for the state and 1.1 times greater than the industrial soil clean-up target level of 3.7 mg/kg. Evaluating the amount of arsenic with respect to potential water contamination, the 26,800 tons is enough to increase the arsenic concentration of a volume of water equal to 650 times the size of Lake Okeechobee by 10 ug/L, which is the proposed federal drinking water limit for arsenic.

A long-term management plan aimed at minimizing the impacts of arsenic from treated wood should be composed of two parts. It should a) focus on recovering as much of the arsenic that is associated with CCA-treated wood currently in service and b) focus on waste minimization. Approximately 5,600 tons or 20% of the arsenic currently in service can be recovered from wood used in marine/fresh water applications and utility poles. The remainder of the arsenic is associated with outdoor decks, fences, landscape timbers, highway construction, and other miscellaneous uses. The one advantage of most of these remaining uses is that non-arsenical waterborne wood treatment preservatives are available and can be substituted for CCA-treated wood. For example, the non-arsenical wood treatment preservatives ACQ, CBA, CC, and CDDC, have been standardized for the “light duty” uses, such as use in outdoor decks, fences, and landscape timbers. Use of these alternative chemicals for these “light duty” uses could therefore significantly decrease the amount of arsenic (associated with CCA-treated wood) requiring ultimate disposal.

Chapter IV, Leaching of Chromium, Copper, and Arsenic from New CCA-Treated Wood and C&D Debris Wood Mulch

Leaching tests confirmed observations gathered as part of the deck-soil study: the metals in the CCA preservative do leach from the wood under normal environmental conditions. It is frequently cited that the metals do not leach from CCA-treated wood because the chemical is "fixed." While fixation is used to describe the treatment efficacy, something that is well fixed (e.g. 95% fixed) may still leach more than enough to exceed applicable environmental standards or risk-based goals. This was evidenced by the fact that a majority of samples leached using the TCLP exceeded the US EPA's toxicity characteristic limit for arsenic. If not for the regulatory exclusion from being a hazardous waste, CCA-treated wood would routinely be characterized as a hazardous waste. If the exemption were not in place, the cost of disposing CCA-treated wood would likely be much higher.

The TCLP is conducted using a simulated landfill-acid and involves size reducing the waste to less than 9.5 mm. These test requirements are often cited as being unrealistic when assessing certain management scenarios. To address this concern, alternative leaching tests, as well as leaching tests at larger particle sizes were conducted. While copper did leach much less using a synthetic rainwater test (SPLP), arsenic and chromium leached similar amounts as TCLP. Over one-half of the SPLP tests performed exceeded the toxicity characteristic value of 5 mg/L for arsenic. As expected, particle size does have an impact on leaching, but even at the largest particle size (one-100 g block), the arsenic and chromium concentrations were over an order of magnitude above the appropriate ground water guidance concentrations. It was demonstrated that metals, especially arsenic and chromium, continued to leach from the wood in longer leaching tests.

The leaching tests indicate that new CCA-treated wood does not meet the definition of being "non-water soluble" included in the Florida C&D debris regulations. While CCA-treated wood is currently allowed to be disposed in C&D debris landfills, the results show that environmental regulations would be justified in banning the CCA-treated wood from unlined landfill disposal. Since the leaching tests were performed on new, but fixed, CCA-treated wood, one might argue that in service treated wood that had already leached substantial quantities of metals to the environment would not leach upon disposal. Three items indicate that even CCA-treated wood taken out of service would still present a problem for unlined landfill disposal. First, the magnitude by which the leaching tests exceeded the current drinking water standards for arsenic was very large. Second, the multiple extraction procedure (MEP) shows that arsenic continues to leach at appreciable concentrations (above GWCTL) after multiple leachings. Third, the C&D mulch in nearly all cases leached above the GWCTL when tested with the SPLP. The primary question that remains to be explored relative to leaching of "out-of-service" wood is whether it fails TCLP routinely or not.

The evidence of arsenic leaching from C&D debris wood mulch corroborates information collected in previous study years. CCA-treated wood is currently present as part of the recovered C&D debris wood stream. While this may be inadvertent in most cases, it is still happening. If the same guidelines were applied to C&D debris wood mulch as were applied to other land-applied wastes, it would be excluded from land application. While the question of whether land applied mulch would ever cause groundwater problems is debatable, the continued application of such mulch would surely increase the concentration of arsenic in the soils, in a manner similar to that observed under the decks in chapter II. The fact that some of this mulch is being bagged and sold to the general public for home application adds an extra degree of concern to the issue.

Chapter V, Literature Reviews for Future Research

Analytical methods have been identified for chromium speciation analysis, arsenic speciation analysis, and for analysis of the organic co-biocides associated with alternative chemical treated wood products. The methods identified for chromium speciation analysis includes a carbonate-hydroxide extraction followed by analysis using ion chromatography. Initial work with arsenic speciation analysis will include use of the SDDC method which has the capacity to analyze for two arsenic species. Efforts will also focus on identifying readily available equipment (such as an HPLC-ICP/MS and HPLC-HG-AFS) for analyzing additional arsenic species. AWPA standards will be utilized to analyze the organic co-biocides associated with CDDC, and ACQ. A GC method will be implemented to analyze the tebuconazole found in CBA and an IC method will be utilized to analyze for the citrate component found in CC.

Overall Conclusion From This Study

Overall, results indicate that CCA-treated wood does indeed leach arsenic, chromium and copper and thereby increases the metals concentrations in surrounding soil during its service life. The areal extent and volume of soil impacted are significant. The impacts of the increased concentrations on human and ecological health, however, are open to interpretation. While the current 1-in-a-million cancer risk level for arsenic in residential soils is 0.8 mg/kg in Florida, some have questioned the true risk resulting from such concentrations. Future work should focus on evaluating the health impacts associated with these increases.

This study also emphasizes the need to recapture the arsenic associated with CCA-treated wood during its disposal. The quantity of arsenic associated with CCA-treated wood currently in service is significant. Current methods of disposal such as use as mulch or disposal within unlined landfills would not be permitted if current policy practices for waste materials were applied. Efforts should focus on establishing a holistic disposal management plan for CCA-treated wood that would recapture the CCA and dispose of it in an environmentally acceptable manner. Future research should focus on economical options for ultimate disposal.

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APPENDIX A

ADDITIONAL GRAPHS AND FIGURES FOR DECK SOIL STUDY

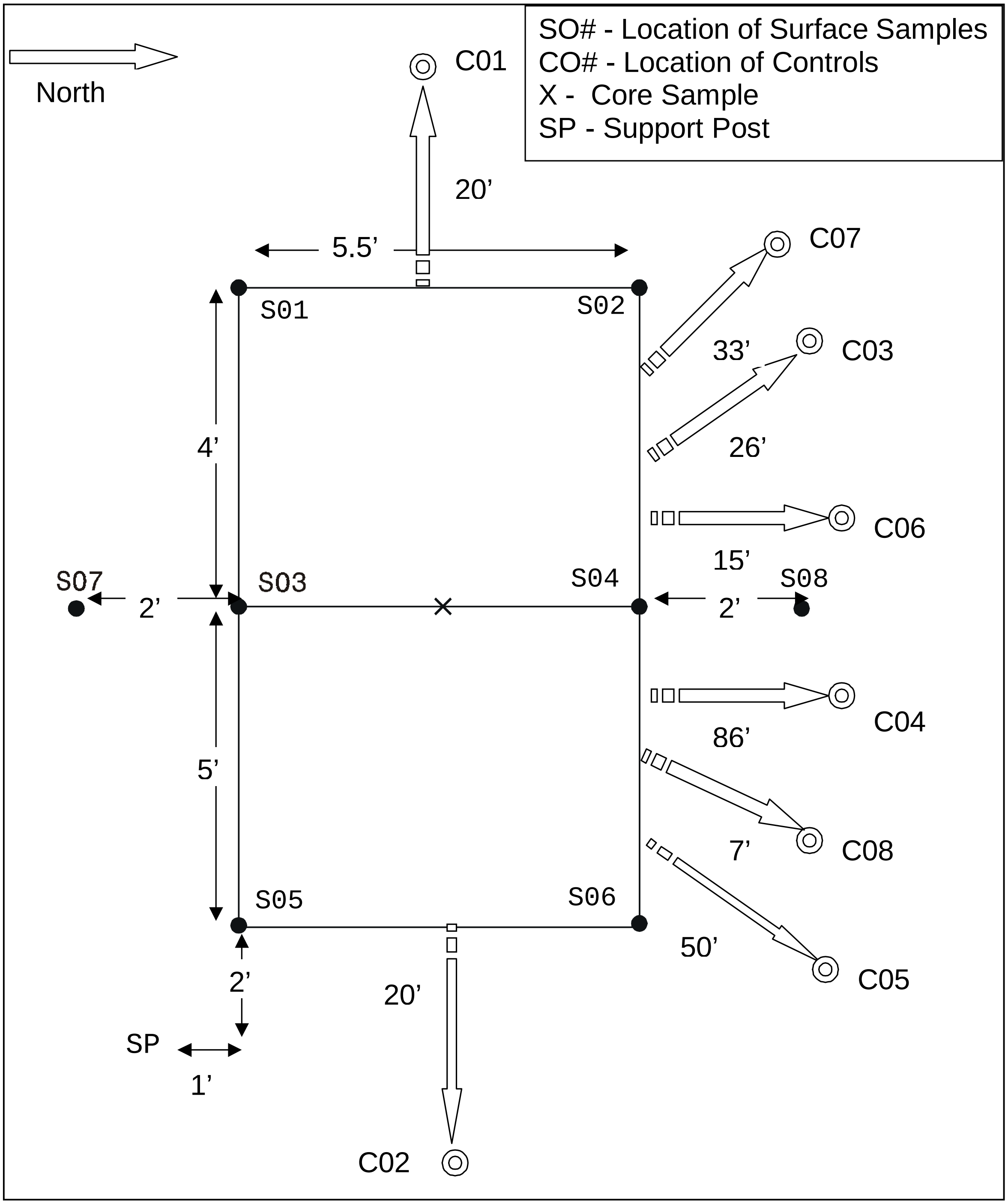


Figure A.1: Sampling Locations for Deck at Bivens Arm Park, BP

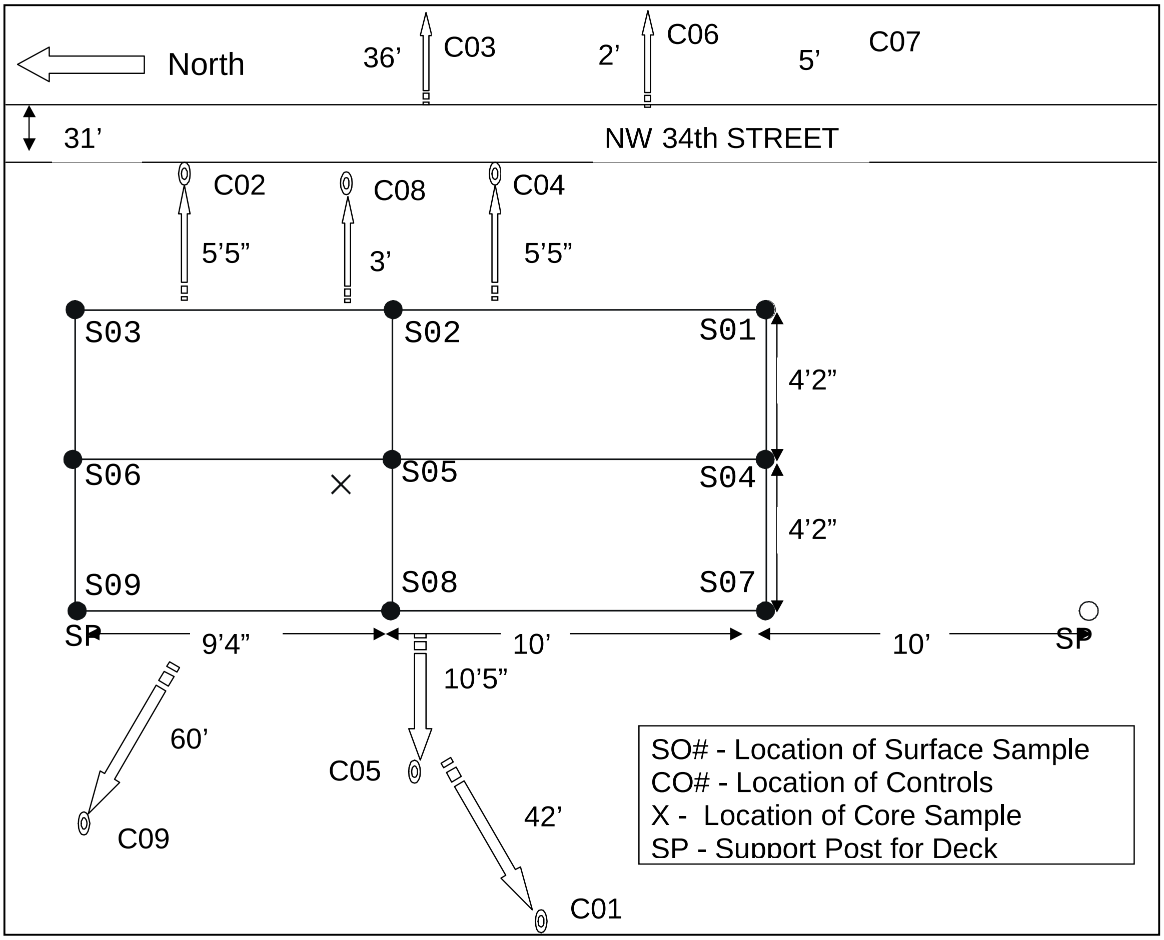


Figure A.2: Sampling Locations for Deck at 34th Street Bridge, BR

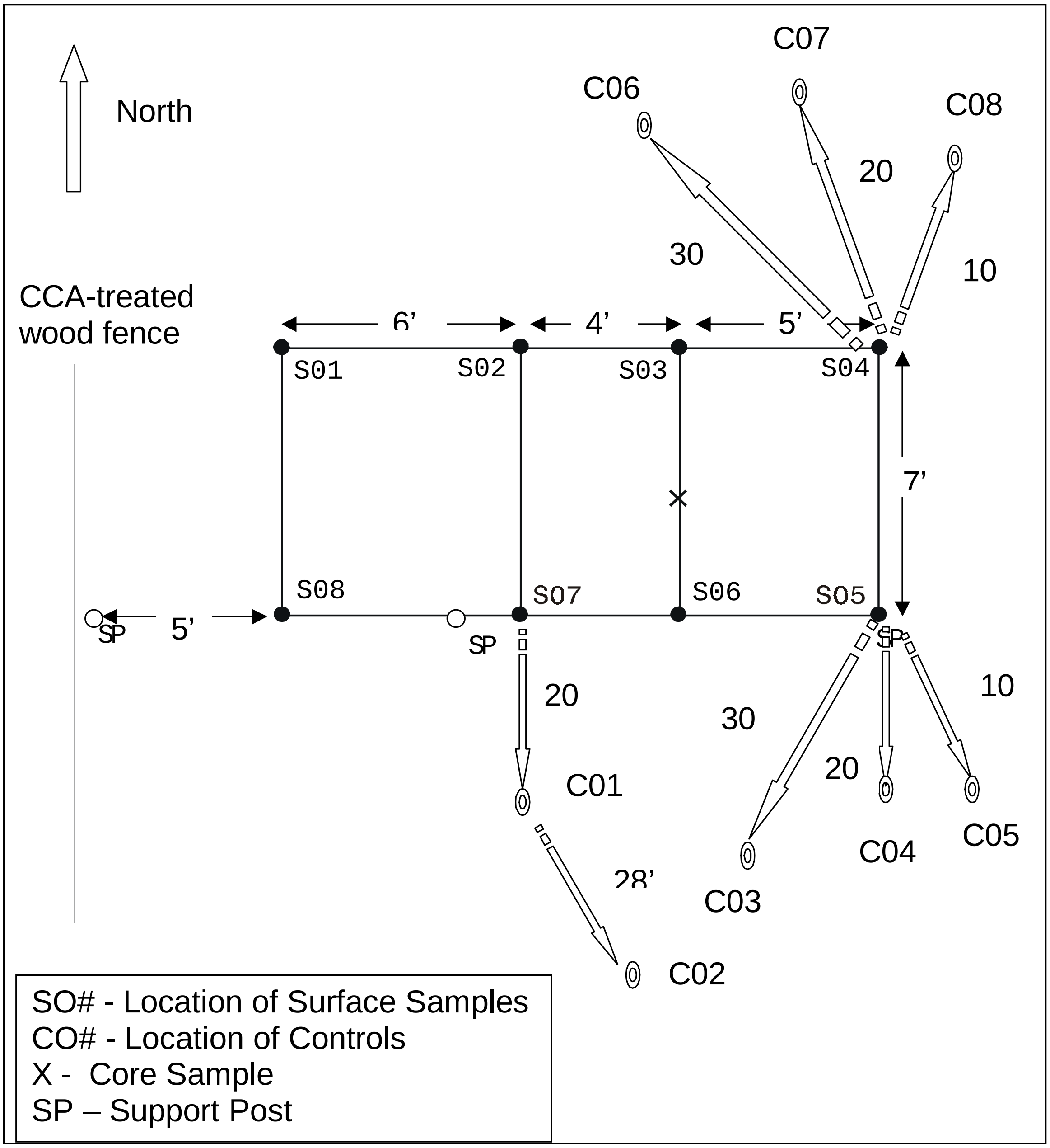


Figure A.3: Sampling Locations for Deck at Paynes Prairie, PP

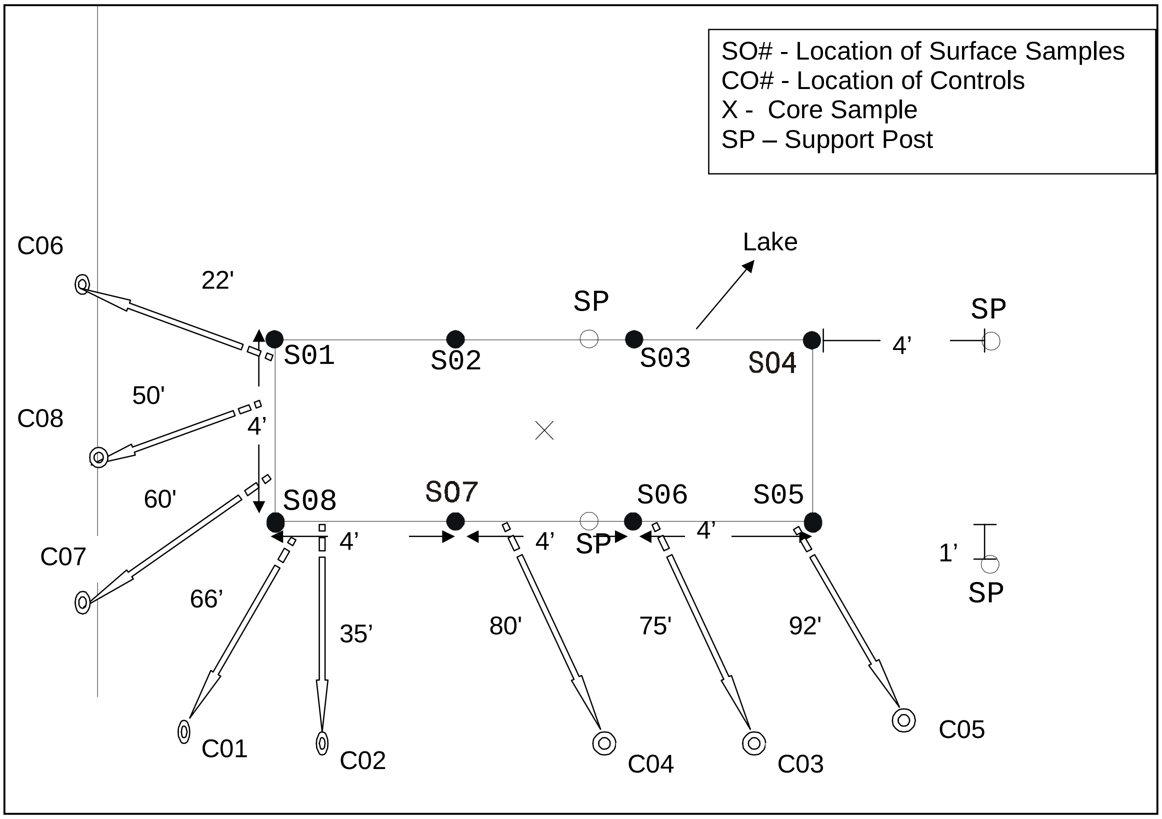


Figure A.4: Sampling Locations for Deck at Tom Brown Park, TB

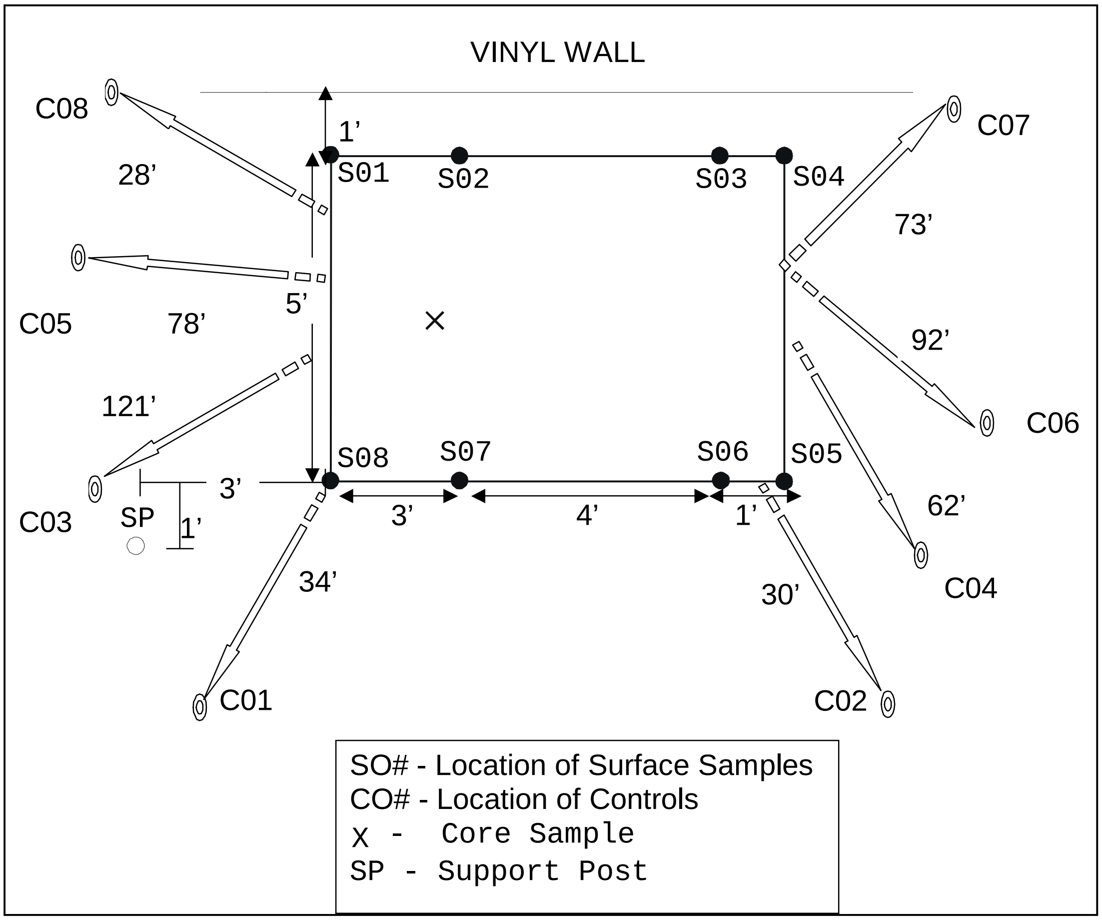


Figure A.5: Sampling Locations for Deck at Maclay Gardens, MG

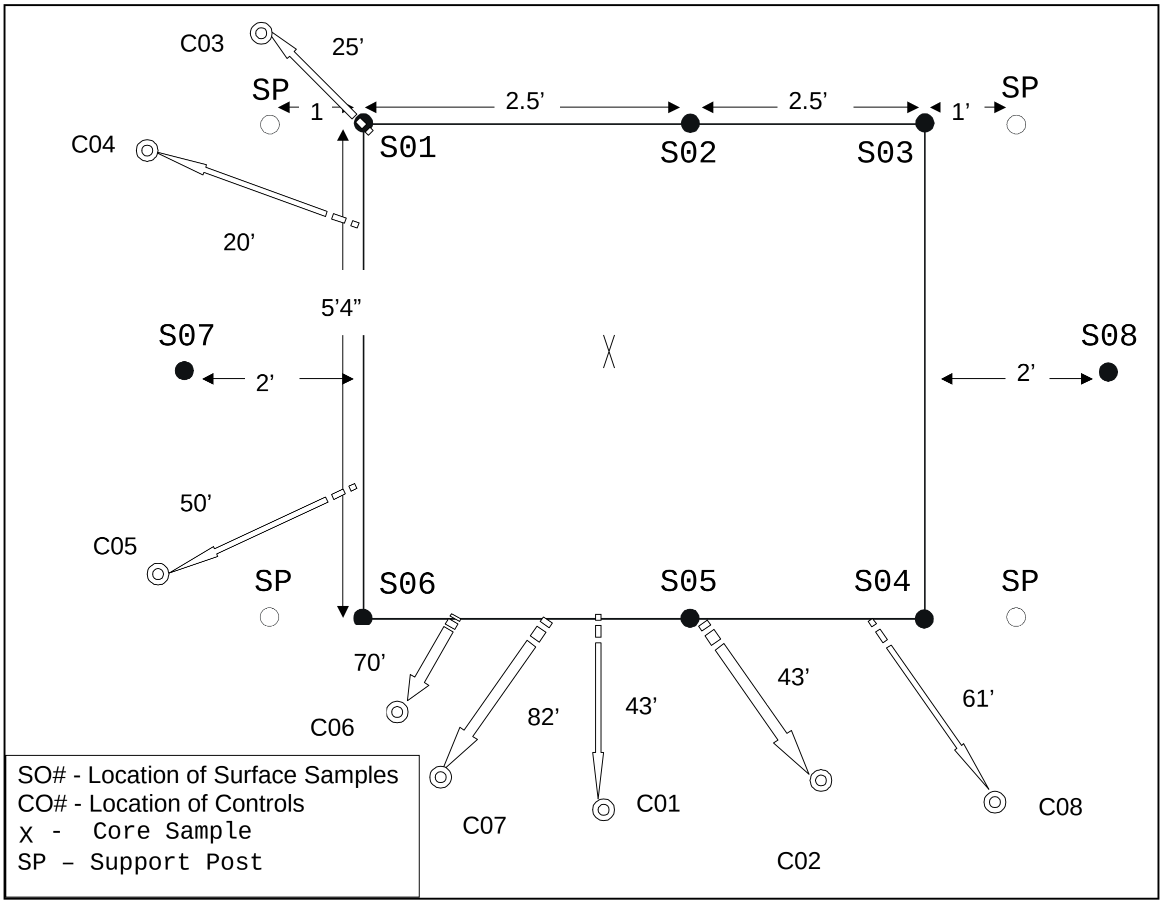


Figure A.6: Sampling Locations for Deck at Lake Talquin, LT

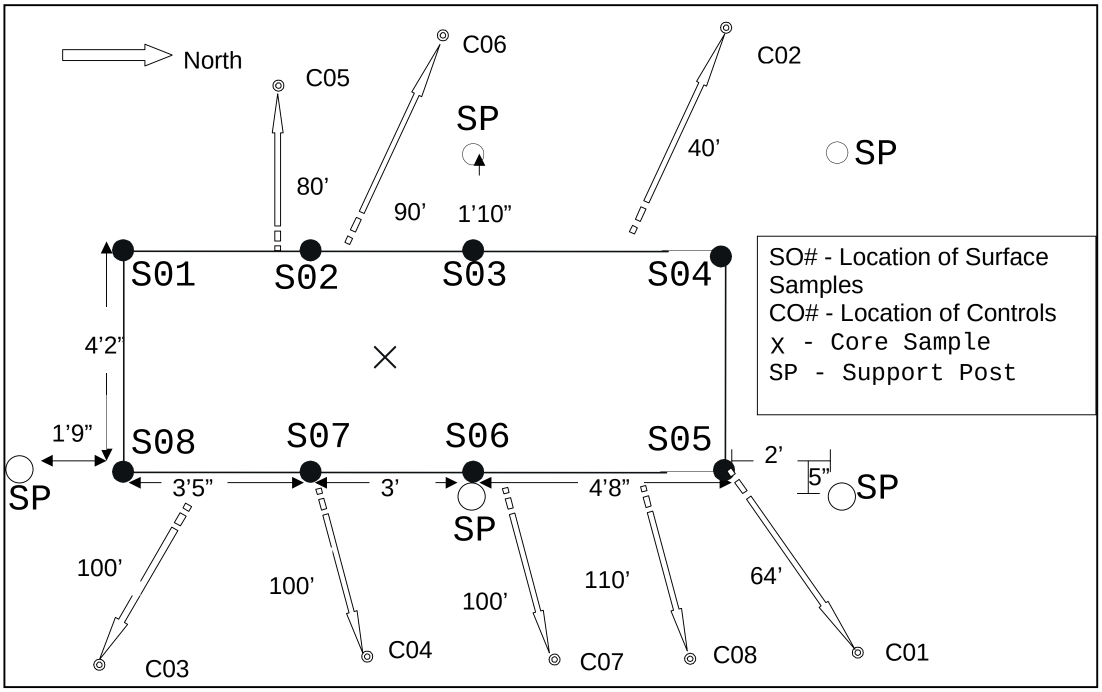


Figure A.7: Sampling Locations for Deck at A.D. Barnes Park, AD

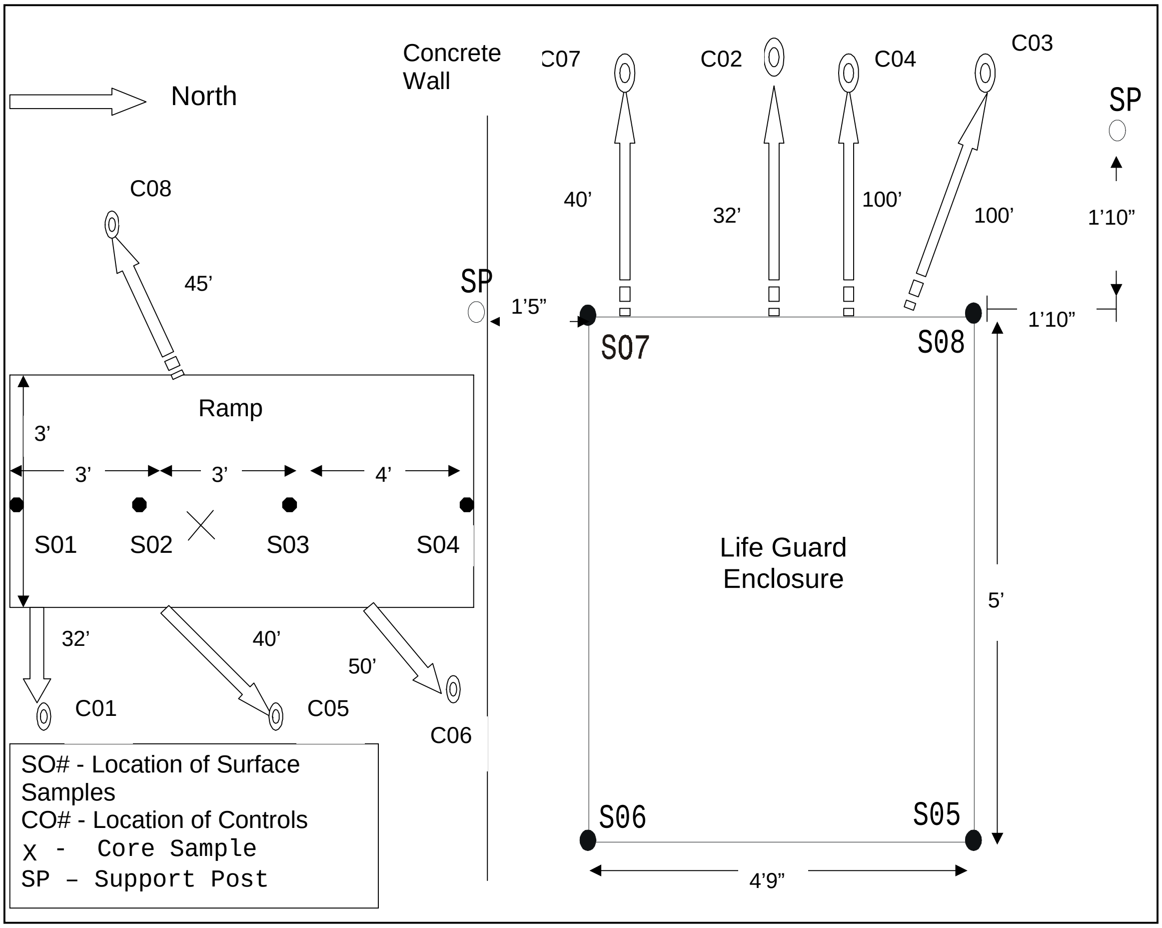


Figure A.8: Sampling Locations for Deck at Tropical Park, TP

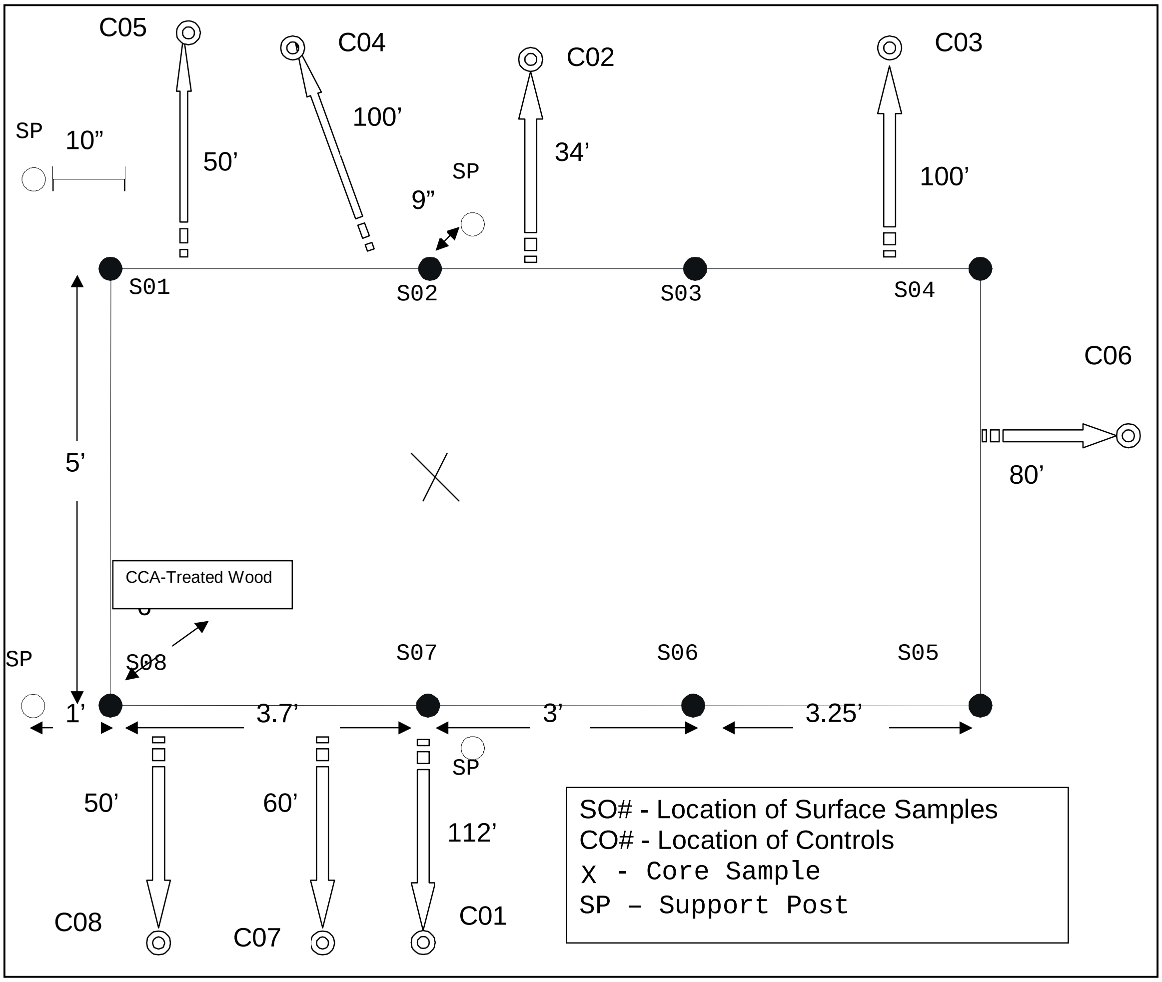


Figure A.9: Sampling Locations for Deck at Oleta River Park, OP

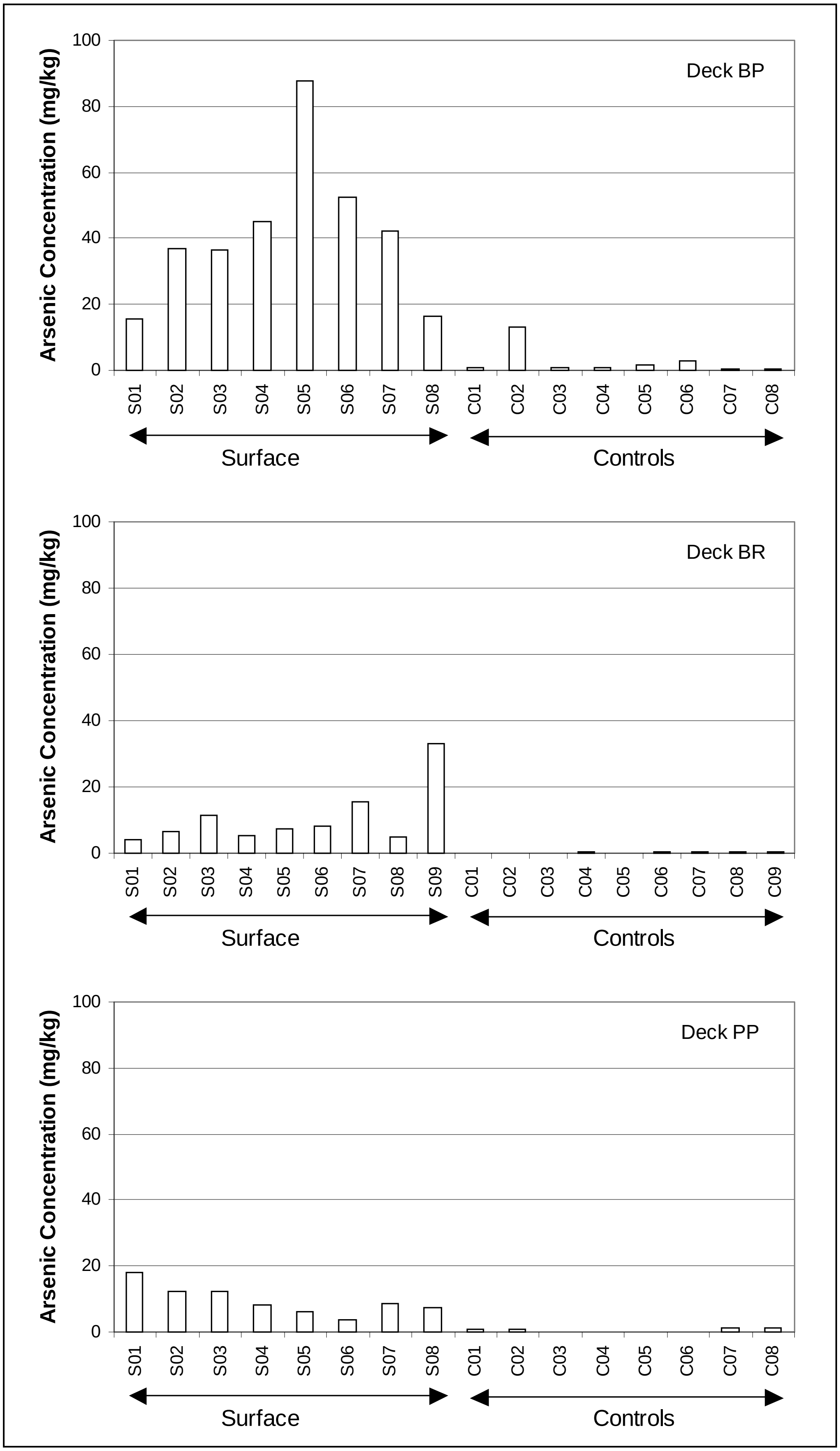


Figure A.10: Arsenic Concentrations Below the Gainesville Decks

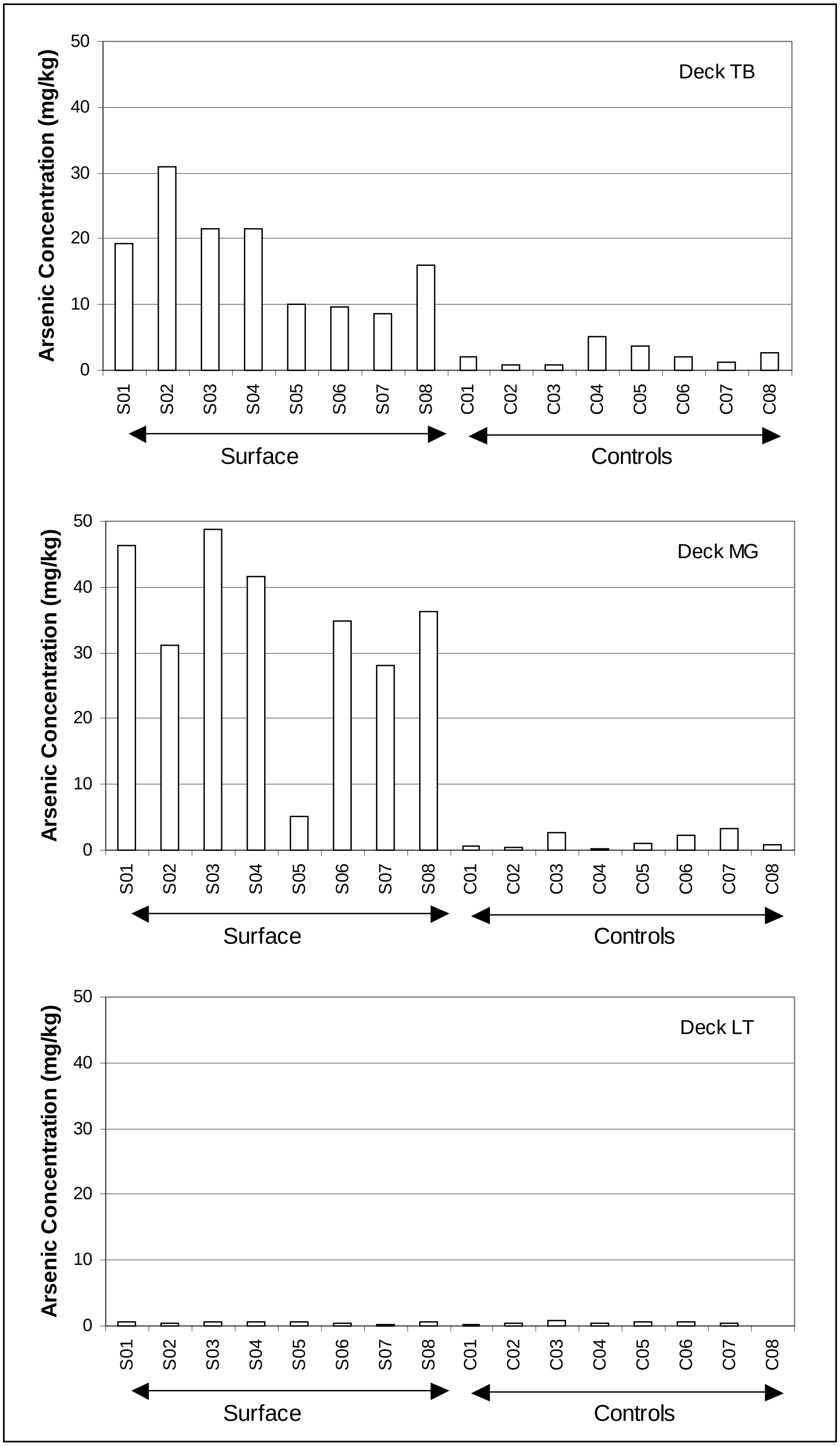


Figure A.11: Arsenic Concentrations Below the Tallahassee Decks

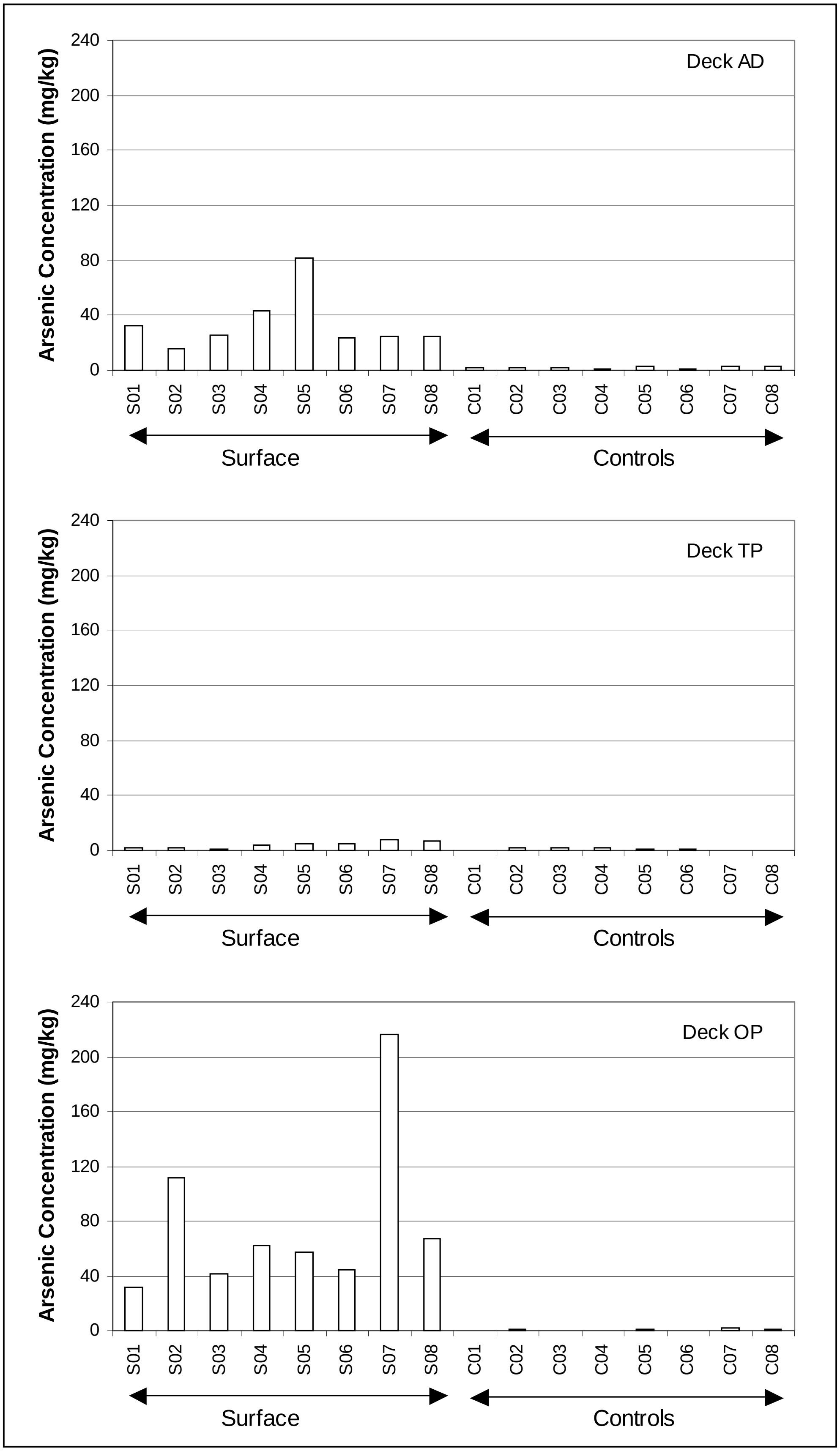


Figure A.12: Arsenic Concentrations Below the Miami Decks

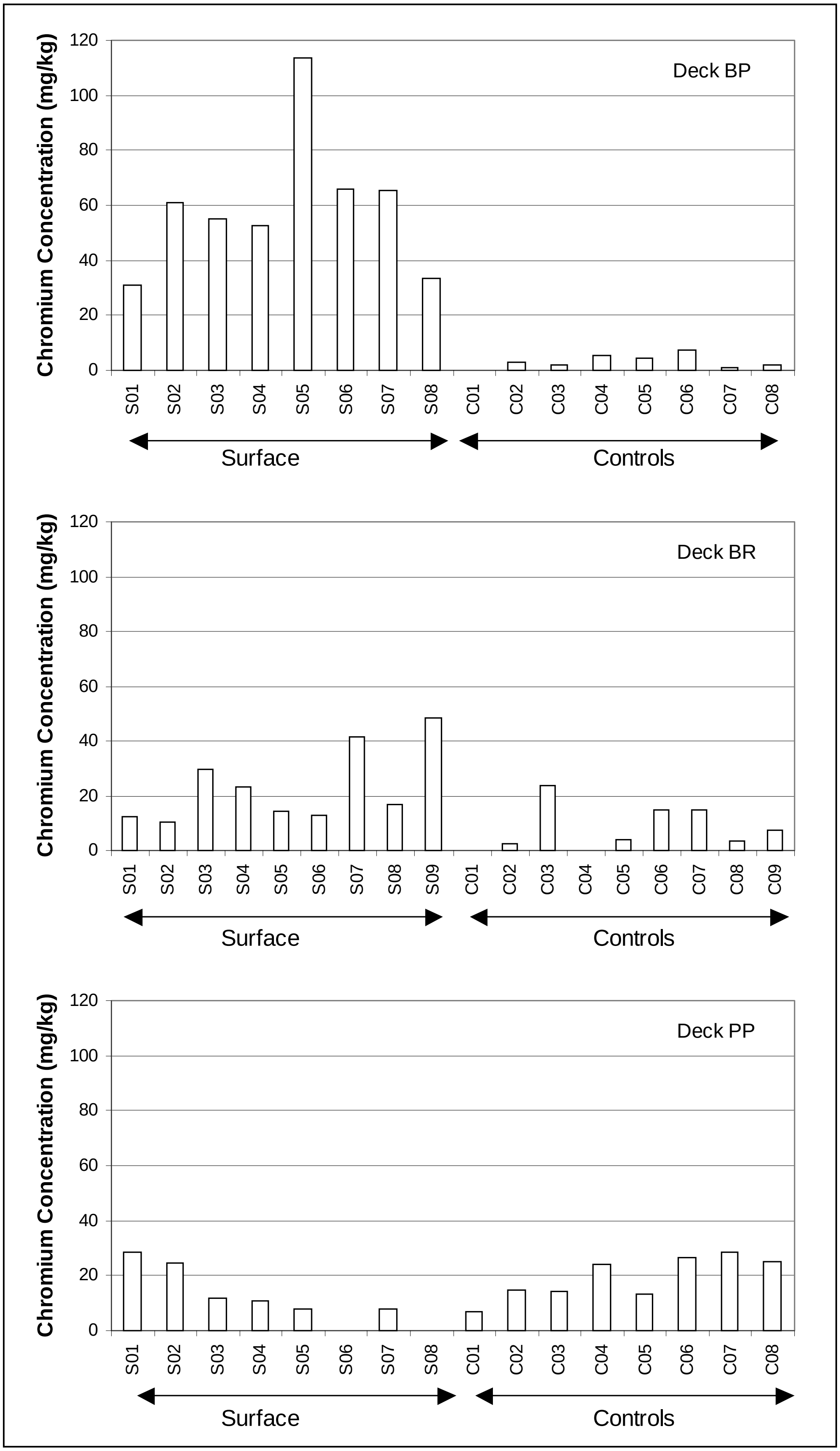


Figure A.13: Chromium Concentrations Below the Gainesville Decks

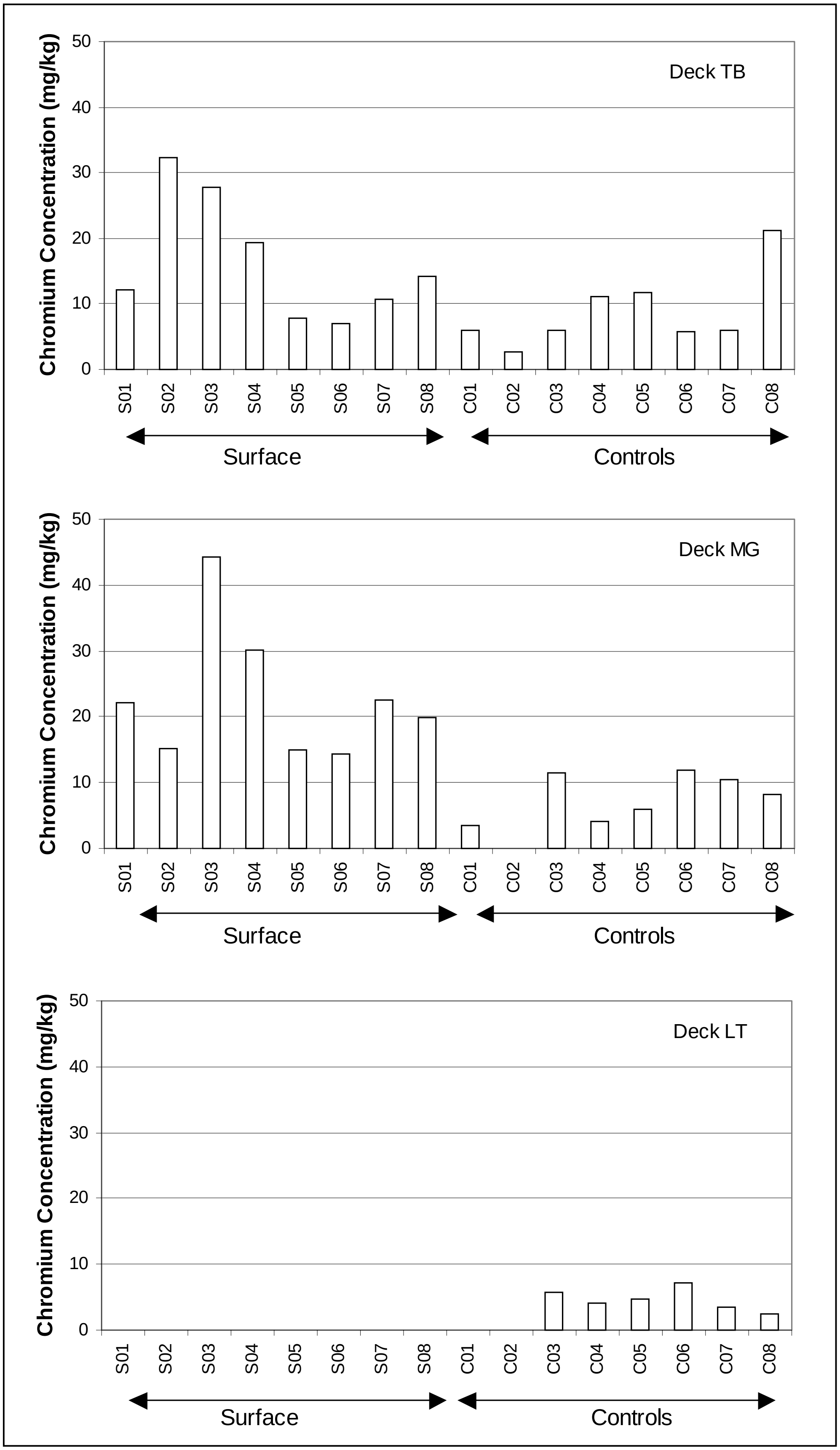
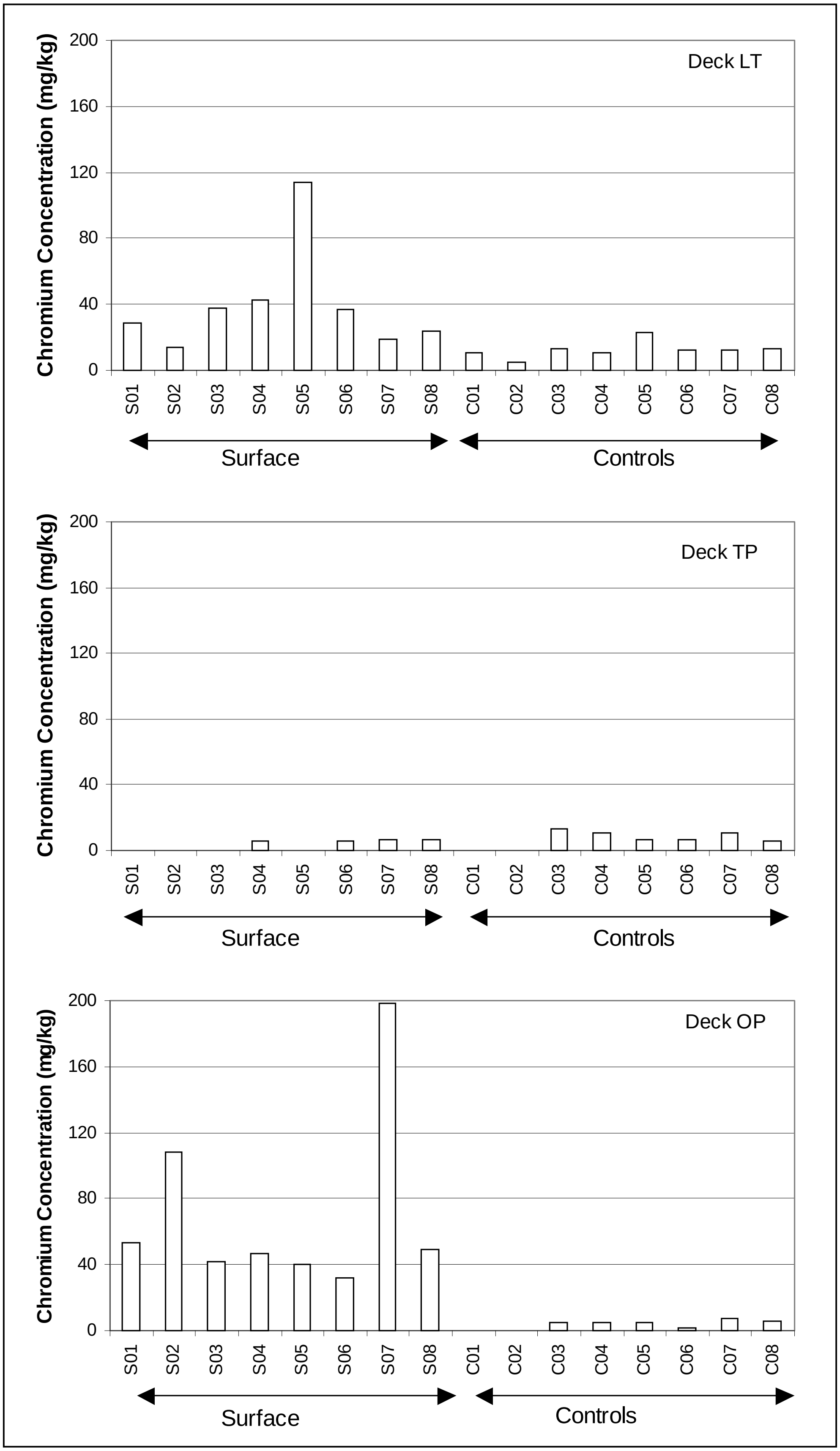


Figure A.14: Chromium Concentrations Below the Tallahassee Decks



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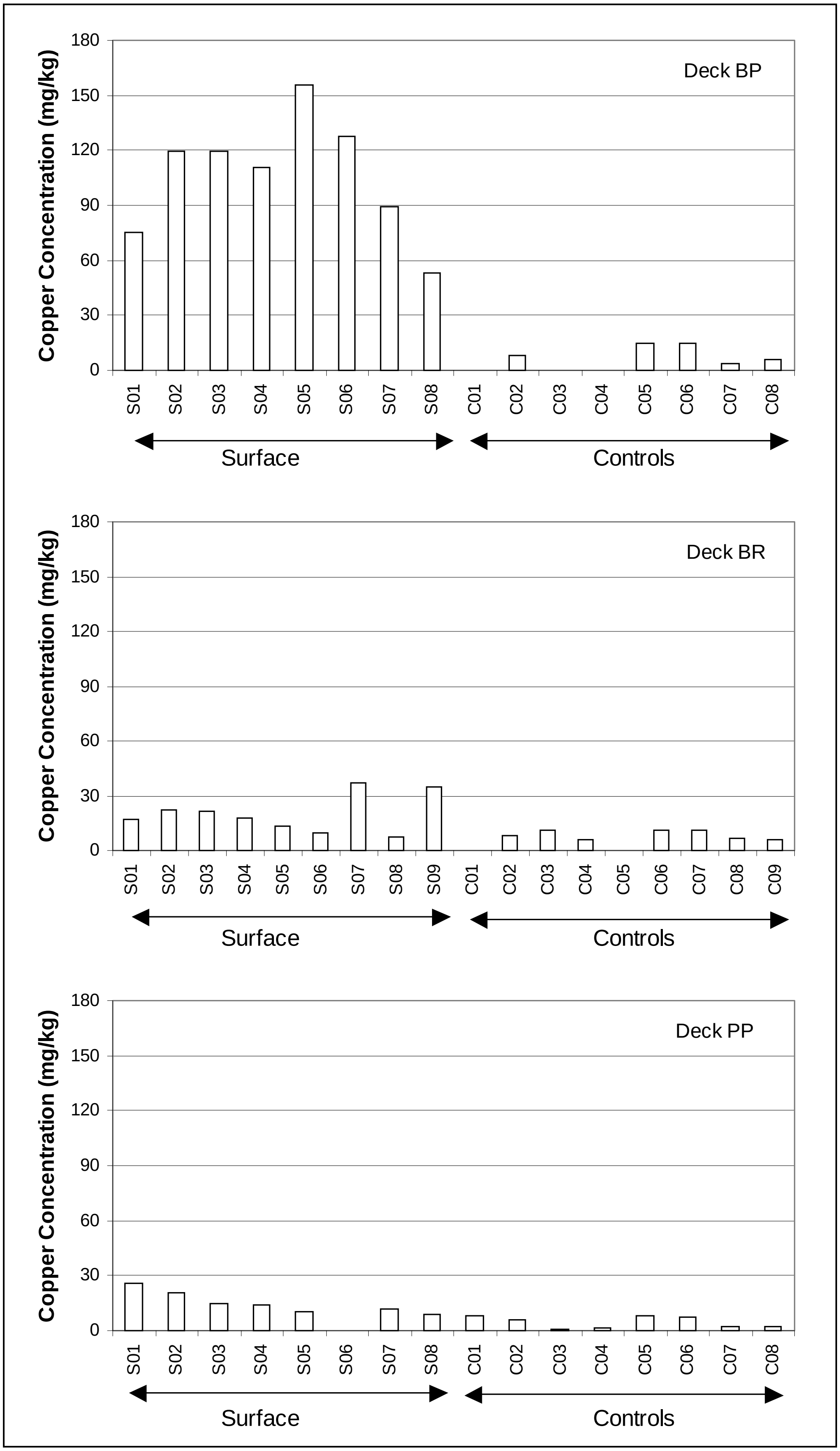

Figure A.16: Copper Concentrations Below the Gainesville Decks

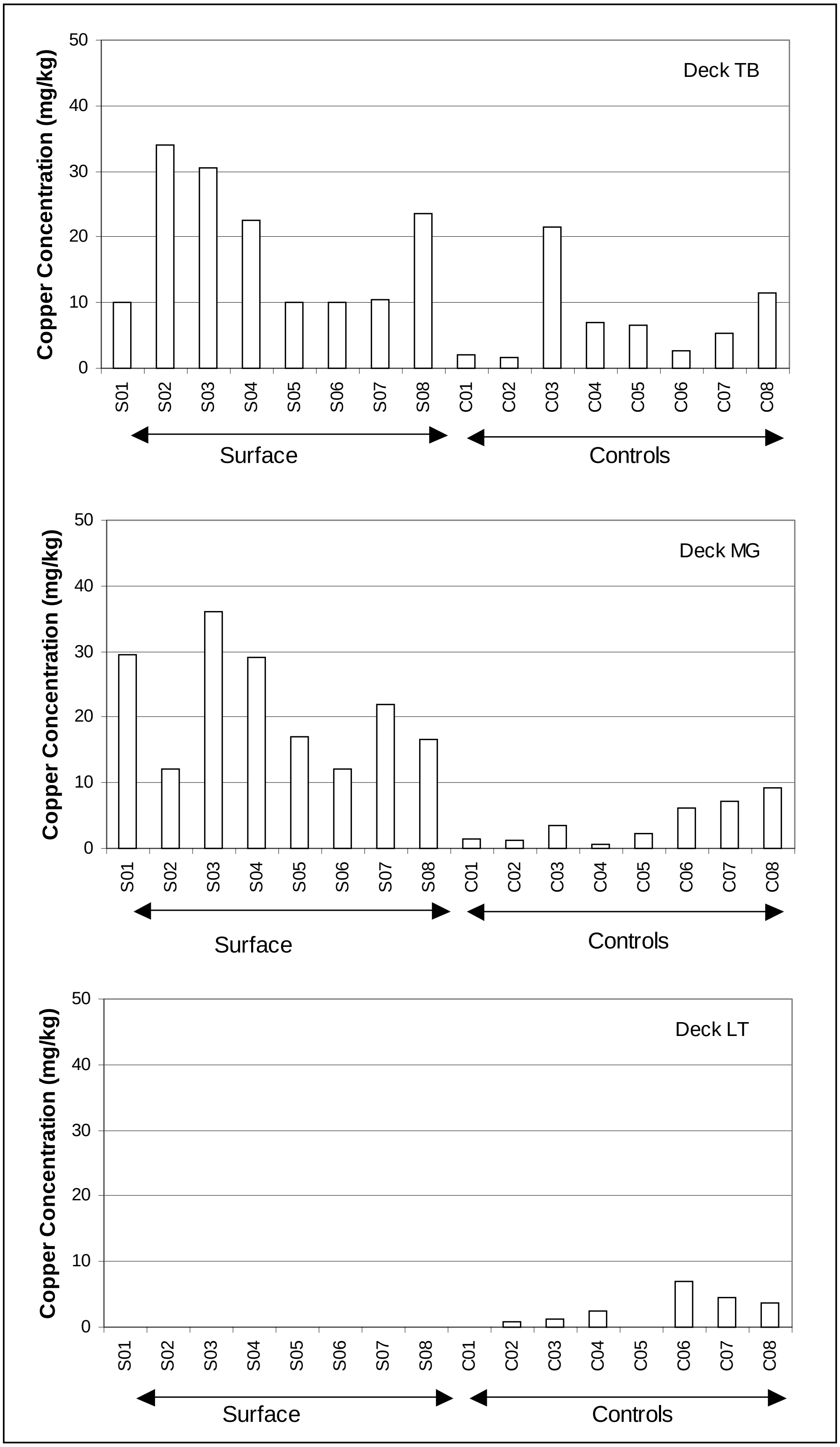

Figure A.17: Copper Concentrations Below the Tallahassee Decks

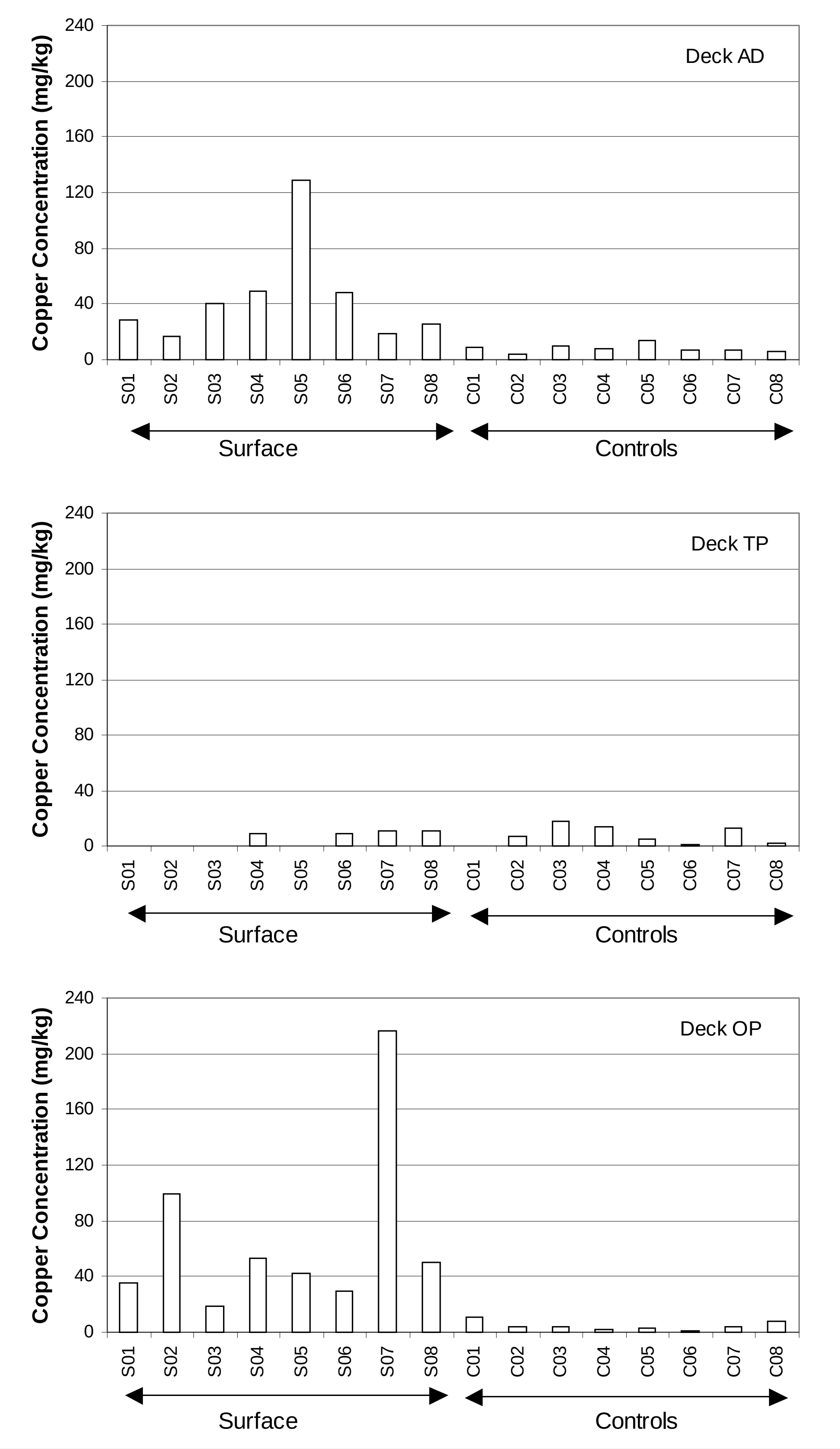

Figure A.18: Copper Concentrations Below the Miami Decks

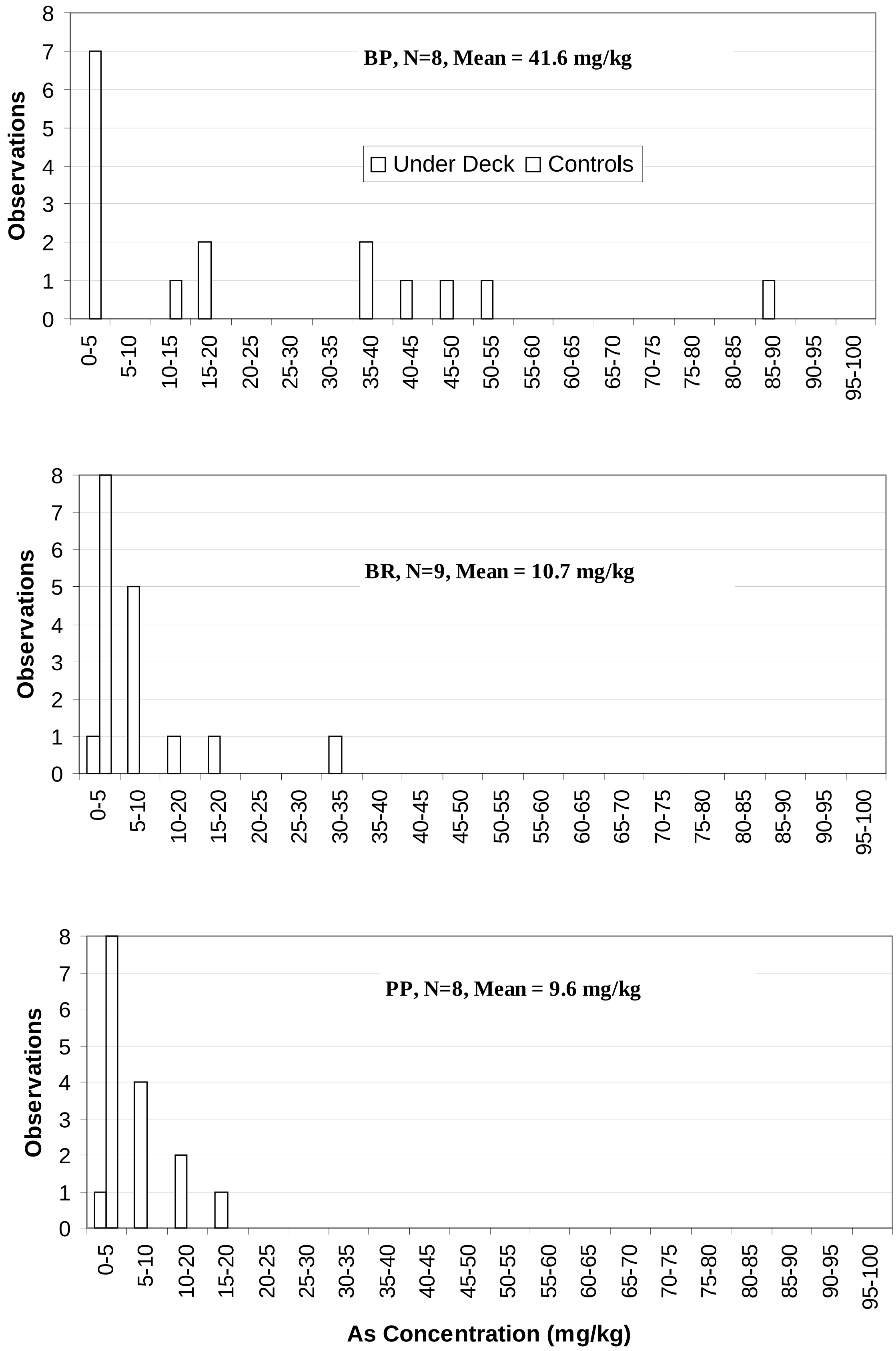

Figure A.19: Arsenic Distribution Below the Gainesville Decks

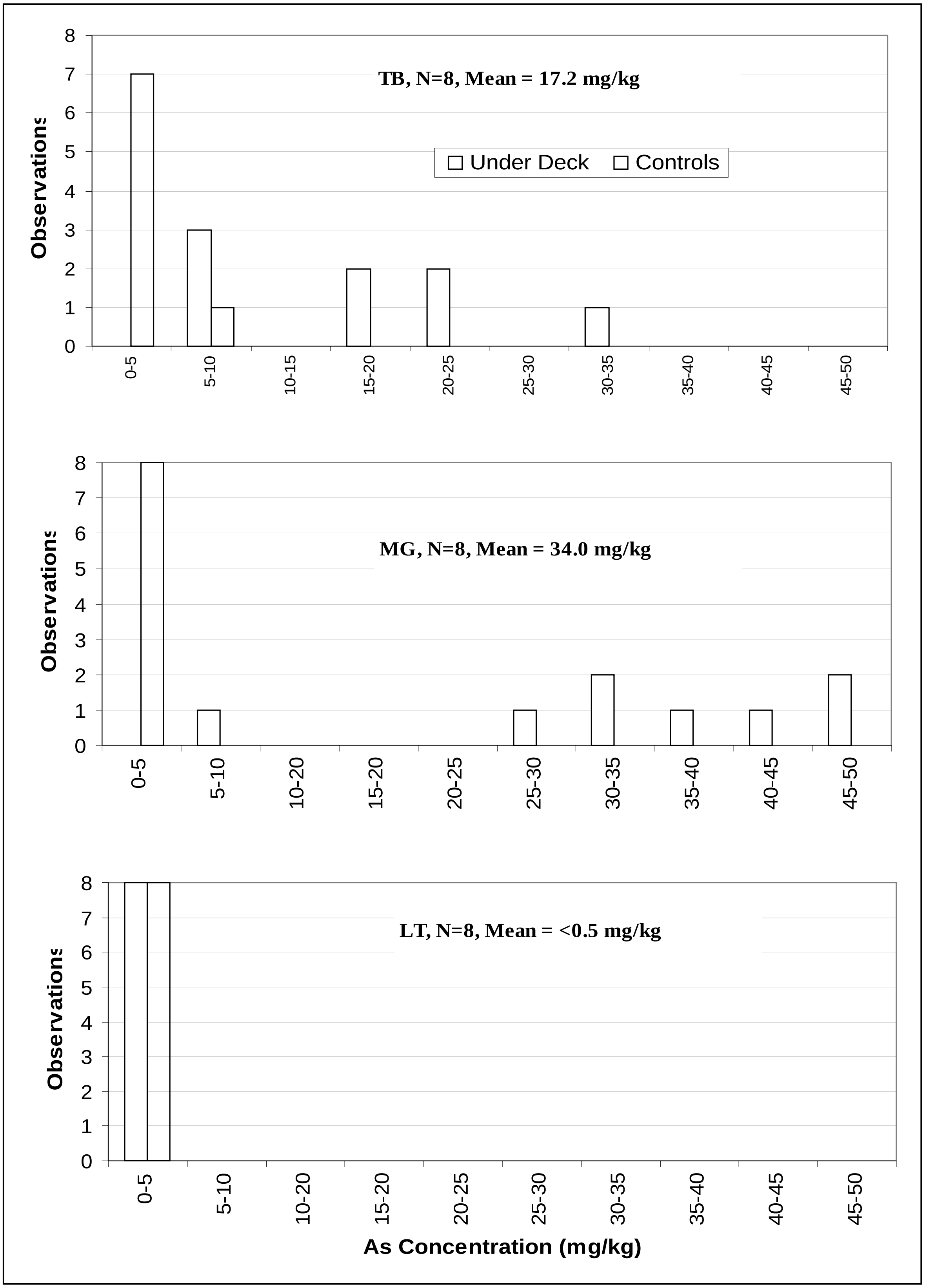

Figure A.20: Arsenic Distribution Below the Tallahassee Decks

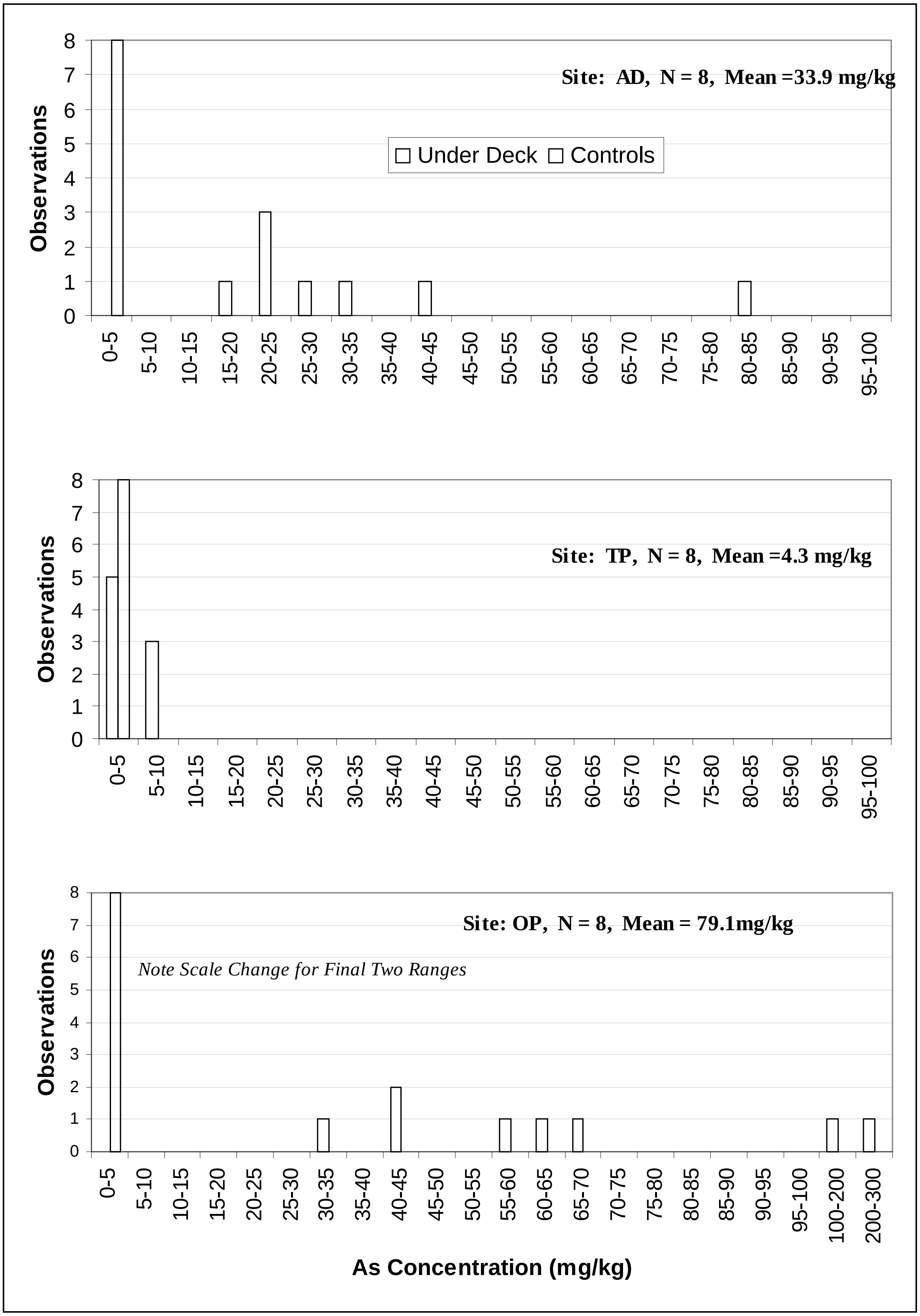

Figure A.21: Arsenic Distribution Below the Miami Decks

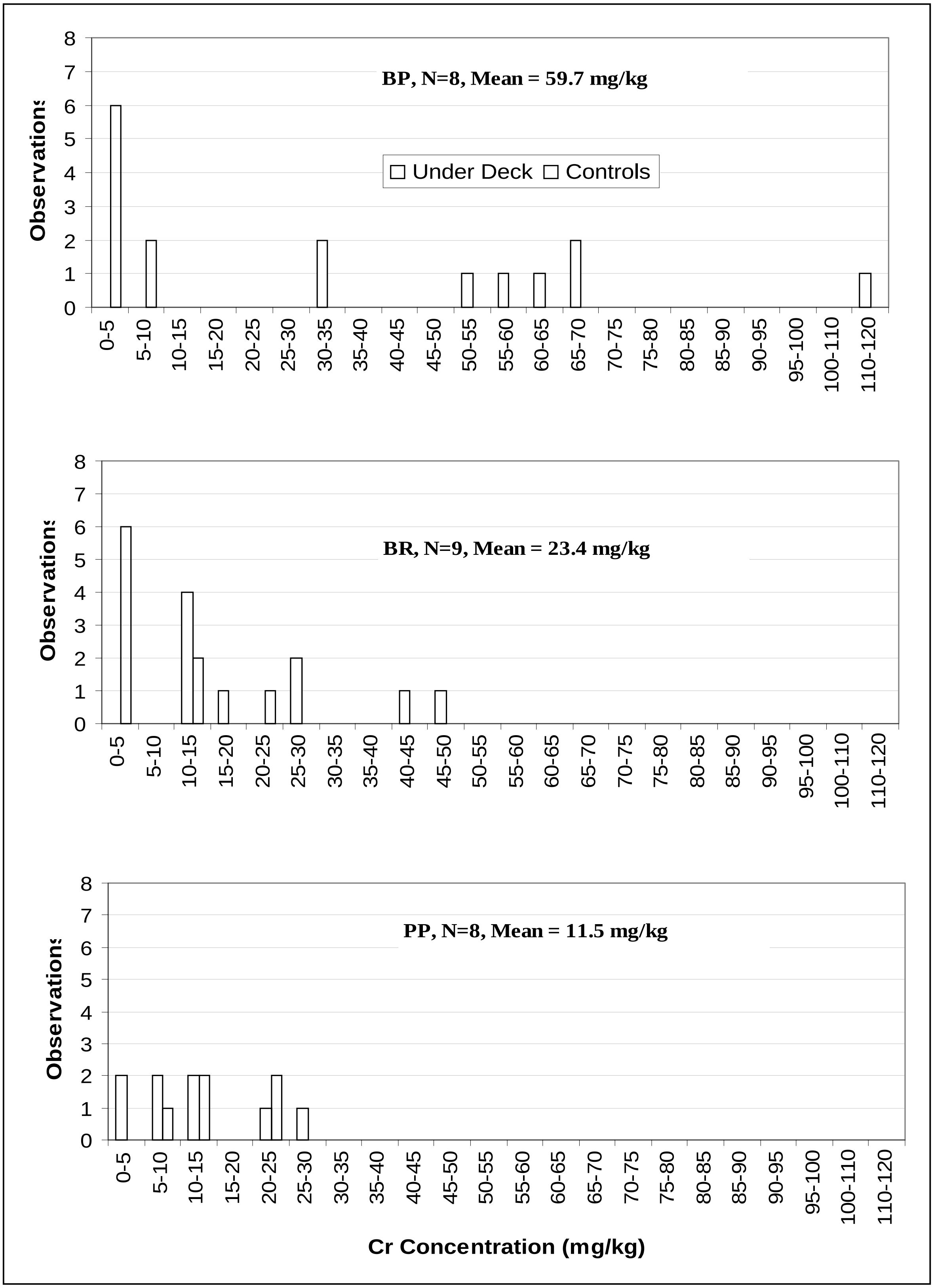

Figure A.22: Chromium Distribution Below the Gainesville Decks

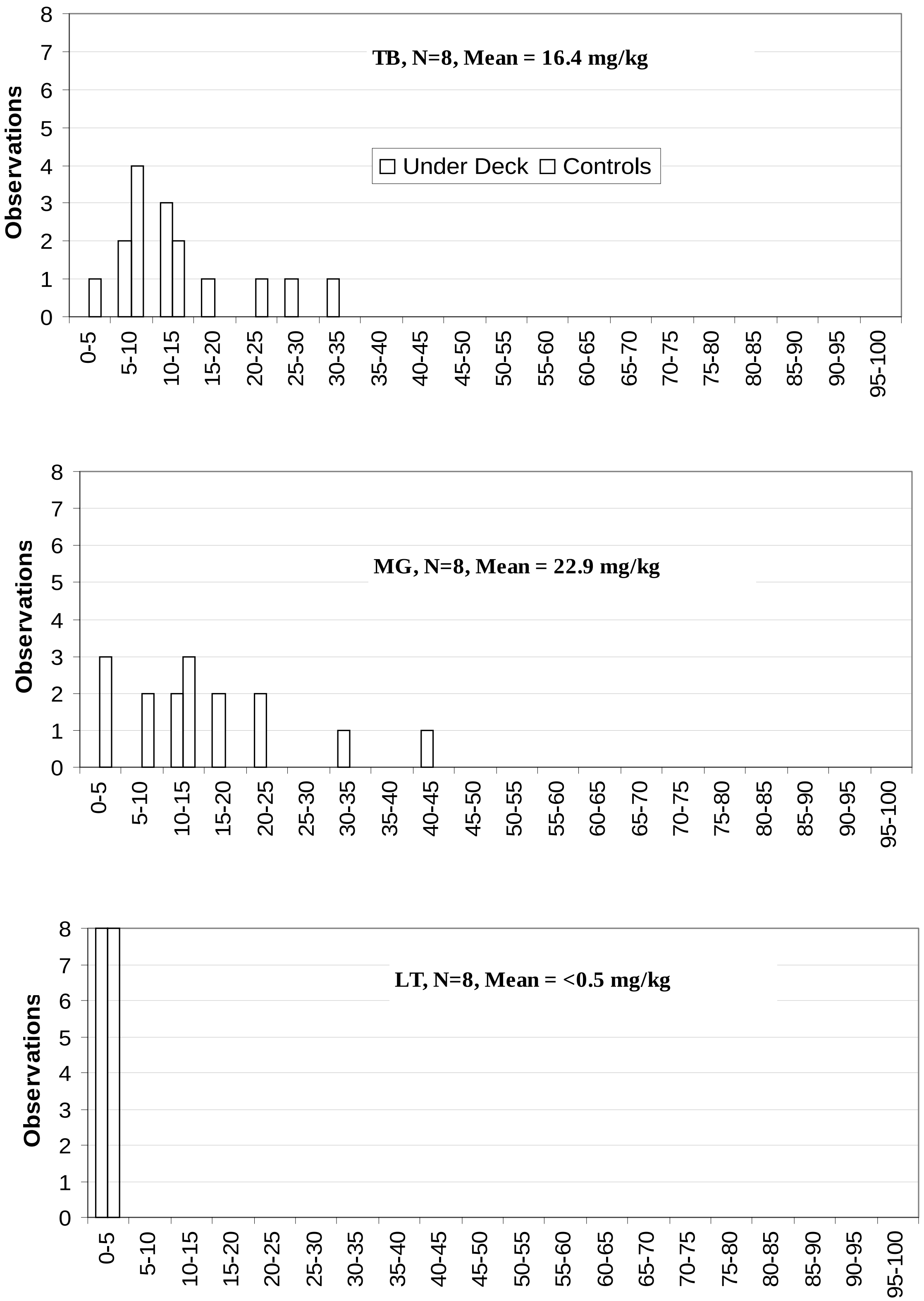

Figure A.23: Chromium Distribution Below the Tallahassee Decks

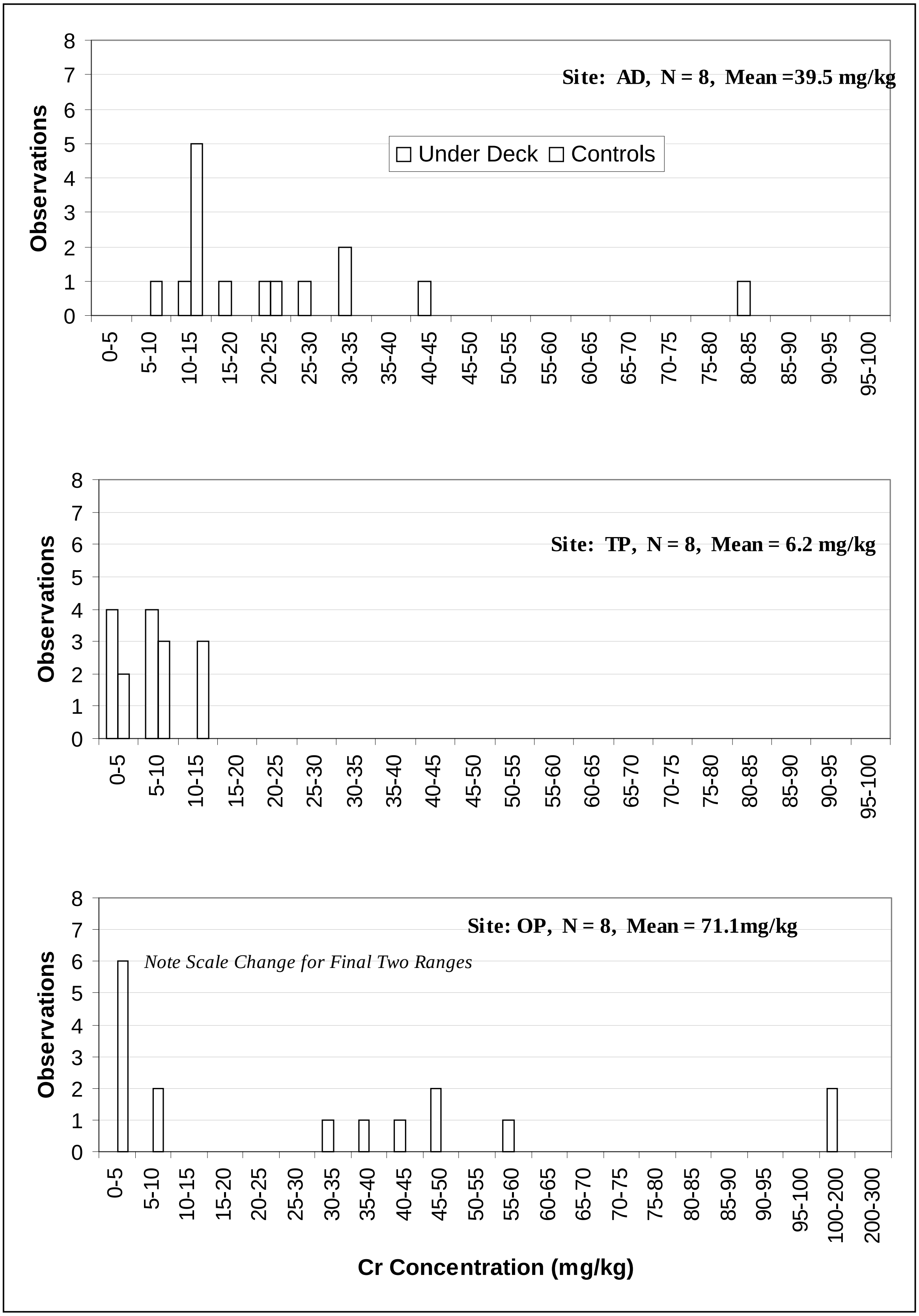

Figure A.24: Chromium Distribution Below the Miami Decks

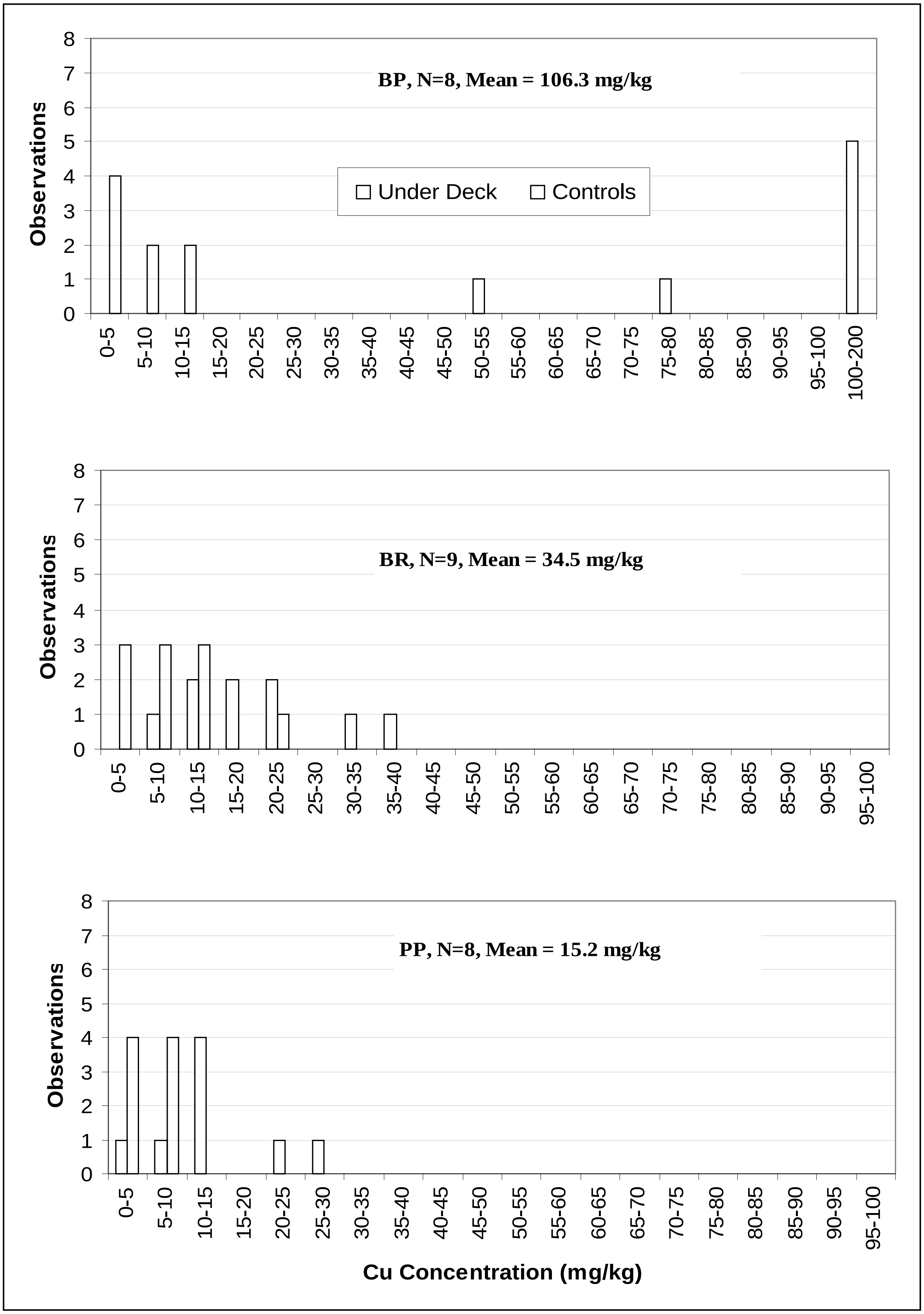

Figure A.25: Copper Distribution Below the Gainesville Decks

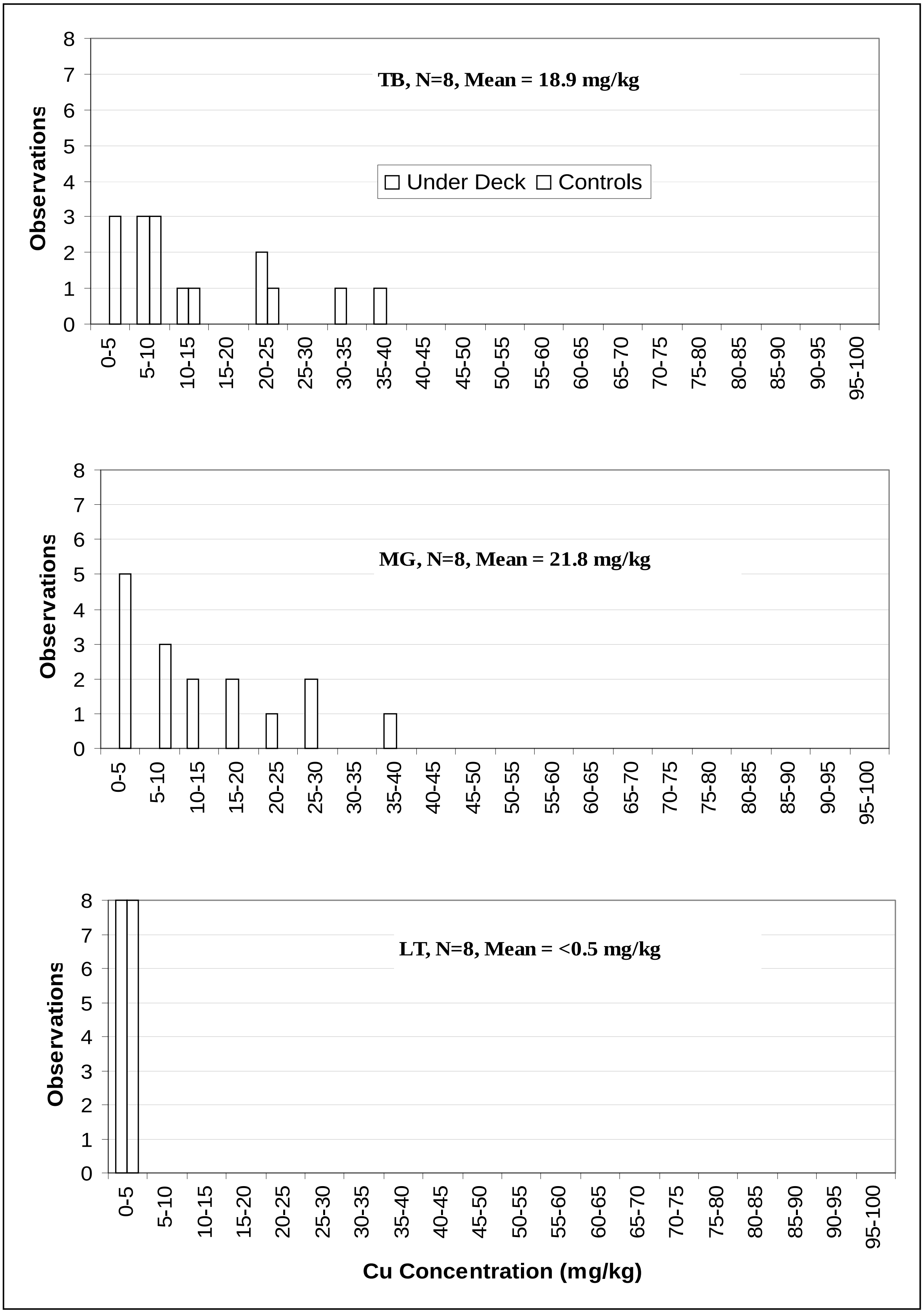

Figure A.26: Copper Distribution Below the Tallahassee Decks

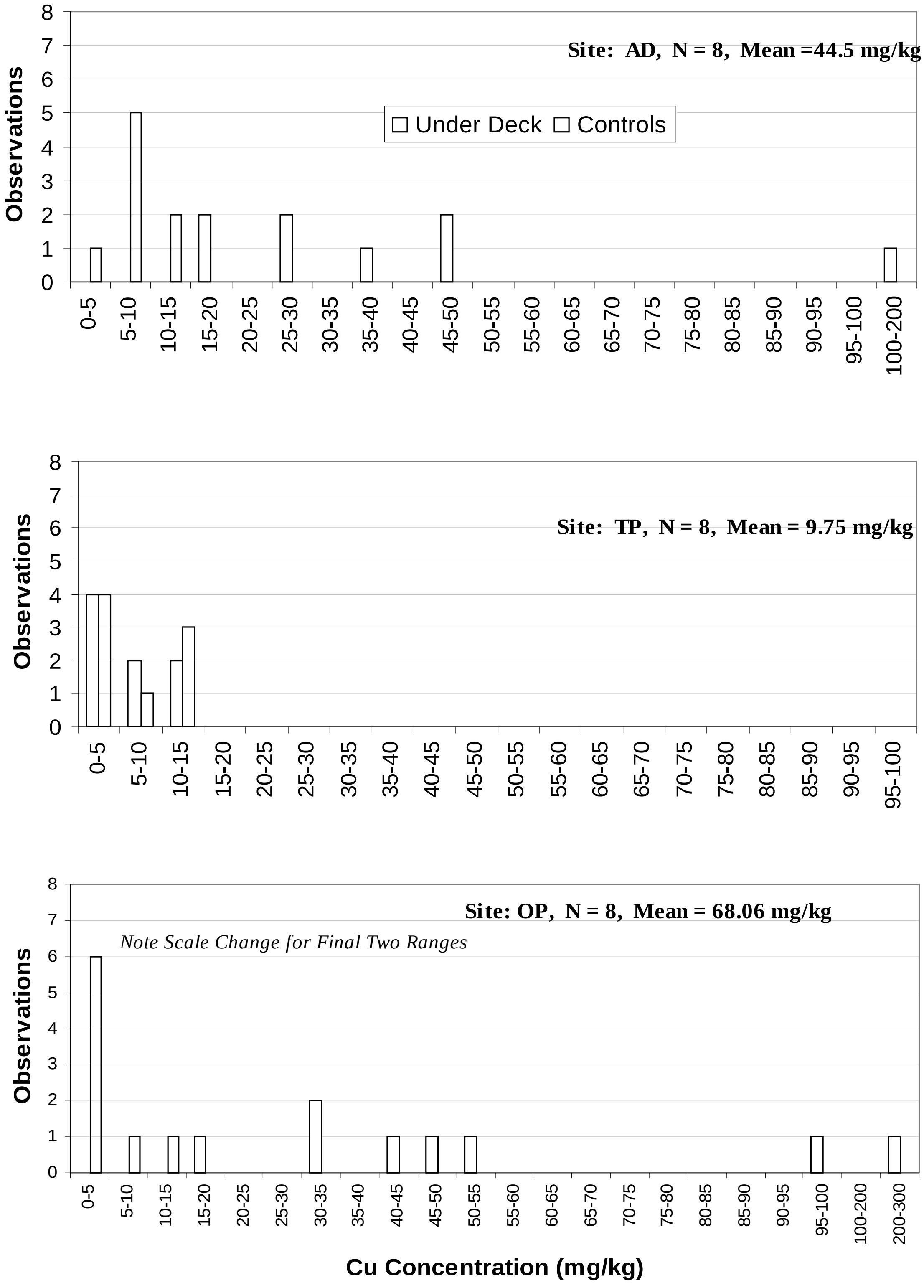

Figure A.27: Copper Distribution Below the Miami Decks

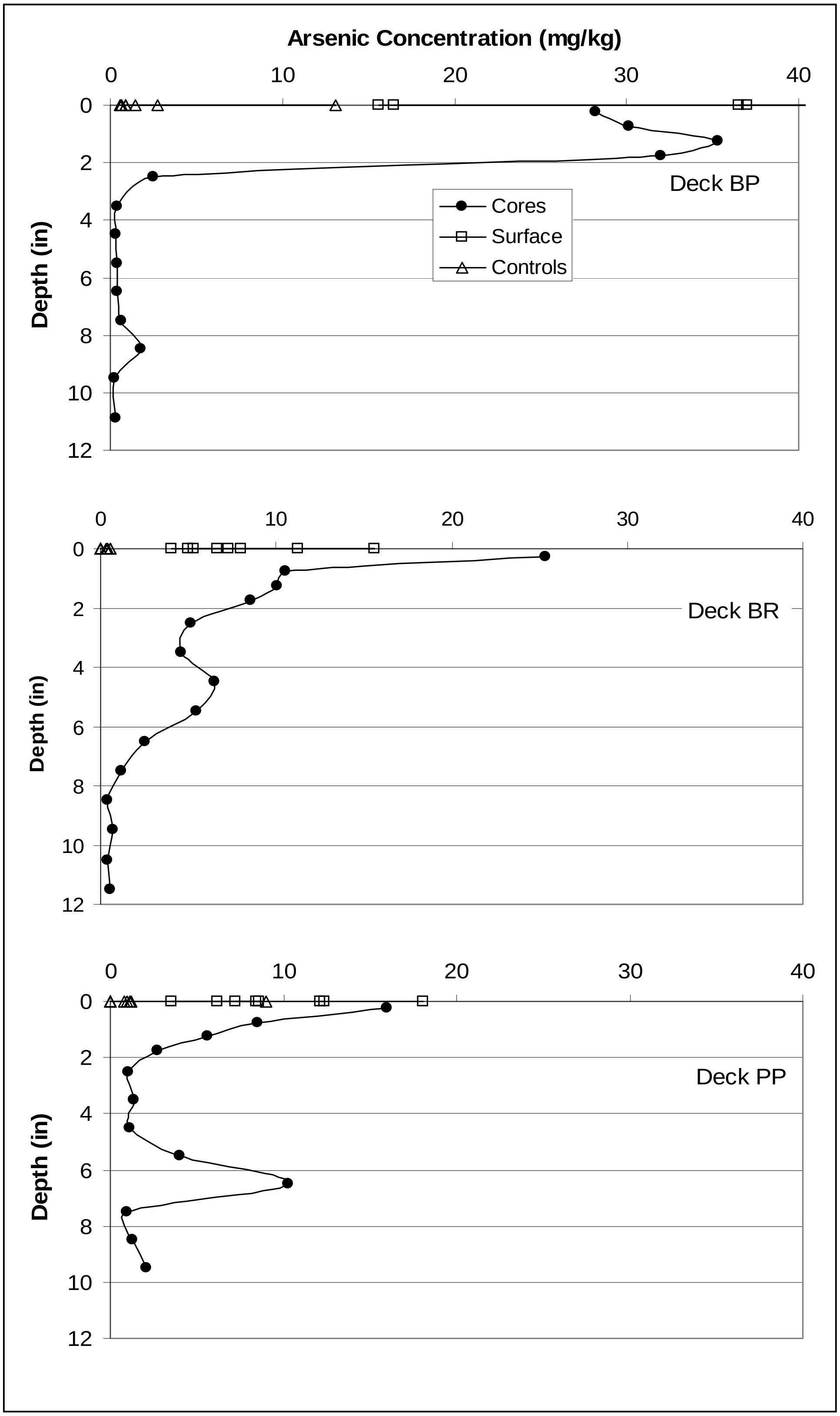

Figure A.28: Arsenic Concentrations as a Function of Depth Below the Gainesville Decks

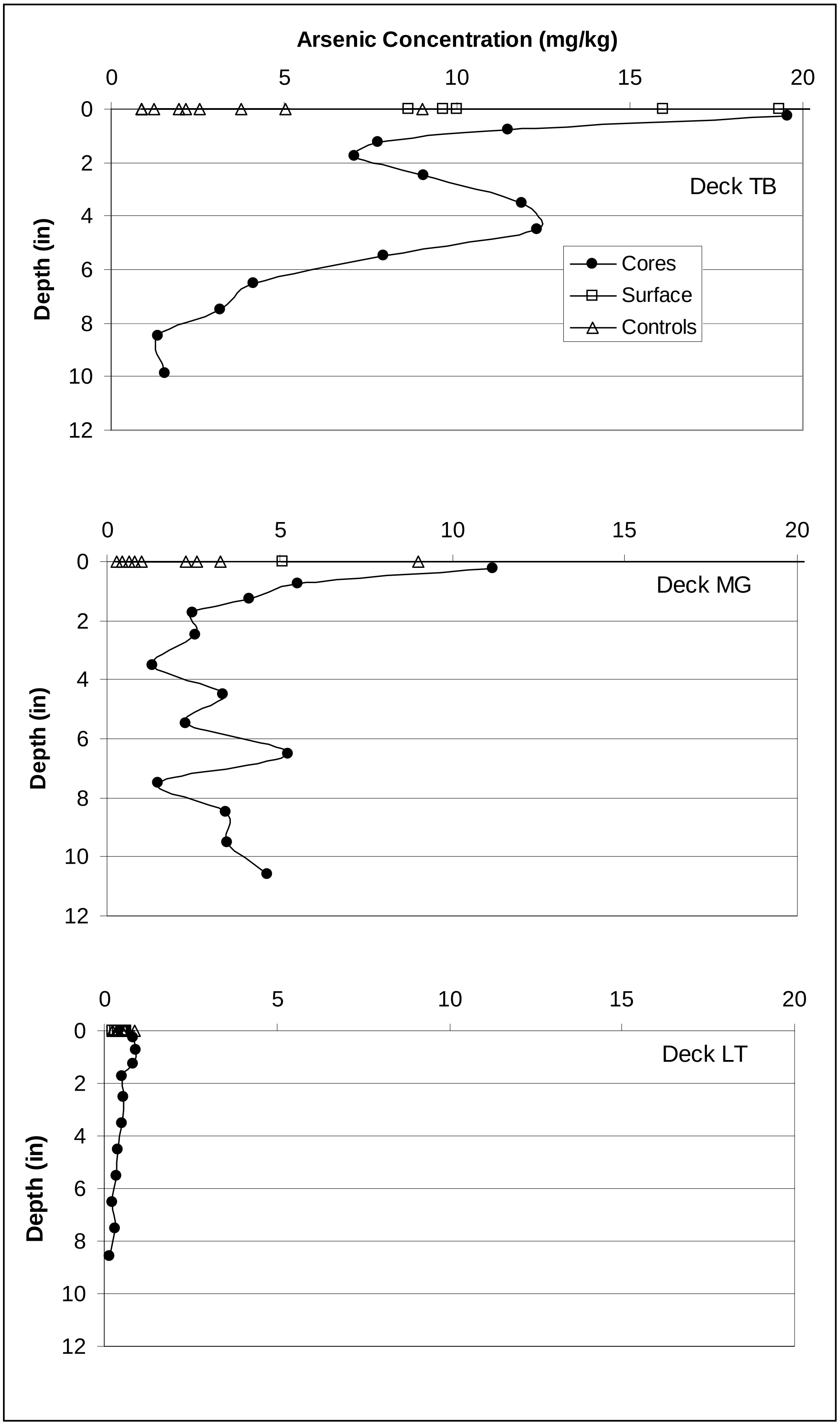

Figure A.29: Arsenic Concentrations as a Function of Depth Below the Tallahassee Decks

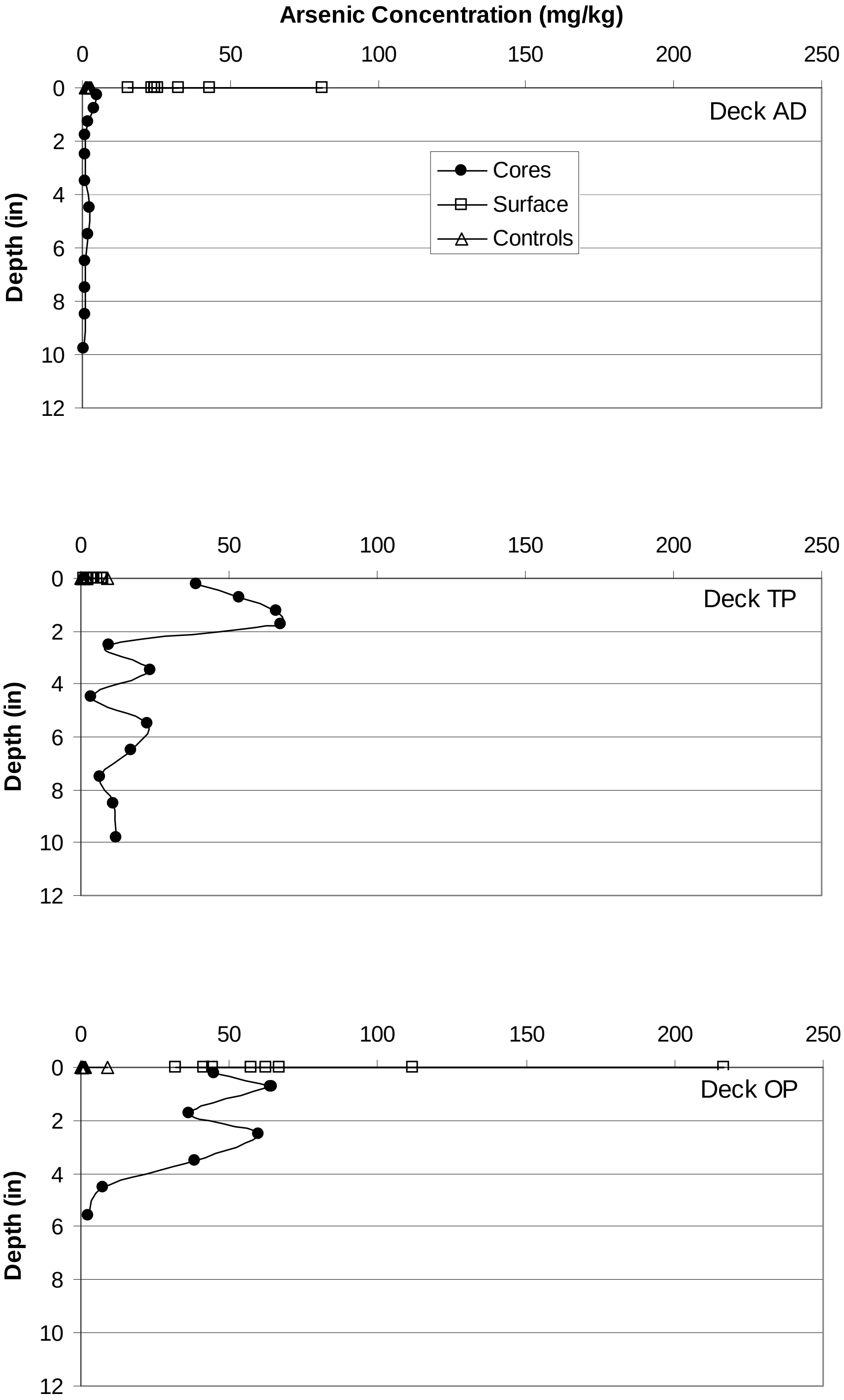

Figure A.30: Arsenic Concentrations as a Function of Depth Below the Miami Decks

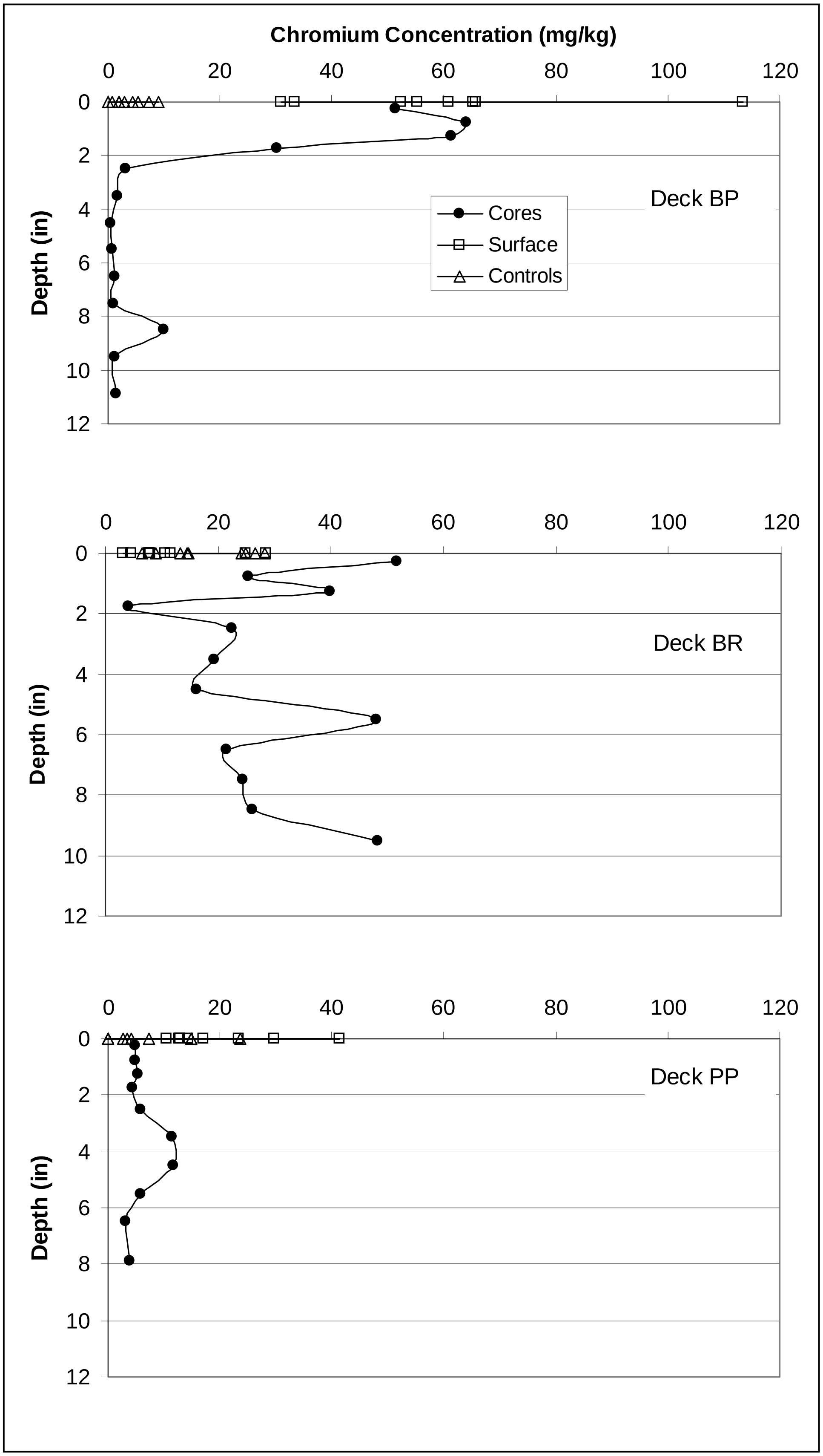

Figure A.31: Chromium Concentrations as a Function of Depth Below the Gainesville Decks

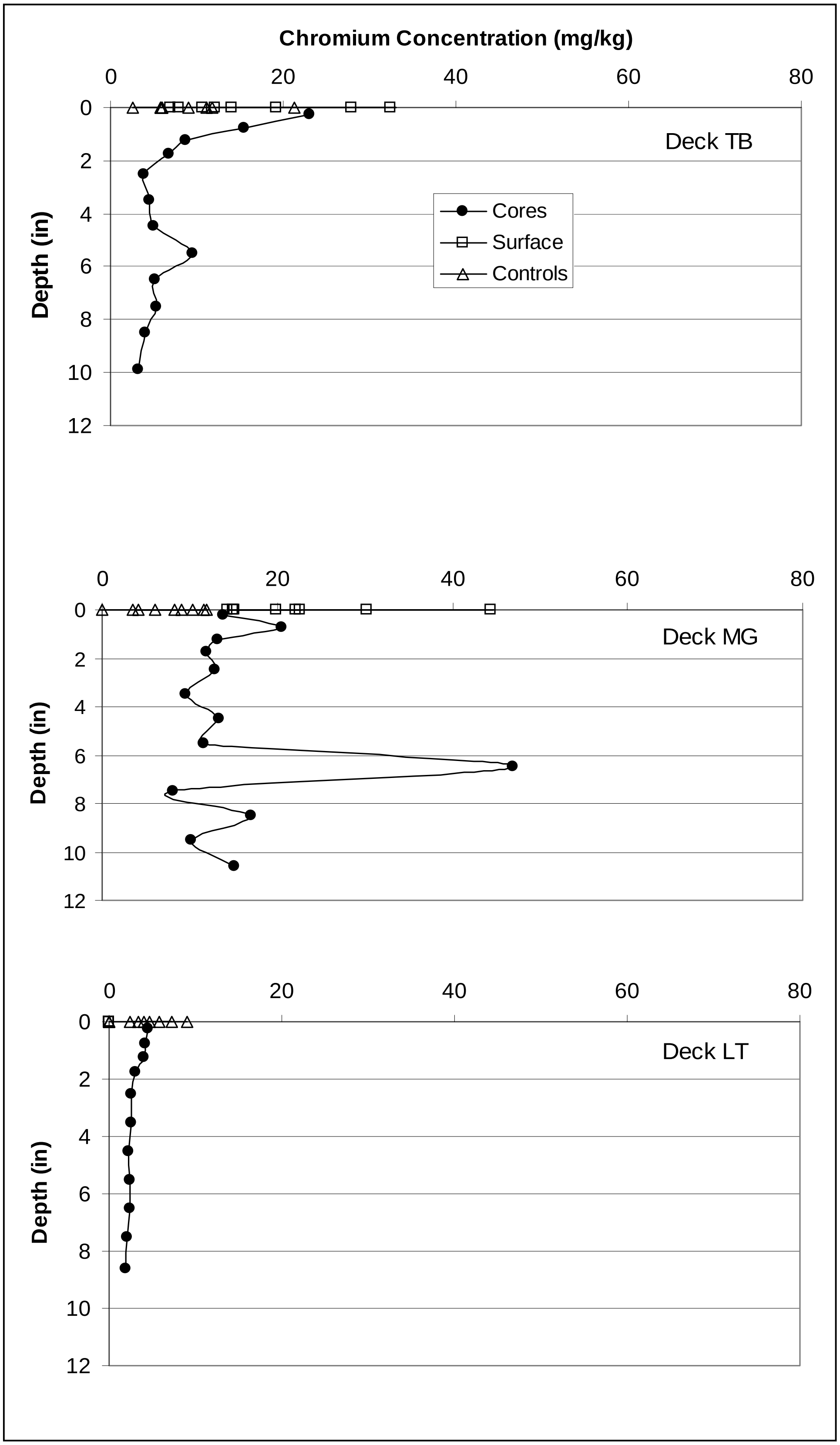

Figure A.32: Chromium Concentrations as a Function of Depth Below the Tallahassee Decks

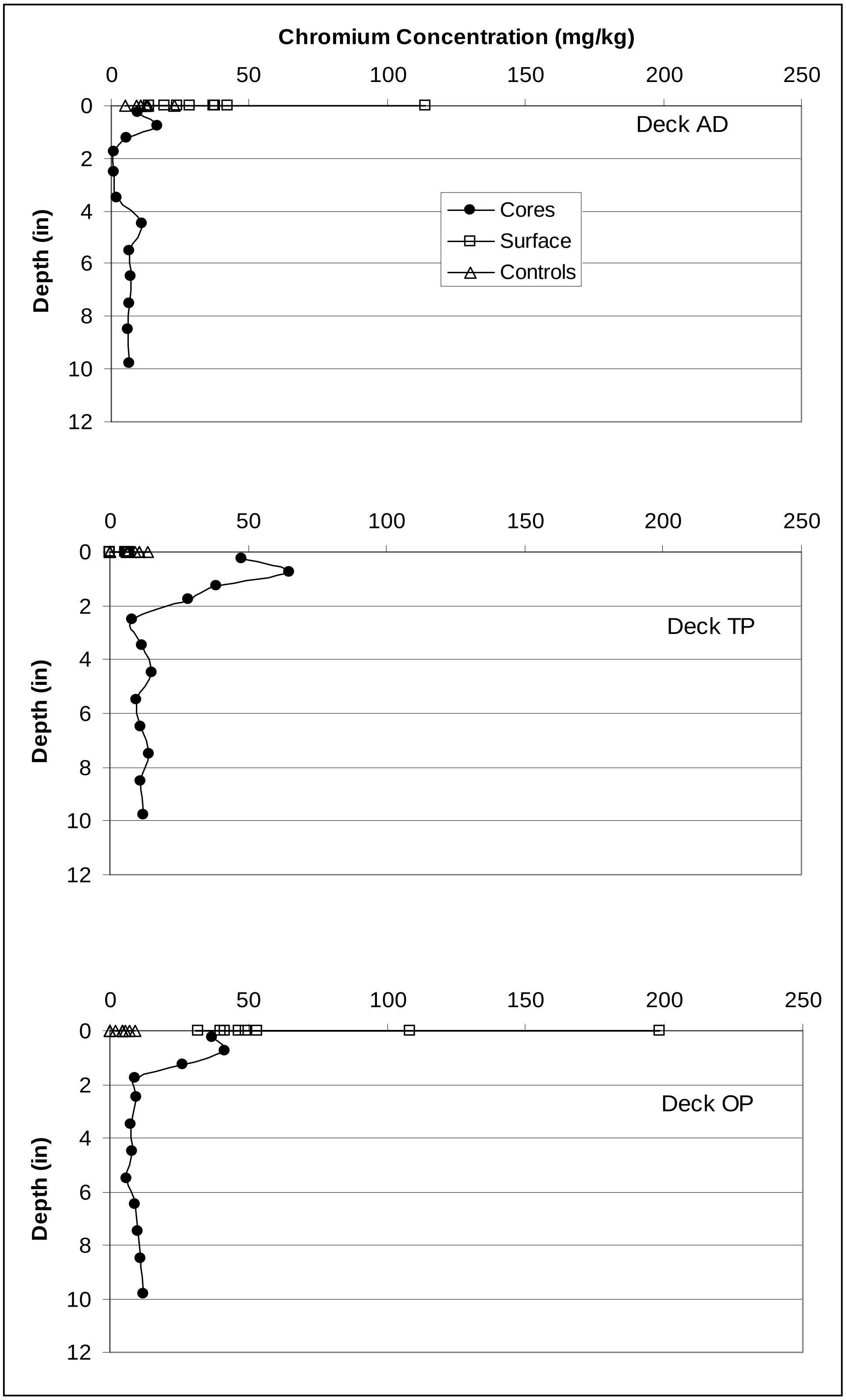

Figure A.33: Chromium Concentrations as a Function of Depth Below the Miami Decks

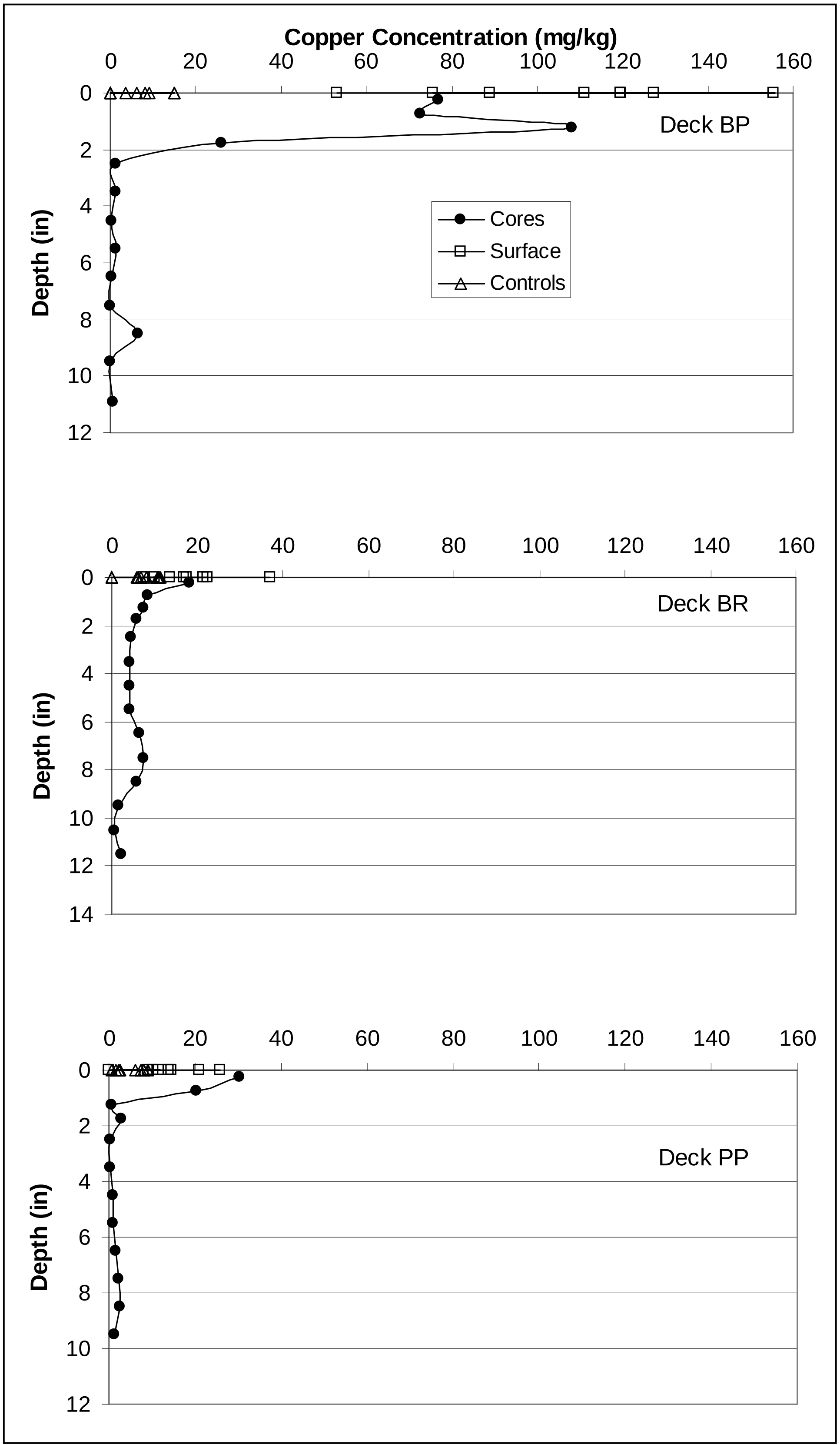

Figure A.34: Copper Concentrations as a Function of Depth Below the Gainesville Decks

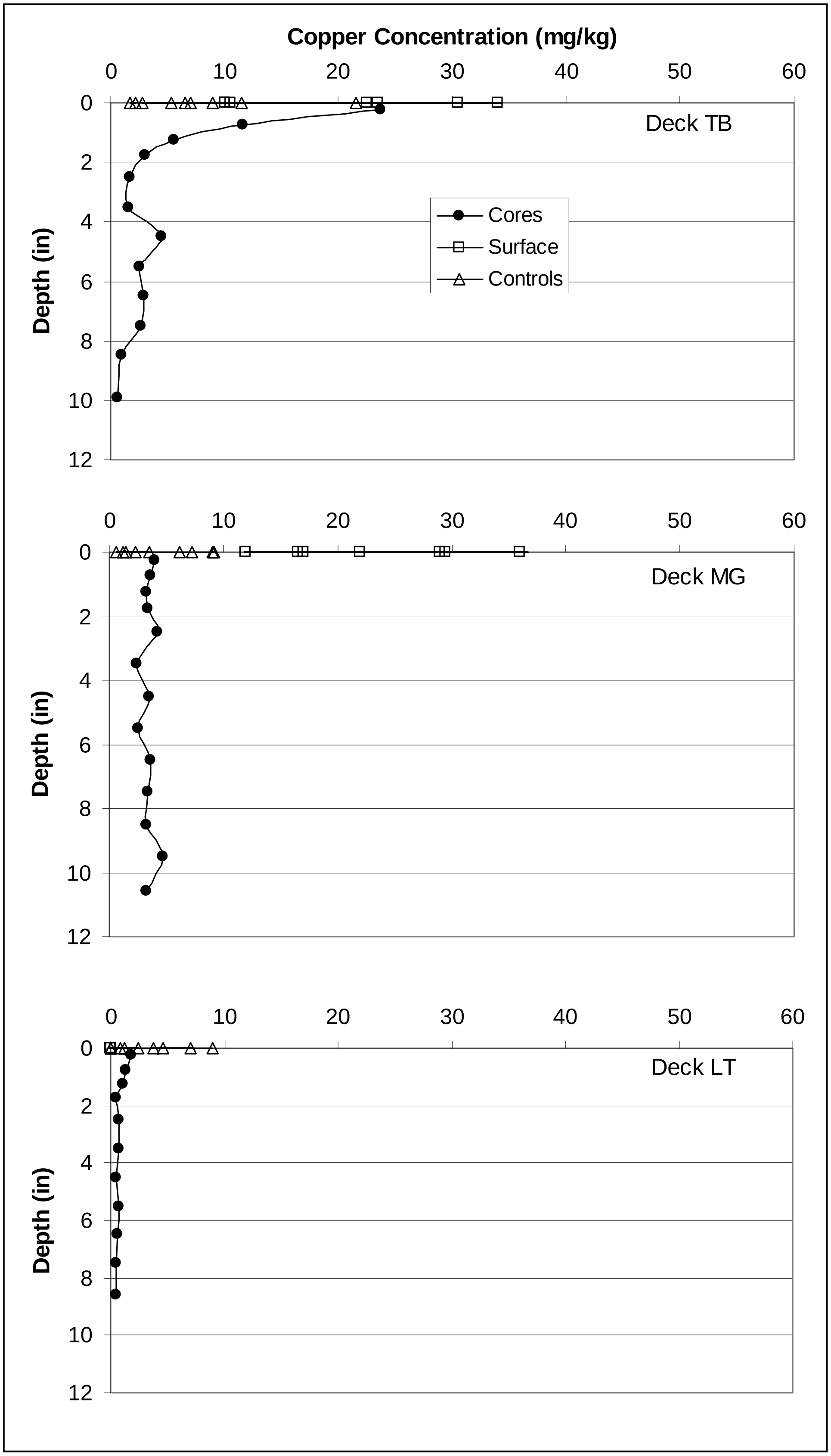

Figure A.35: Copper Concentrations as a Function of Depth Below the Tallahassee Decks

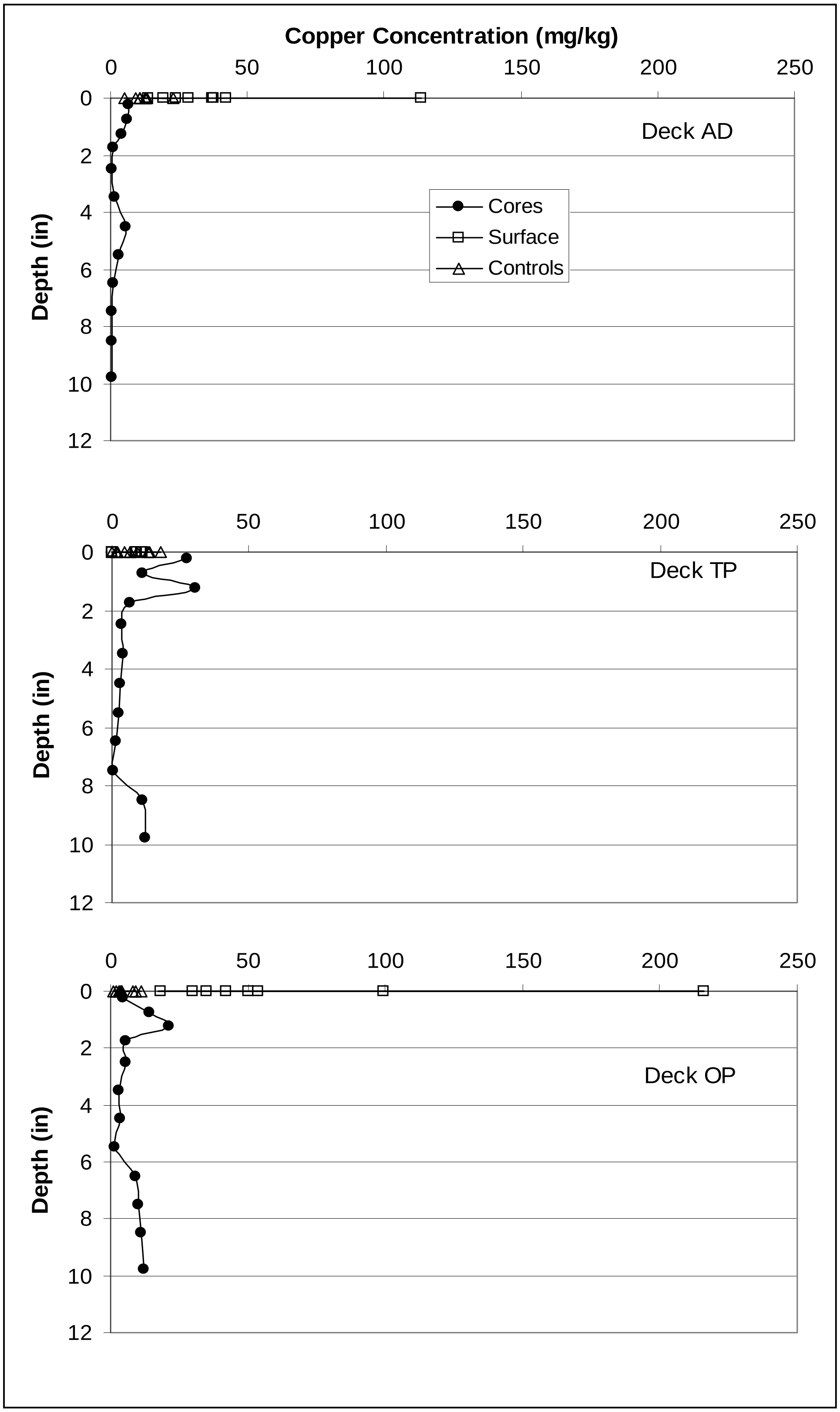

Figure A.36: Copper Concentrations as a Function of Depth Below the Miami Decks

APPENDIX D

LIST OF TECHNICAL ADVISORY GROUP MEMBERS AND MEETING ATTENDEES

Name/Title	Organization	Address	Telephone	email
Kevin Archer, Ph.D. Product Development Manager	Chemical Specialties Inc.	One Woodlawn Green Suite 250 200 East Woodlawn Road Charlotte, NC 28217	(704)522-0825 (800)421-8661 Fax: (704)527-8232	kevina@chemspec.com http://www.chemspec.com http://www.treatedwood.com
Phil Badger	General Bioenergy, Inc.	P.O. Box 26 Florence, Alabama 35631-0026	(256)740-5634 Fax: (256)740-5530	pbadger@bioenergyupdate.com
Lee Casey, Chief Environmental Compliance Division	Metro-Dade County Dept. of Solid Wste. Mgt.	8675 NW 53 Street Suite 201 Miami, FL 33166	(305)594-1670 Fax:(305)594-1581	le1@co.miami-dade.fl.us
Kenneth E. Cogan Plant Manager Alternate: Bob Gruber, Vice President Regulatory Affairs	Hickson Corporation	1579 Koppers Road Conley, GA 30027 1955 Lake Park Dr., Suite 250 Smyrna, GA 30080	(404)363-6300 Fax: (404)363-8585 (770)801-6600 Fax: (770)801-8170	ken_cogan@hicksoncorp.com bob_gruber@hicksoncorp.com
David Dee, Attorney Alternate: Pete Rosendahl, VP Environmental Relations	Landers & Parsons Florida Crystals Incorporated	310 West College Avenue P.O. Box 271 Tallahassee, FL 32302 316 Royal Poinciana Plaza Palm Beach, FL 33480	(850)681-0311 Fax: 850-224-5595 (561)655-6303 Fax:(561)659-9846	ddee@landersandparsons.com
Keith D. Drescher, Environmental Specialist Alternate: Russel S. Ketchem, Corporate Recycling Coordinator	Florida Power & Light	2455 Port West Blvd., Bldg. A West Palm Beach, FL 33407	(561)845-4968 (561)845-3366 Fax: (561)845-3308 (561)845-4976 Fax: (561)845-4889	keith_drescher@email.fpl.com Russell_S_Ketchem@FPL.Com
Jeffrey Fehrs, P.E. Consultant	Jeffrey Fehrs, Consultant	20 Hideaway Lane Williston, VT 05495	(802)865-3480 Fax: (802)872-8255	jefehrs@together.net
Jim Gabbert	Meyer & Gabbert Excavating Contractors Recycling	8001 Fruitville Road Sarasota, FL 34241	(941)377-5370 (941)486-1352 Fax: (941)378-0844	jgabbert@co.sarasota.fl.us

Table D.1: Technical Advisory Group Members for Year 3

Name/Title	Organization	Address	Telephone	email
Bill Gay, Wood Preserving Vice President Alternate: Jim Hickman	Langdale Forest Products Co.	P.O. Box 1088 Valdosta, GA 31603-1088	(912)333-2513 Fax: (912)3332533 (912)333-2501	wgay@surfsouth.com jhickman@surfsouth.com
Danny Kreiser Manager	East Coast Recycling	4880 Glades Cut-off Road Ft. Pierce, FL 34981	(561)461-5833 (561)595-0009	
William Krumbholz, Environmental Manager Alternate: Jeff Gould, Professional Geologist II, Waste Cleanup	Dept. of Env. Protection Solid Waste Division	2295 Victoria Ave., Suite 364 Ft. Myers, FL 33901 P.O. Box 2549 Ft. Myers, FL 33902-2549	(941)332-6975 Fax:(941)332-6969	Bill.Krumbholz@dep.state.fl.us Jeffrey.Gould@dep.state.fl.us
Dave Mason Engineer 2 Alternate: Richard Tedder, Professional Engineer 3	Dept. of Environmental Protection	2600 Blair Stone Road MS# 4565 Tallahassee, FL 32399-2400	(850)921-9237 Fax: (850)414-0414	David.Mason@dep.state.fl.us
Jim Nix, Head Operator	Kodiak, Inc.	PO Box 99 Hwy. 278 East at Airport Road Allendale, SC 29810	(803)584-9137 Fax: (803)584-2208	NixJ@Kodiakwood.com
George Parris, Ph.D Director of Environmental & Regulatory Affairs	American Wood Preservers Institute	2750 Prosperity Avenue, Suite 550 Fairfax, VA 22031-4312	(703)204-0500 Fax: (703)204-4610	internet site: http://www.awpi.org
Michael E. Provenza Environmental Health and Safety Manager Alternate: Gary Hurst, General Manager	Robbins Manufacturing	13001 N. Nebraska Ave. Tampa, FL 33612 P.O. Box 17939 Tampa, FL 33682	(813) 971-3030 Fax: (813)972-3980	
John Schert Executive Director	Florida Center for Solid and Hazardous Waste Management	University of Florida 2207 NW 13 Street, Suite D Gainesville, FL 32609	(352)392-6264 Fax: (352)846-0183	fcshwm@eng.ufl.edu
Chih-Shin Shieh, Ph.D Principal Researcher/Director	Florida Institute of Technology, Research Center for Waste Utilization,DMES	150 W. University Blvd. Melbourne, FL 32901	(407) 768-8000 x7240 Fax: (407)674-7212	cshieh@fit.edu

Table D.1 (con’d): Technical Advisory Group Members for Year 3

Name/Title	Organization	Address	Telephone	email
Helena Solo-Gabriele, Ph.D, P.E Assistant Professor (Graduate Students:Kelvin Gary, Naila Hosein, Bernine Khan, Monika Kormienko)	University of Miami, Dept. of Civil, Arch. & Environ. Engrg.	P.O. Box 248294 Coral Gables, FL 33124-0630	(305)284-3489 or (305)284-3391 Fax: (305)284-3492	hmsolo@miami.edu
August (Gus) Staats Manager of Environmental Services	Osmose Wood Preserving Division	P.O. Drawer 0 Griffin, Georgia 30224-0249	(770)228-8434 Fax: (770)229-5225	
Donald R. Surrency, Manager of Plant and Sales Alternate: Jim Healey, Plant Manager	Koppers Industries, Inc.	P.O. Box 1067 Gainesville, FL 32609 200 NW 23 Ave. Gainesville, FL 32605	(352)376-5144 1-800-342-6860 Fax: (352)371-4657	don_surrency@koppers.com jim_healey@koppers.com
Ram Tewari, Ph.D., P.E., Project Manager	Broward County Commission Solid Waste Operations Division	201 S. Andrews Avenue Fort Lauderdale, FL 33301	(954)765-4202 x254 (954)680-0087 x224 Fax:(954)765-4237	rtewari@co.broward.fl.us
Timothy Townsend, Ph.D Assistant Professor (Graduate Students: Kristin Stook, Jin-Kun Song, Thabet Tolaymat)	University of Florida Dept.of Environ. Engrg.Sci., Solid & Haz.Wst Prgrm	333 New Engineering Bldg. Gainesville, FL 32611-6450	(352)392-0846 Fax: (352)392-3076	ttown@eng.ufl.edu
George Varn, Jr. Project Manager Alternate:G. Micheal Hollingsworth, Comptroller	Varn Wood Products	P.O. Box 128 Hoboken, GA 31542	(912)458-2187 Fax: (912)458-2190	justpine@aol.com

Table D.1 (con’d): Technical Advisory Group Members for Year 3

Attendees of the Technical Advisory Group Meeting Held December 9, 1999 at the University of Miami, College of Engineering, Coral Gables, Florida

Kevin Archer, Chemical Specialties Inc., Charlotte, NC
Sean Bennie, University of Miami, Coral Gables, FL
Mark Bingham, Dade Recycling, Miami, FL
Scott Conklin, Universal Forest Products, Grand Rapids, MI
Diana Davis, Florida Power and Light, Juno Beach, FL
David Dee, Landers & Parsons, Tallahassee, FL
Louis DiVita, Delta Recycling Corp., Pompano Beach, FL
Rick Donaldson, Great Southern Wood Preserving, Bushnell, FL
Keith Drescher, Florida Power and Light, West Palm Beach, FL
Tom Evans, Coastal Lumber, Weldon, NC
Kelvin Gary, University of Miami, Coral Gables, FL
Bill Gay, Langdale Forest Products, Valdosta, GA
Alex Gomez, Dade Recycling, Miami, FL
Jeff Gould, Florida Dept. of Environmental Protection, Ft. Myers, FL
Bob Gruber, Hickson Corp., Smyrna, GA
Jimmy Harris, Great Southern Wood Preserving, Bushnell, FL
Jim Healey, Koppers Industries Inc., Gainesville, FL
Jim Hickman, Langdale Forest Products, Valdosta, GA
Naila Hosein, University of Miami, Coral Gables, FL
Gary Hurst, Robbins Manufacturing, Tampa, FL
Mitch Joiner, Osmose Wood Preserving, Griffin, GA
Russel Ketchem, Florida Power and Light, West Palm Beach, FL
Bernine Khan, University of Miami, Coral Gables, FL
Frank Klasnick, Osmose Wood Preserving, Griffin, GA
Monika Kormienko, University of Miami, Coral Gables, FL
Danny Kreiser, East Coast Recycling, Ft. Pierce, FL
William Krumbholz, Florida Department of Environmental Protection, Ft. Myers, FL
Jim Langdale, Langdale Forest Products, Valdosta, GA
Marc Laurent, Miami-Dade County Solid Waste, Miami, FL
Dave Mason, FL Dept. of Environ. Protection, Tallahassee, FL
Jerry McMullan, Florida Power and Light, West Palm Beach, FL
Russ Morgan, Occidental Chemical, Castle Hayne, NC
Don Pardue, Wood Treaters, Jacksonville, FL
George Parris, American Wood Preservers Inst., Fairfax, VA
Scott Ramminger, American Wood Preservers Inst., Fairfax, VA
Jay Robbins, Robbins Manufacturing, Tampa, FL
Tom Roberts, Delta Recycling Corp., Pompano Beach, FL
Steven Roundtree, Southeastern Lumber Manufacturers Assoc., Forest Park, GA
John Schert, Univ. Florida Florida Center for Solid and Haz. Waste Mgt., Gainesville, FL
Jim Seufert, Universal Forest Products, Grand Rapids, MI
Helena Solo-Gabriele, University of Miami, Coral Gables, FL
Gus Staats, Osmose Wood Preserving Division, Griffin, GA
Kristin Stook, University of Florida, Gainesville, FL
Thabet Tolaymat, University of Florida, Gainesville, FL
Tim Townsend, University of Florida, Gainesville, FL
George Varn Jr., Varn Wood Products, Hoboken, GA
Shakir Wissa, Southern Soft Wood Inc., Orlando, FL
Edward Zillioux, Florida Power and Light, Juno Beach, FL

Attendees of the Technical Advisory Group Meeting Held March 17, 2000 at the University of Florida, Reitz Union, Gainesville, Florida

Kevin Archer, Chemical Specialties Inc., Charlotte, NC
Allison Barnes, University of Florida, Gainesville, FL
David Bullock, Wood Protection Products, Charlotte, NC
Diana Davis, Florida Power and Light, Juno Beach, FL
David Dee, Landers & Parsons, Tallahassee, FL
Dottie Delfino, Univ. FL Florida Center for Solid and Haz. Waste Mgt., Gainesville, FL
Rick Donaldson, Great Southern Wood Preserving, Bushnell, FL
Keith Drescher, Florida Power and Light, West Palm Beach, FL
Kelvin Gary, University of Miami, Coral Gables, FL
Alex Green, University of Florida - Dept. of Mechanical Engineering, Gainesville, FL
Bob Gruber, Hickson Corp., Smyrna, GA
Tim Hannon, Pride of Florida, Starke, FL
Jim Healey, Koppers Industries, Gainesville, FL
Scott Hiaasen, Palm Beach Post, West Palm Beach, FL
Jim Hickman, Langdale Forest Products, Valdosta, GA
Naila Hosein, University of Miami, Coral Gables, FL
Jake Huffman, University of Florida - School of Forest Resources, Gainesville, FL
Gary Hurst, Robbins Manufacturing, Tampa, FL
Russel Ketchem, Florida Power and Light, West Palm Beach, FL
Kim Kochran, University of Florida, Gainesville, FL
Monika Kormienko, University of Miami, Coral Gables, FL
William Krumbholz, Ft. Myers, FL
Lena Ma, University of Florida - Soil and Water Science, Gainesville, FL
Dave Mason, FL Dept. of Environ. Protection, Tallahassee, FL
Ron Matus, Gainesville Sun, Gainesville, FL
Jerry McMullan, Florida Power and Light, West Palm Beach, FL
John Mousa, Alachua County Environ. Protection, Gainesville, FL
Kevin O’Donnell, Florida Power and Light, West Palm Beach, FL
Don Pardue, Wood Treaters, Jacksonville, FL
Michael Provenza, Robbins Manufacturing, Tampa, FL
Scott Ramminger, American Wood Preservers Inst., Fairfax, VA
Dan Rawson, Florida Power and Light, West Palm Beach, FL
Bill Robbins, Robbins Manufacturing, Tampa, FL
Jay Robbins, Robbins Manufacturing, Tampa, FL
Rhonda Rogers, Univ. FL Florida Center for Solid and Haz. Waste Mgt., Gainesville, FL
Steve Rountree, Southeastern Lumber, Forest Park, GA
Roger Sanders, Florida Power and Light, West Melbourne, FL
John Schert, Univ. Florida Florida Center for Solid and Haz. Waste Mgt., Gainesville, FL
Robert A. Schmidt, University of Florida - School of Forest Resources, Gainesville, FL
Jim Seufert, Universal Forest Products, Grand Rapids, MI
Helena Solo-Gabriele, University of Miami, Coral Gables, FL
Jin Kun Song, University of Florida, Gainesville, FL
Gus Staats, Osmose Wood Preserving Division, Griffin, GA
Kristin Stook, University of Florida, Gainesville, FL
Don Surrency, Koppers Industries, Gainesville, FL
Thabet Tolaymat, University of Florida, Gainesville, FL
Tim Townsend, University of Florida, Gainesville, FL
Yongchul Yang, University of Florida, Gainesville, FL
Edward Zillioux, Florida Power and Light, Juno Beach, FL

Attendees of the Technical Advisory Group Meeting Held July 28, 2000 at the Florida Dept. of Environmental Protection Bldg located in Tallahassee, Florida

Kevin Archer, Product Development Manager, Chemical Specialties Inc, Charlotte, NC
David Bullock, Wood Protection Products, Charlotte, NC
Jennifer Caldwell-Kurka, Florida Department of Environmental Protection, Tallahassee, FL
Jenna Carlson, University of Florida, Gainesville, FL
Lee Childers, Suwannee Lumber Mfg., Cross City, FL
Jan Rae Clark, Florida Department of Environmental Protection, Tallahassee, FL
Raoul Clarke, Florida Department of Environmental Protection, Tallahassee, FL
Steve Cox, Co XRF, Atlanta, GA
Keith Drescher, Environmental Specialist, Florida Power and Light, West Palm Beach , FL
David Dee, Landers and Parsons, Tallahassee, FL
Richard Gentry, Florida Home Builders Association, Tallahassee, FL
Jack Glenn, Florida Home Builders Assoc., Tallahassee, FL
Peter Goren, Florida Department of Environmental Protection, Tallahassee, FL
Phil Gornick, Florida Forestry Assn, Tallahassee, FL
Bob Gruber, Hickson Corp., Smyrna, GA
David Hahn, University of Florida, Gainesville, FL
Julie Hauserman, St. Petersburg Times, Tallahassee ,FL
Jim Healey, Koppers Industries, Inc., Gainesville, FL
Ron Henricks, Florida Department of Environmental Protection, Tallahassee, FL
Jim Hickman, Langdale Forest Products Co, Valdosta, GA
William Hinkley, Florida Department of Environmental Protection, Tallahassee, FL
Naila Hosein, University of Miami, Coral Gables, FL
Gary Hurst, Robbins Manufacturing, Tampa, FL
Robbin Jackson, Elementis, Corpus Christi, TX
Francine Joyal, Florida Department of Environmental Protection, Tallahassee, FL
Mike Kaiser, Burns and McDowell, Jacksonville, FL
Russell Ketchem, Florida Power and Light, West Palm Beach, FL
Bernine Khan, University of Miami, Coral Gables, FL
Curt Leonard, Florida Forestry Assn, Tallahassee, FL
Lena Ma, University of Florida, Gainesville, FL
Tom Marr, Osmose Inc., Griffin GA
Dave Mason, Southern Forest Products Association, Kenner, LA
Dave Mason, Florida Department of Environmental Protection, Tallahassee, FL
Daniel Moore, Dept. of Agriculture and Consumer Services, Tallahassee, FL
Karen S. Moore, Florida Department of Environmental Protection, Tallahassee, FL
Russ Morgan, Scientist, Occidental Chemical, Castle Hayne, NC
Gus Olmos, Alachua County, Gainesville, FL
John Paling, John Paling and Co, Gainesville FL
Keith Parmer, Dept. of Agriculture and Consumer Services, Tallahassee, FL
George Parris, Ph.D., American Wood Preservers Institute, Fairfax, VA
Mike Petrovich, Hopping Green Sams & Smith, P.A., Tallahassee, FL
Scott Ramminger, American Wood Preservers' Institute, Fairfax, VA
Tom Roberts, Delta Recycling, Ft. Lauderdale, FL
John Schert, Florida Center for Solid and Hazardous Waste Management, Gainesville, FL
Jay Sego, Coastal Lumber Co., Havana, FL.
Jim Seufert, Universal Forest Products, Grand Rapids, MI
Helena Solo-Gabriele, University of Miami, Coral Gables, FL

Attendees of the Technical Advisory Group Meeting Held July 28, 2000 at the Florida Dept. of Environmental Protection Bldg located in Tallahassee, Florida

(continued)

August Staats, Osmose Wood Preserving Division, Griffin, Georgia
Kristin Stook, University of Florida, Gainesville, FL
Donald Surrency, Koppers Industries, Inc., Gainesville, FL
Richard Tedder, Florida Department of Environmental Protection, Tallahassee, FL
Laurie Tenace, Florida Department of Environmental Protection, Tallahassee, FL
Thabet Tolaymat, University of Florida, Gainesville, FL
Timothy Townsend, University of Florida, Gainesville, FL
Tuck Tucker, Gulf Power, Pensacola, FL
George Varn, Jr., Varn Wood Products, Hoboken, GA

Attendees Via Teleconference
Bonaventure Akinlosutu U.S. Environmental Protection Agency, Washington D.C.
Winston Dang, U.S. Environmental Protection Agency, Washington D.C.
Najm Shamim, U.S. Environmental Protection Agency, Washington D.C.