WASTE INNOVATIONS

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Dept. of Environmental Protection
Siting Coordination Office

April 3, 2024

UPS TRACKING: 1Z2AW7392492847947

Ms. Ann Seiler
Florida Department of Environmental Protection Siting Coordination Office, MS 5500
2600 Blair Stone Road Tallahassee,
Florida, 32399-3900

Re: Petition for Modification of Conditions of Certification:
South Broward Resource Recovery Facility:
Wheelabrator South Broward, Inc.

Dear Ms. Seiler:

On behalf of the Wheelabrator South Broward, Inc. ("Wheelabrator"), I am hereby filing this petition ("Petition") for a modification of the Conditions of Certification (PA85-21H) for Wheelabrator's South Broward Resource Recovery Facility ("SBRRF"). In this Petition, Wheelabrator respectfully requests the Florida Department of Environmental Protection ("Department" or "FDEP") to approve the recycling and beneficial use of the bottom ash that is produced by Wheelabrator's waste-to-energy ("WTE") facility. The following sections of this Petition explain why Wheelabrator's request for a modification should be granted pursuant to Section 403.516(1)(c), Florida Statutes (2018), and FDEP Rule 62-17.211(1)(b), Florida Administrative Code ("F.A.C.").

A. Wheelabrator's Need for a Modification

The construction and operation of the WTE facility in Wheelabrator's SBRRF was approved by the Governor and Cabinet (collectively, "Siting Board"), pursuant to the Florida Electrical Power Plant Siting Act ("PPSA"), Sections 403.501-.518, Florida Statutes. The Siting Board's approval of the SBRRF is subject to the Conditions of Certification. Sections B.5 of the Conditions of Certification provide for the disposal of Wheelabrator's ash residue in the lined landfill or other method approved by the Southeast District Office, but the Conditions of Certification do not address the recycling or beneficial use of ash residue. To remedy this deficiency, Wheelabrator wants the Department to approve and adopt a new Condition of Certification that expressly authorizes Wheelabrator to recycle and beneficially use its bottom ash residue, subject to appropriate conditions and limitations.

B. The Factual Justification for a Modification

Wheelabrator has been working with researchers from the University of Florida to evaluate the environmental impacts associated with the recycling and reuse of Wheelabrator's bottom ash. The research demonstrates that Wheelabrator's bottom ash can be used in a beneficial manner, without violating the Department's requirements for the protection of human health and the environment.

In this Petition, Wheelabrator is seeking authorization to blend bottom ash with aggregate and then use the blended material as road base course. In addition, Wheelabrator wishes to establish a procedure for obtaining approval for other uses of bottom ash, including the use of blended bottom ash in concrete and asphalt pavement.

C. The Anticipated Environmental Effects of the Proposed Modification

The technical evaluation report prepared by the University of Florida concluded that when bottom ash is recycled in a manner consistent with the procedures and constraints identified, will not pose a significant threat to human health and the environment.

D. The Department's Legal Authority to Approve the Modification The

Florida Legislature has given the Department clear statutory authority to approve Wheelabrator's proposed use of bottom ash. Section 403.7045(5), Florida Statutes, states:

> "The department shall work with solid waste management facilities that burn solid waste to identify and develop methods for recycling and reuse of ash residue or treated ash residue, and the department may allow such recycling or reuse by an applicant who demonstrates that no significant threat to public health will result and that applicable department standards and criteria will not be violated." (Emphasis added).

The Department also has the legal authority to modify the Conditions of Certification. In Section A.XXIII.A of the Conditions of Certification, the Siting Board's authority to approve PPSA modifications was delegated to the Department for cases such as this one.

E. Compliance with FDEP Rule 62-17.211, F.A.C.

FDEP Rule 62-17.211, F.A.C., identifies the procedural and substantive requirements for obtaining approval of a modification. To satisfy these requirements, Wheelabrator is submitting the following documents with this Petition:

1. A report entitled "WIN Waste Innovations South Broward Waste-to-Energy Facility Demonstration Roadway Project: Beneficial Use of WTE Bottom Ash as Road Base", which was prepared by the Sustainable Materials Management Research Laboratory, Herbert Wertheim College of Engineering, at the University of Florida.

2. A draft appendix we propose to be included in the Conditions of Certification to address the request, titled "APPENDIX D-Bottom Ash Use for Pilot Project".

3. A proposed Condition of Certification (Section B. I. B. 18) that is entitled "Beneficial Use of Ash." This document contains the proposed Condition of Certification that Wheelabrator is requesting the Department to approve in this case.

4. An application fee payable to the Department in the amount of Ten Thousand Dollars ($10,000), pursuant to FDEP Rule 62-17.293(1)(c)2, F.A.C.

These documents provide the information required by FDEP Rule 62-17.211(1)(b)1, F.A.C. and describe Wheelabrator's proposed plan for recycling and reusing bottom ash. The report prepared by the University of Florida describes the anticipated effects of the proposed project on the environment and demonstrates that such effects should be nominal. Wheelabrator's submitted documents contains specific requirements for monitoring, testing, and recordkeeping, which are designed to ensure the long term protection of human health and the environment As indicated in these documents, the implementation of Wheelabrator's plan will not require any changes to the PPSA-approved layout or design of Wheelabrator's PPSA. The bottom ash will be processed and aged, as necessary, on Wheelabrator's PPSA-approved landfills or at other locations that are approved in advance by the Department. The only proposed changes to the Conditions of Certification are shown in Item 3 above.

Wheelabrator is sending this Petition and the attached documents to all of the parties to the original PPSA proceedings, and the parties to the previous PPSA modification proceedings, at the last address on record for each party, pursuant to FDEP Rule 62-17.211(1)(b)2.a, F.A.C.

F. Conclusion

Based on the information contained herein, Wheelabrator respectfully requests the Department to approve Wheelabrator's Petition for a modification of the Conditions of Certification governing the PPSA. Wheelabrator also respectfully requests the Department to promptly publish notice of this Petition in the Florida Administrative Register, pursuant to FDEP Rule 62- 17.211(1)(b)4, F.A.C.

Thank you for your assistance with this matter. If you have any technical questions concerning Wheelabrator's proposal to recycle and beneficially use its bottom ash, please contact Nicole Walters, EHS Manager, at 954.581.6606.

Sincerely,

Davin Siewrattan,
Plant Manager

Enclosures

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WIN Waste Innovations South Broward Waste-to-Energy Facility Demonstration Roadway Project: Beneficial Use of WTE Bottom Ash as Road Base

Prepared for:

WIN Waste Innovations South Broward Inc.
4400 South State Road 7
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Prepared by:

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Sustainable Materials Management Research Laboratory
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List of Acronyms

BUD	Beneficial Use Demonstration
DWS	Drinking Water Standard
EPA	U.S. Environmental Protection Agency
F.A.C	Florida Administrative Code
FDEP	Florida Department of Environmental Protection
FDOT	Florida Department of Transportation
GCTL	Groundwater Cleanup Target Level
HELP	Hydrologic Evaluation of Landfill Performance
IWEM	Industrial Waste Management Evaluation Model
LR	Limerock
LS	Liquid-to-solid
PPE	Personal Protective Equipment
RCA	Recycled Concrete Aggregate
SCS CN	Soil Conservation Service Curve Number
SCTL	Soil Cleanup Target Level
SMMRL	Sustainable Materials Management Research Lab
UF	University of Florida
WTE	Waste to Energy

1.0 Introduction

1.1 Objectives

WIN Waste Innovations of South Broward, Inc. (WIN) and the University of Florida's Sustainable Materials Management Research Laboratory (UF) are investigating the feasibility of using waste-to-energy (WTE) facility bottom ash (BA) from WIN's South Broward Facility to construct roadways. WIN is particularly interested in utilizing BA as a substitute for limerock and other traditional aggregates typically used in road base construction. The UF team performed physical and chemical testing of the South Broward Facility BA and explored alternative road base scenarios that included using three BA derived aggregates: BA, BA blended with limerock (LR), and BA blended with recycled concrete aggregate (RCA). Physical testing presented here includes particle size distribution, moisture-density relationship, and strength, compared to state guidelines for graded aggregate road base materials. Chemical analysis includes characterization of BA, aggregates, and BA-aggregate blends for direct exposure and leaching-to-groundwater risk, as well as site specific fate and transport modeling. This work indicates that 15:85 blends of BA:LR and BA:RCA do not pose a significant threat to human health and the environment and met the Florida Department of Transportation's (FDOT) minimum performance requirements for road base aggregates. This data is included in this report.

The next step in the feasibility investigation is to construct a pilot-scale demonstration roadway on WIN's South Broward Facility site. Based on laboratory testing and literature results, the UF team recommends ash-derived road base aggregate containing WTE BA from the South Broward Facility at up to 15%, blended with 85% LR or RCA. The proposed demonstration roadway will be constructed in segments with road base consisting of 15:85 blends of BA:LR and BA:RCA. Two additional segments of 100% LR and 100% RCA will be constructed as controls to provide a basis for comparison. All segments will be encapsulated with an asphalt layer following construction. New and previously established groundwater monitoring wells and lysimeters installed beneath the demonstration roadway will be used to evaluate long-term leaching to groundwater performance, and physical testing will be performed to evaluate long-term performance of the roadway.

Section 403.7045(5) of the Florida Statutes authorizes the Department of Environmental Protection to allow beneficial reuse of WTE ash residue when an applicant demonstrates that "no significant threat to public health will result and that applicable Department standards and criteria will not be violated." This document is intended to support WIN's application for Florida Department of Environmental Protection (FDEP) approval of this demonstration project by presenting the results of a risk assessment that considers the public health implications of using South Broward Facility BA as a road base material. The evaluation supporting this document incorporates the results of total concentration analysis, leaching tests, hydrologic modeling, constituent fate and transport modeling, and proposed control and monitoring measures that apply specifically to the pilot project site at the South Broward Facility.

1.2 Overview and Organization

This report begins in Section 1.0 by introducing the objectives of UF's work with WIN in exploring the reuse options of WTE BA from the South Broward Facility as an aggregate in road base. Section 2.0 gives background information on the use of BA as a road base material and describes the proposed BA reuse scenarios for South Broward. The physical evaluation of the beneficial use of the road is presented in Section 3.0. Section 4.0 discusses the risk assessment approach. Sections 5.0 and 6.0 consider the direct exposure and leaching test results from the risk assessment. Section 7.0 details the HELP modeling results. Section 8.0 uses data from previous sections and site-specific parameters provided by WIN to report fate and transport modeling. Section 9.0 discusses the management of the BA while constructing the road. Section 10.0 details the monitoring of the road including the way data will be collected. Section 11.0 provides a summary of the proposed demonstration project and risk mitigation recommendations. Appendix A displays the relationship between the moisture and density of various materials. Appendix B includes additional data regarding the trace element leaching concentrations for the blended material.

2.0 Proposed Demonstration Project Background

2.1 Overview of BA Reuse

Several recycling scenarios for WTE BA have been identified and extensively studied in the literature, including partial coarse or fine aggregate replacement in portland cement concrete (PCC) or hot mix asphalt (HMA), as a replacement for cement kiln feed, or as an aggregate for road base (Schafer et al., 2019; Townsend et al., 2020; Cho et al., 2020). Despite widespread BA recycling in other countries, especially in Europe, BA recycling is less common in the US due to disposition requirements outlined by the Resource Conservation and Recovery Act (RCRA), where BA and fly ash (FA) are co-mingled for proper disposal (Clavier et al., 2019; Liu et al; 2019). However, interest in BA reuse for roadway construction continues to grow in the US.

Reuse approaches for BA as a road base material include as a partial or complete replacement of traditional granular material (such as LR or RCA) in road base construction. The road base layer consists of a 6 to 12-inch layer of compacted aggregate underlying a PCC or HMA pavement layer and provides structural support to distribute vehicle loads into the underlying subgrade. The base layer provides the opportunity to recycle substantial amounts of BA, as it is the thickest layer in a pavement structure and requires the largest amount of aggregate material. Past laboratory and field scale experiments indicate that BA blended with other granular base materials can produce an appropriate aggregate material for road base. These results helped guide recommendations for the South Broward BA road base pilot project.

Laboratory studies were performed on the South Broward Facility BA to determine its chemical and physical performance as a road base aggregate. Previous studies on BA reuse applications indicated that ash should be aged prior to reuse to allow atmospheric carbon dioxide to raise the BA pH and reduce the potential of leaching of heavy metals to groundwater (Schafer et al., 2019). Therefore, BA collected from the South Broward Facility was stockpiled and allowed to carbonate for approximately 60 days, referred to as aged BA. Physical and geotechnical testing was conducted on the aged and the daily fresh (non-aged) BA to assess the strength properties (gradation, compaction, bearing strength) using appropriate American Society for Testing and Materials (ASTM) or Florida Department of Transportation (FDOT) methods. These tests were also performed on BA-aggregate blends, including FDOT approved LR and RCA local to the South Broward facility. The data produced from this suite of testing demonstrated that the South Broward BA and several blended products would meet the appropriate FDOT specifications for road base. The blends chosen for this demonstration project are listed in Table 2-1.

Table 2-1: Each test section for the proposed road with its respective blends and the percent of each respective material

TEST SECTION	ROAD BASE COMPOSITION		
	LR	RCA	BA
CONTROL 1	-	100%	-
BA MIX 1	85%	-	15%
CONTROL 2	100%	-	-
BA MIX 2	-	85%	15%

2.2 Proposed Demonstration Roadway

The proposed demonstration roadway will be constructed at WIN's South Broward Facility as shown in Figure 2-1. The roadway will be constructed over an existing 20-foot wide unpaved limerock access road and will serve as the perimeter access road for the recent Cell 1C1 monofill expansion as shown in Figure 2-2. The demonstration road will include a 16-foot wide asphalt pavement over a 10-inch thick aggregate base, and include 2-foot wide limerock shoulders as shown in Figure 2-3. The UF team has developed an approach to incorporate the BA as a base material for this pilot project by blending with the most common road base aggregates used in Florida: LR and RCA. Each BA-amended section will be installed following the mix designs described in Table 2-1 or equivalent and will be placed along with control sections containing LR or RCA and no BA. Figure 2-2 provides conceptual drawings regarding the placement and positioning of each of the tested road base segments.

Figure 2-1. Location of the demonstration road at the WIN South Broward WTE Facility.

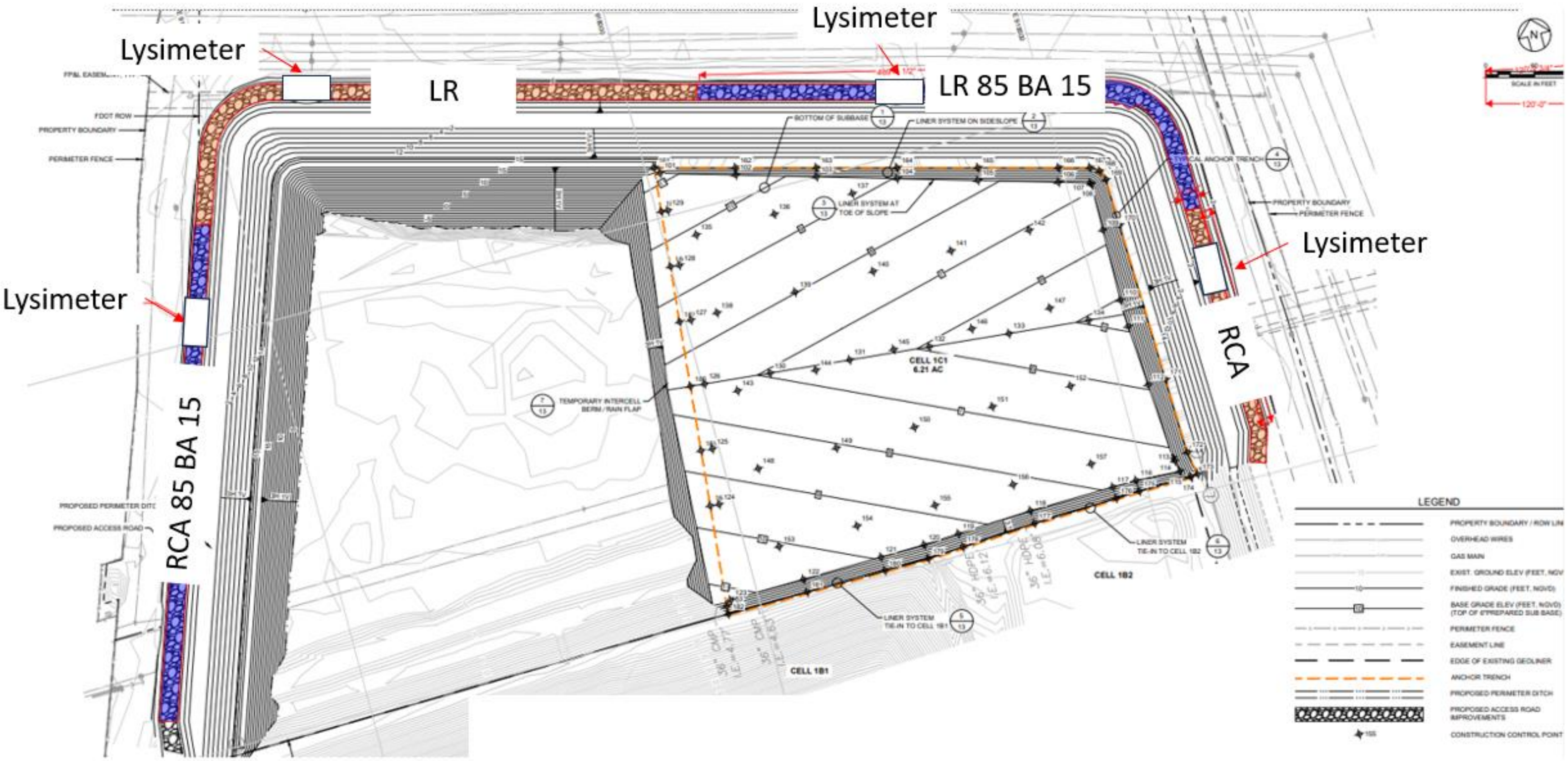

Figure 2-2: Proposed pilot road configuration and conceptual design drawings.

2.3 Road Design

The proposed pilot road has been designed according to FDOT Standard Specifications for Road and Bridge Construction Section 200 (FDOT, 2022); a traditional asphalt roadway includes an asphalt layer, a 6-12 inch base layer, a subbase layer, and the existing subgrade. The asphalt layer serves as the pavement layer, providing friction and smoothness necessary for traffic. The aggregate base course acts to distribute the load beneath the asphalt layer while providing strength and drainage to the road. The sub-base is an optional layer that also contributes to strength and acts as structural support between the base course and the soil. In this pilot road, each of the test and control sections will have a 10-inch-thick base layer, constructed in three courses and not extending past the width of the asphalt pavement, and be overlain by 3-inches of asphalt pavement. Table 2-2 presents the location of the test sections and lysimeters according to stationing format (typical format for road plans). Stationing describes the length along the road where a point of interest is, with one station being equal to 100ft. For example, a point of interest found after 150-ft of road length would be denoted as being at Station 1+50. The layout of the pilot road is displayed in Figure 2-2

A significant factor affecting beneficial use assessment includes infiltration through the pavement layer and the base and the impact on leaching performance and element mobility. To thoroughly understand the behavior of the ash amended roadways in-situ, the UF team has developed a set of lysimeters designed to be implemented beneath the aggregate base course to collect any potential infiltration. The lysimeter is a catchment system for water that flows through the base, implementing a design similar to leachate collection systems in landfills. In this proposed design, a 40-ft length of the road will have a drainage 200-mil geo-composite and 30-mil PVC liner underlying the base for half the road width as shown in Figures 2-4 through 2-7. In this 40-ft length, the bottom of the base will slope inwards from either side into a six-inch deep, one-foot-wide lined trench filled with gravel. Within the trench, a 2-inch schedule 40 PVC pipe will sit surrounded by the gravel. The trench and pipe slope outwards from the road center towards the shoulder, following the slope of the pavement. For the length of pipe beneath the base the PVC pipe will be slotted to collect leachate. At the edge of the road, the trench and pipe will be sealed with the 30-mil PVC liner and the pipe (without slots) will continue outwards past the road, a minimum of 5-ft from the shoulder, into a collection reservoir. The quantities of leachate collected in each lysimeter will be recorded and samples will be analyzed.

Table 2-2: The location and length of each test section and lysimeter is listed. Each station represents 100 feet. Station 0+00 is the starting point of construction.

Test Section	Base Material	Stationing				Length (ft)	
		Section Begin	Lysimeter Begin	Lysimeter End	Section End	Section	Lysimeter
Control 1	RCA	0+00	2+00	2+40	3+00	300	40
BA Mix 1	RCA/BA	3+00	9+00	9+40	10+00	700	40
Control 2	LR	10+00	14+60	15+00	17+50	750	40
BA Mix 2	LR/BA	17+50	19+00	19+40	24+00	650	40

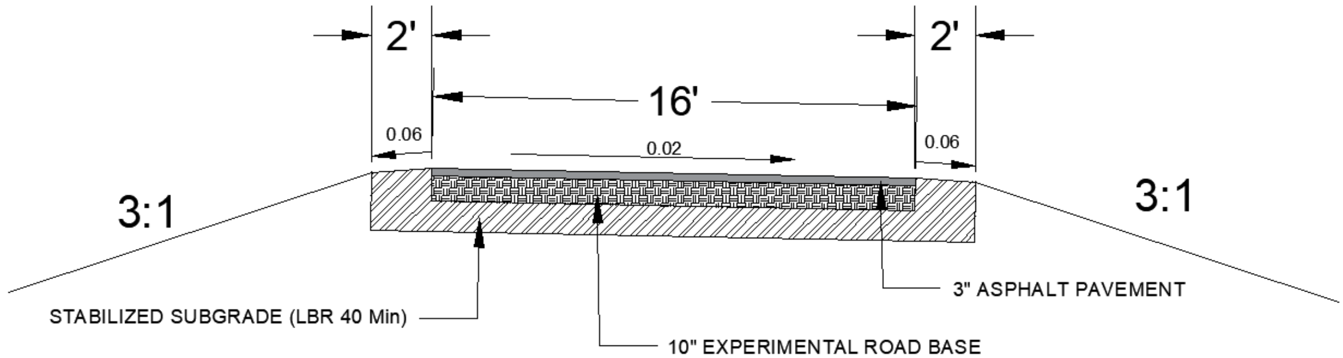

Figure 2-3: Cross section of the proposed demonstration road including 2-foot wide shoulders, the 3-inch deep asphalt pavement, 10-inch deep experimental road base, and stabilized subgrade.

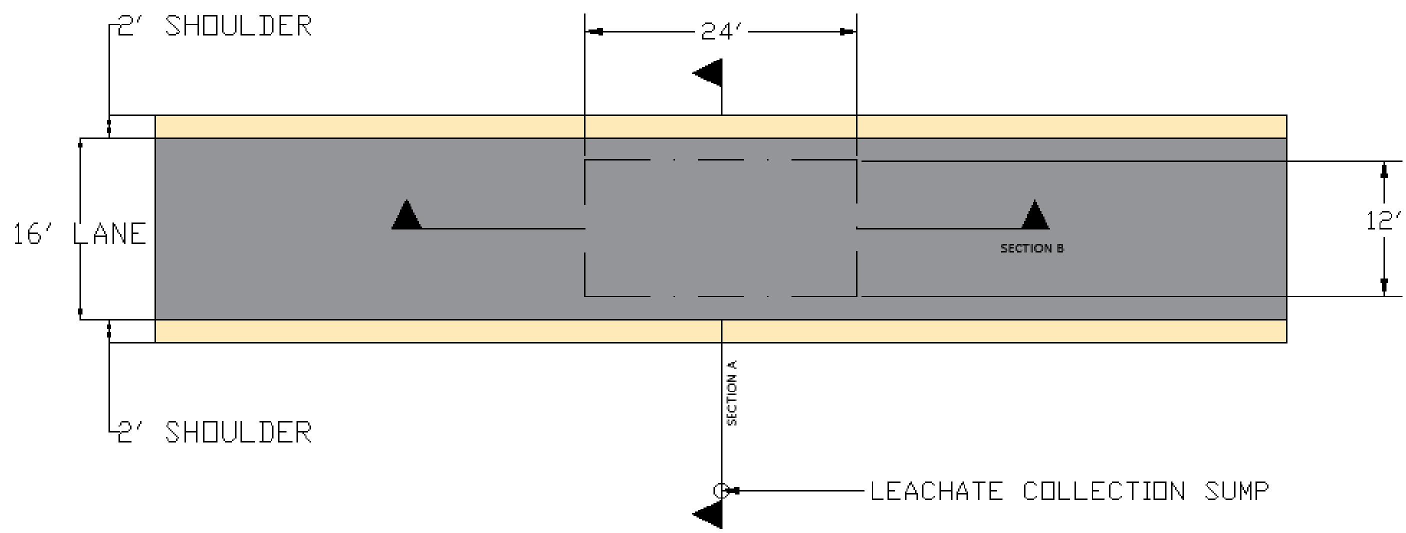

Figure 2-4: Plan view of lysimeter design. 24-ft by 12-ft collection area is centered on the road, captured infiltration is led to a collection vessel or sump located a minimum of 5-ft from the shoulder.

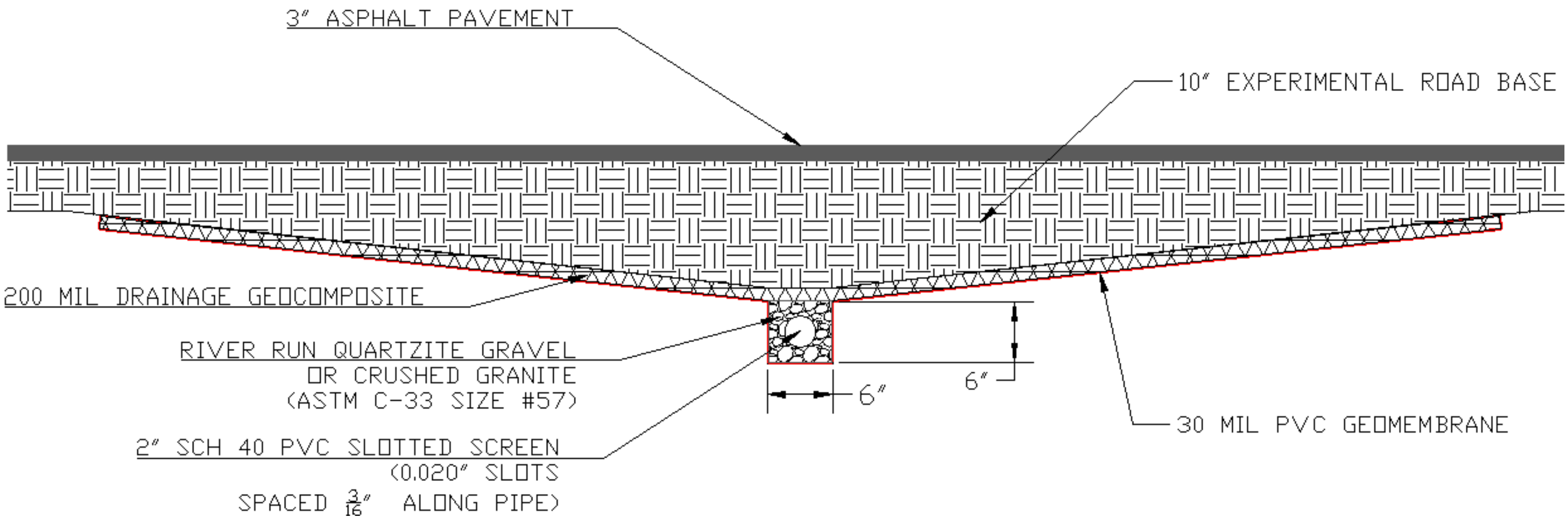

Figure 2-5: Cross section of a lysimeter, marked in Figure 2-3 as "Section B." The lysimeter collects infiltration through into a 6in-by-6in trench, containing a 2in PVC pipe with slots surrounded by gravel. Drainage geocomposite facilitates the flow of water into the trench. The geomembrane acts as an impermeable layer in the collection system, preventing infiltration from traveling past the base layer.

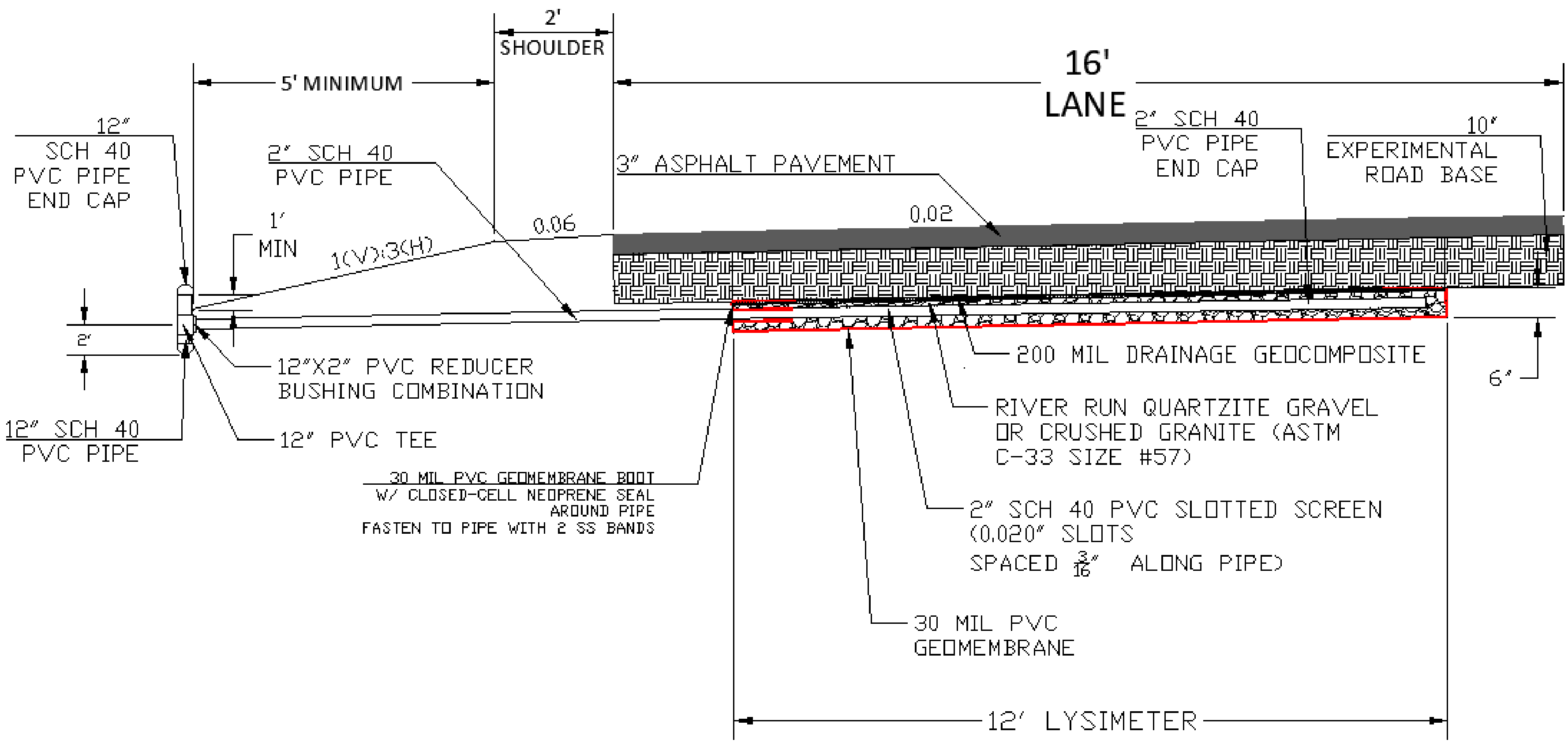

Figure 2-6: Cross section of a lysimeter, marked in Figure 2-3 as "Section A." Water traveling through the base layer is directed into the trench along the slopes shown in Section B. The trench is filled with drainage media and holds a slotted PVC pipe. Collected infiltration enters the slots of the pipe which directs the flow into a collection vessel, located a minimum of 5f-t from the road shoulder. The pipe is only slotted along the 12-inch length of the collection area and a geomembrane boot with neoprene seal further isolates the collection area.

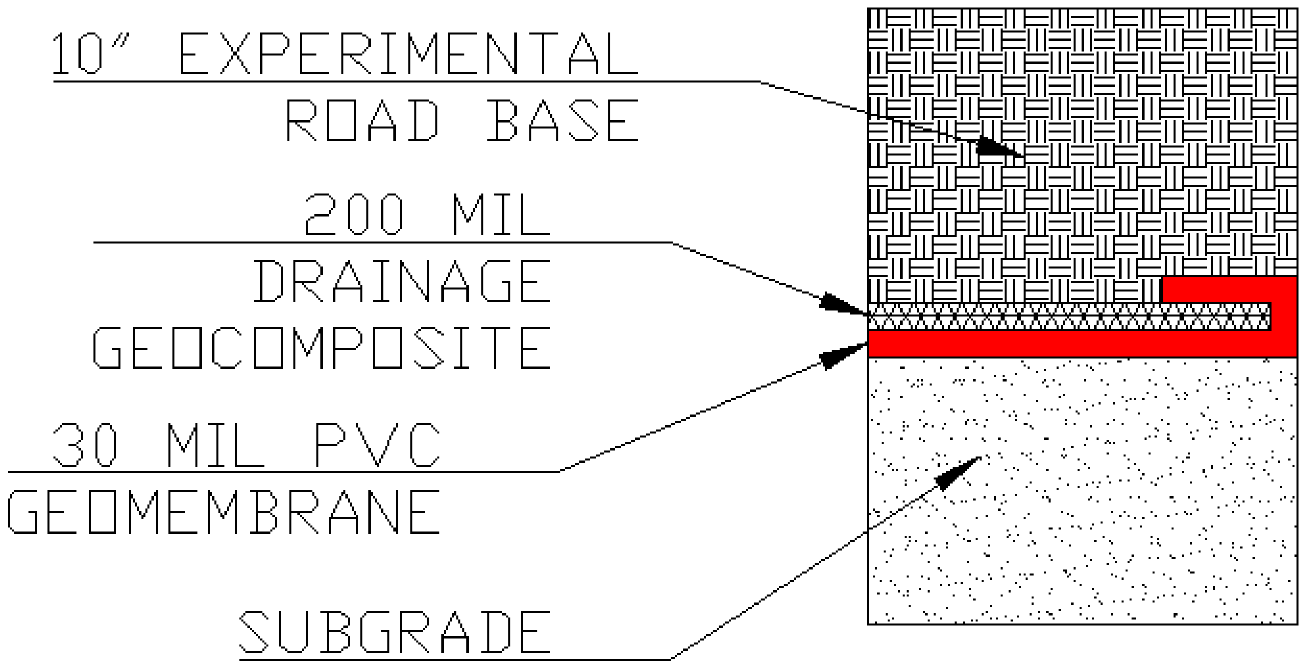

Figure 2-7: Lysimeter detail drawing showing the drainage geocomposite overlaying the geomembrane. The two layers separate the base from the subgrade and divert the infiltration flow to create a collection system. The geomembrane is wrapped over the edge of the geocomposite to secure the membrane and isolate the collection area.

2.4 Factors Affecting Beneficial Use of WTE BA

The proposed recycling scenario for South Broward BA as a blended road base aggregate was found to be feasible from a civil engineering standpoint, with additional data included in Section 3.0 and Appendix A. Ultimately, the reuse of BA will likely be dictated by the amount of environmental risk posed by each scenario, and the institutional or engineering controls associated with each. For example, the reuse of BA in an unbound road base not blended with other aggregates poses the highest direct exposure and leaching risks and would likely require a number of restrictions (end-of-life management of the roadway, dust control during construction, etc). However, the use of BA in a blended fashion would likely require fewer controls due to the lower estimated exposure and leaching risks. The reuse approach depends on physical and chemical behavior results and BA available for use, and any form of reuse is likely to be granted with a number of restrictions (e.g. distance of the roadway from well fields, end-of-life management of the roadway, dust control during construction, etc.).

3.0 Beneficial Use Physical Evaluation

This pilot project was inspired by past beneficial use projects performed by UF and those found in the literature. The approach investigated here proposes creating a BA-amended road base blended with RCA and LR, aggregates commonly used as road base material in Florida, as a beneficial reuse application for WIN BA. For an application to be classified as a beneficial reuse application, it must (1) not violate air and water standards, (2) not pose significant threat to human health and the environment, and (3) provide a benefit to the environment or community while meeting physical performance requirements (FDEP, 2019). Reusing BA as a substitute for LR or RCA reduces emissions associated with transportation and mining LR or producing RCA and provides an alternative to disposing of BA in a landfill or monofill. UF and WIN developed a plan to test the environmental and physical performance of the road base scenario to determine if this material meets the beneficial use requirements. The UF team has assessed the environmental performance through a risk assessment detailed in sections 5 and 6. To determine the feasibility of the BA road base blends, UF conducted tests to compare the physical performance and qualities of BA and BA road base blends to typical road base materials and required strength thresholds.

Particle size distribution (PSD) is a key factor in the strength of a compacted granular material and can impact physical performance such as ease of compaction. Aggregates can be graded to PSD ranges to improve compaction or drainage. FDOT prescribes a PSD for graded aggregate bases (GAB) and for RCA road base material. The particle size distribution (PSD) of the BA and aggregates alone was determined following ASTM Method C136: Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates (ASTM, 2015) and is displayed in Figure 3-1 along with the PSD for BA and aggregate sources. BA falls outside the recommended PSD for GAB, though only slightly. In fact, the PSD of the BA is coarser than that of collected RCA. This indicates that the sampled BA has a favorable distribution of particle sizes for compaction.

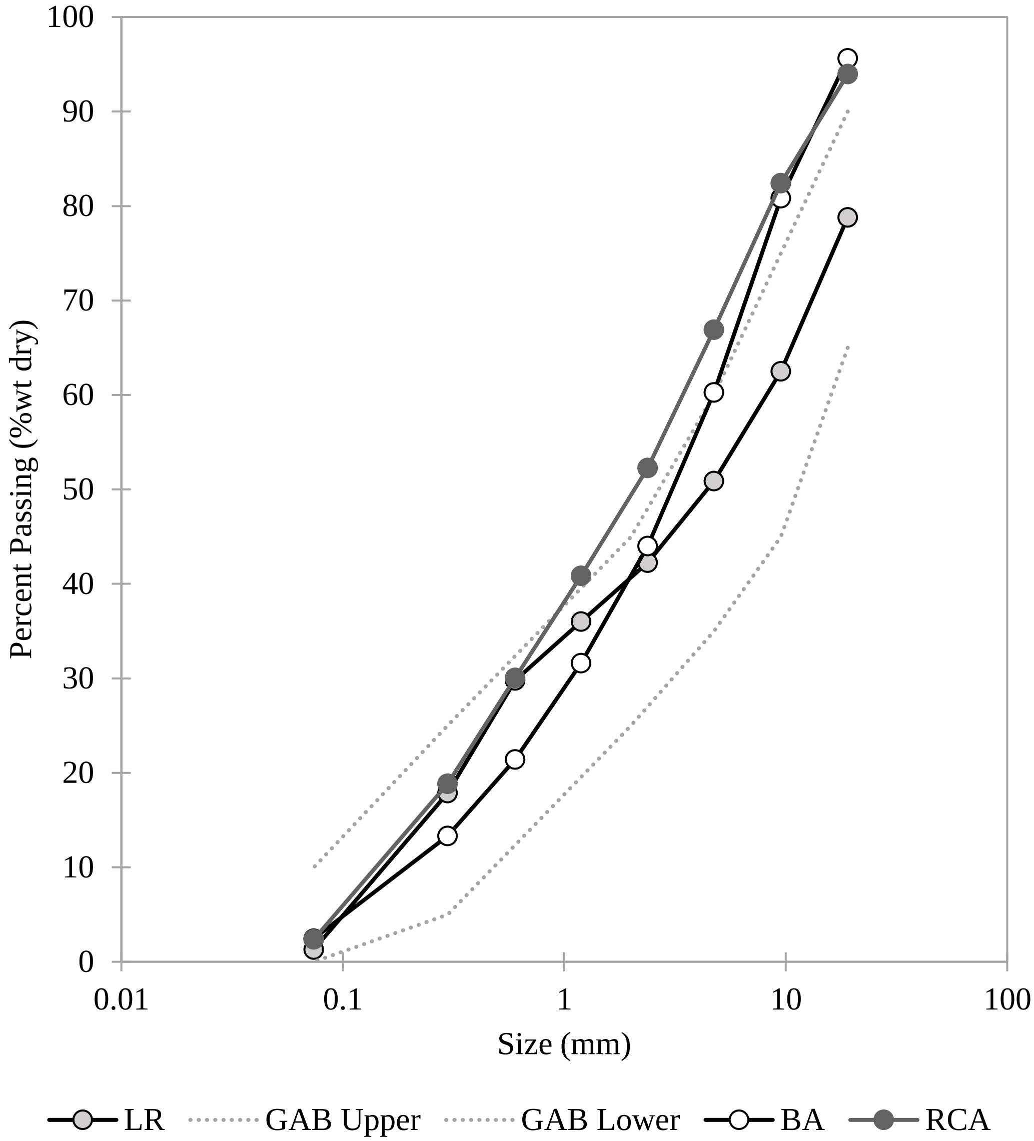

Figure 3-1 Particle Size Distribution (PSD) of South Broward BA and FDOT approved RCA and LR compared to the recommended PSD for graded aggregate base (GAB).

The moisture-density relationship of the BA compared to the zero air voids line is shown in Figure 3-2. The BA had an OWC of 16.2% and MDD of 107.7 pcf. The zero-air void line represents the dry density of a compacted material if there were no air voids between particles; these values were determined using the specific gravity of the BA. Figure 3-3 overlays a plot of limerock bearing ratio (LBR) values against water content over the plot of the moisture-density relationship. The moisture-density plots for the aggregates can be found in Appendix C. The maximum LBR value is used by FDOT to evaluate a material, and an LBR value of 100 represents a material with physical strengths comparable to that of approved LR. The BA exceeded the FDOT requirement with a maximum LBR of 189.6.

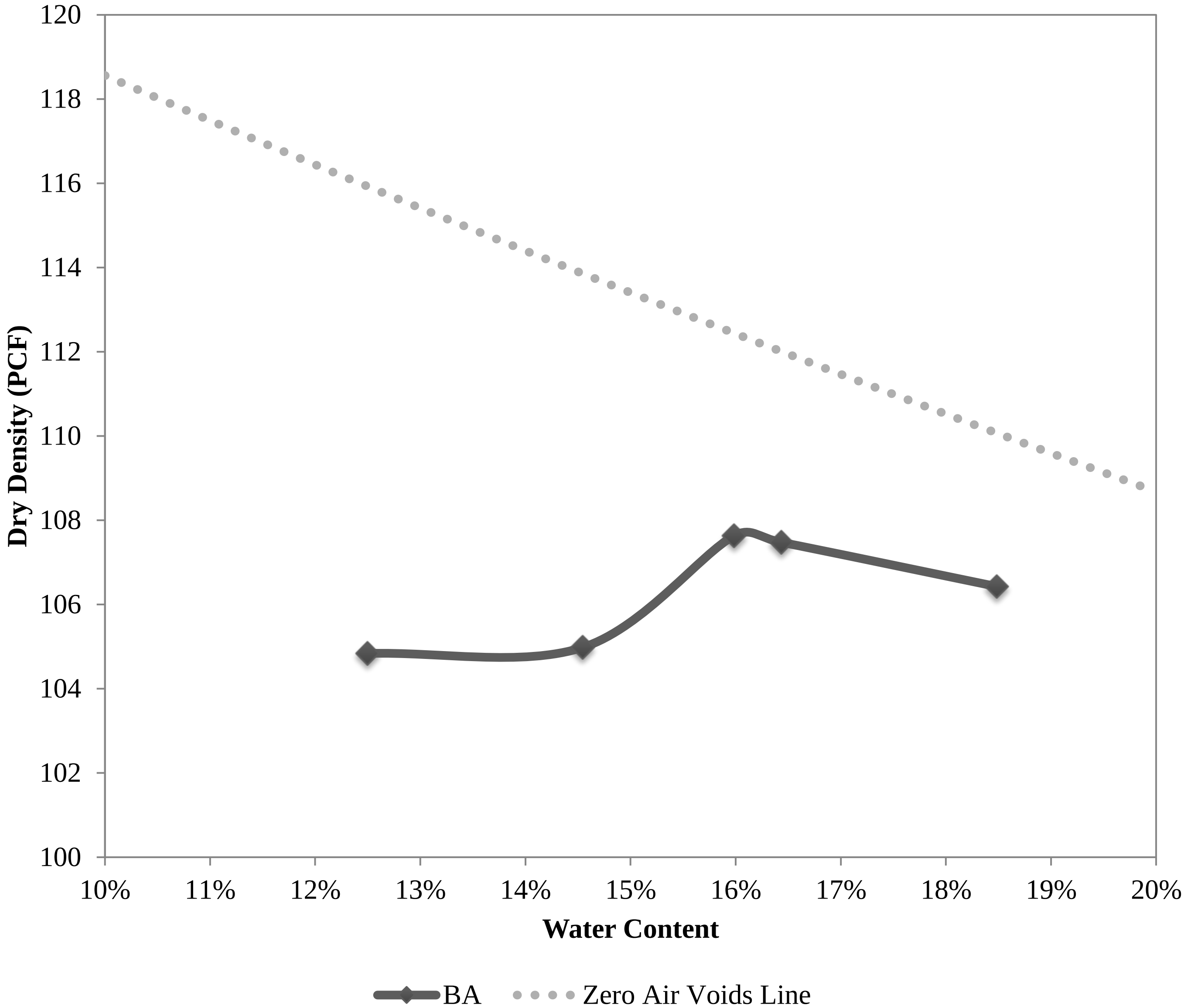

Figure 3-2. Moisture-density relationship of South Broward BA compared to the zero-air voids line.

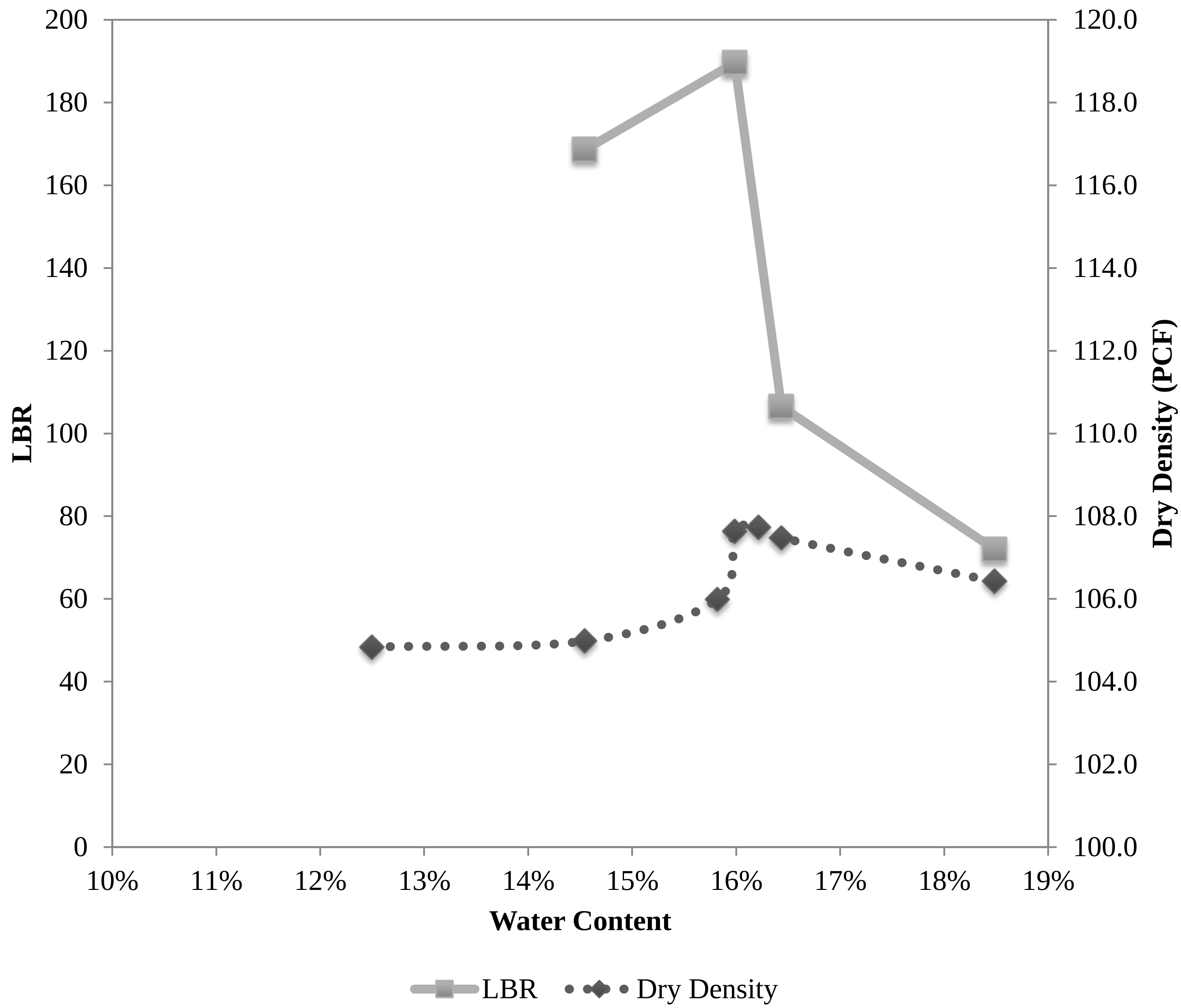

Figure 3-3. LBR value (%) vs water content (%) and moisture-density curve (pcf) for South Broward BA .

Road base material tests prescribed by FDOT were employed to analyze the strength of BA road base blends compared to benchmarks set by DOT. Following method FM 5-515: Florida Method of Test for Limerock Bearing Ratio (LBR), the strengths of the BA, aggregates, and BA-aggregate blends were determined (FDOT, 2017). Approved FDOT LR and RCA vendors are required by FDOT to maintain LBR results at or above 100 and 150 for their material, respectively. UF performed proctor compaction and LBR testing on various blends of BA-aggregate road base to assess the performance of the blends. The blending of BA with LR or RCA produced a material that yielded an LBR that surpasses the FDOT requirement of 100. From the blends tested, road base blends that yielded acceptable LBR results while optimizing BA replacement were selected for use in the pilot road. The LBR from these blends are displayed in Figure 3-4, as well as the LBR from the LR and RCA alone. Figure 3-4 demonstrates that the BA-aggregate blends yield LBR values that meet and exceed the prescribed requirement of 100.

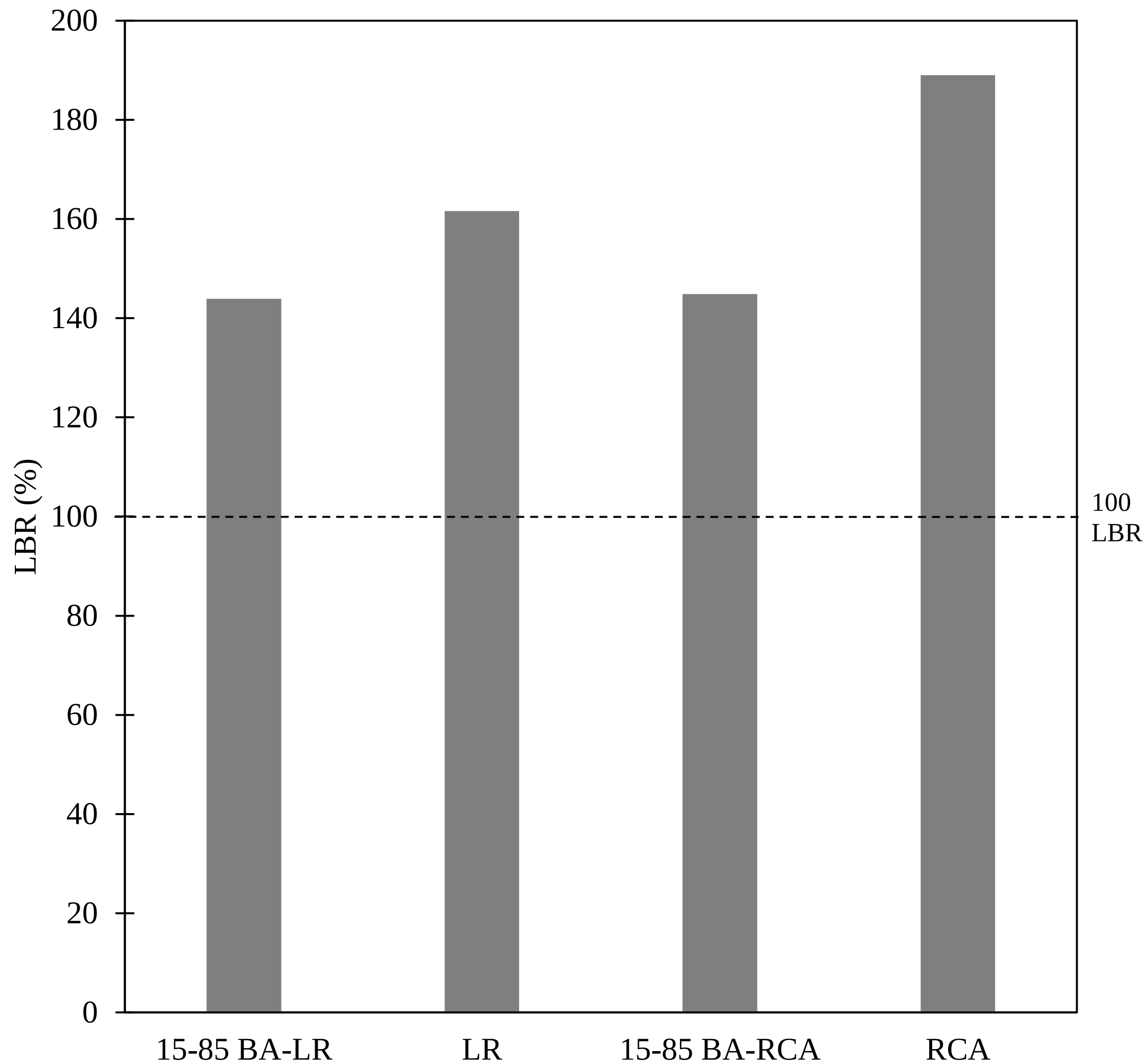

Figure 3-4. LBR results for 15-85 (by mass) BA-aggregate blends, LR, and RCA compared to the FDOT thresholds for LBR for LR (100) (%).

4.0 Risk Assessment Approach

To beneficially reuse a waste material, the potential risk to human health and the environment must be assessed, and appropriate risk mitigation measures should be implemented. The approach used to assess risk associated with the WIN BA demonstration project follows the established approach for the beneficial use of waste materials in the state of Florida (FDEP, 2001; FDEP, 2019). UF has developed similar pilot road demonstration projects for Hillsborough, Palm Beach, and Pasco counties, in which WTE ash was investigated as a full or partial replacement in road base blended with common aggregate materials. Beneficial use projects of this sort require extensive physical and environmental testing of the waste material to provide a full risk assessment.

The two risk pathways considered in the assessment for this demonstration project include direct exposure and leaching to groundwater risk. Direct exposure risk is assessed by examining potential pathways of human contact with the material, such as inhalation, dermal contact, and ingestion. The leaching-to-groundwater pathway is first assessed by examining the leaching behavior of the four proposed road base blends by conducting standardized leaching tests on the materials. These pathways are further discussed in Sections 4.1 and 4.2, and the data presented in Sections 5.0 and 6.0. With this information, the fate and transport behavior of leached constituents from the road base, down to the aquifer, and horizontally to a point of compliance is estimated with a fate and transport model. This is discussed in more detail in Section 4.2. In both cases, the location of the demonstration project and nature of the reuse application (encapsulated below the asphalt pavement) significantly impact the proposed risk mitigation plan. A flow chart displaying the risk assessment process is displayed in Figure 4-1.

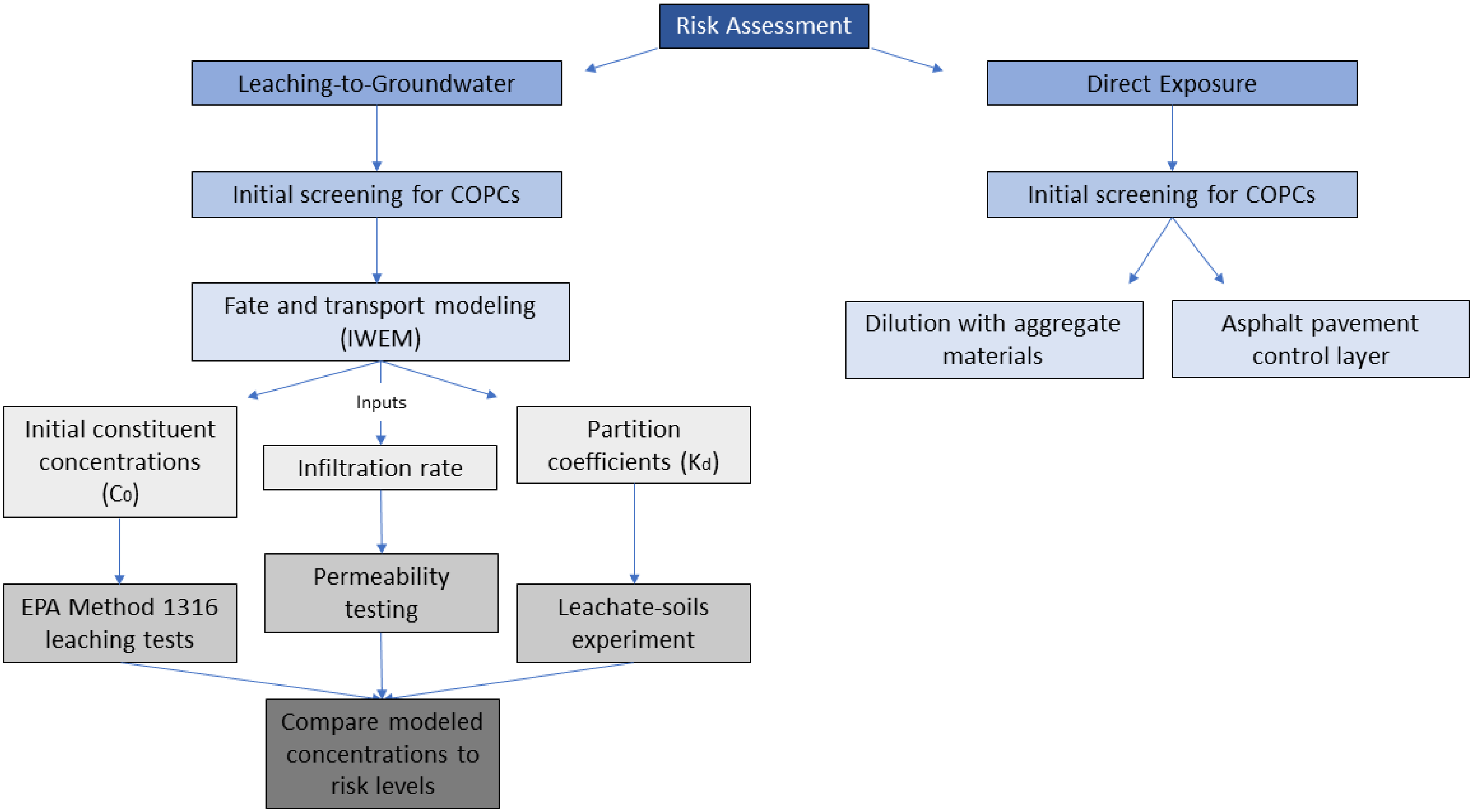

Figure 4-1: Schematic illustrating a typical risk assessment approach.

4.1 Direct Exposure

Direct exposure risk screening involves comparing the total concentration of constituents in the waste material to state regulatory guidelines, in this case, Florida's Soil Cleanup Target Levels (SCTLs). To calculate the total constituent concentrations in the BA-aggregate blends, the materials were first acid digested according to EPA Method 3050B: Acid Digestion of Sediments, Sludges, and Soils (EPA, 1996) to mobilize constituents from complex matrices, allowing any potential environmentally available concentrations to be accurately measured. Prior to digestion, the moisture content of each sample was measured by collecting the weight of the sample before and after spending 24 hours in an oven at 100C. Representative 1–2 gram wet weight size reduced daily samples (n=5) were digested with repeated additions of trace metal grade nitric acid and hydrogen peroxide and refluxed with trace metal grade hydrochloric acid. This digestion was completed by hand following a reagent addition and heating schedule per the test methodology.

Following acid digestion, inductively coupled plasma atomic emission spectrometry (ICP-AES) was employed following EPA Method 200.7: Determination of Metals and Trace Elements in Water and Wastes by Inductively Coupled Plasma-Atomic Emission Spectrometry to determine trace metal concentrations (US EPA, 1994a). The concentrations for each individual material—LR, RCA, and BA—were compared to Florida's SCTLs, which are set by FDEP and can be found in 62-777, F.A.C. (F.A.C. 62-777. Groundwater and Surface Water Cleanup Target Levels, 2005). Due to the methodology of EPA Method 3050B and the small mass of sample required, BA-aggregate blends were not digested but rather estimated by calculating theoretical contributions of each material at the proposed blends using equation 1.

$$\boldsymbol{C_{Blend}}\left(\frac{mg}{kg-dry}\right) = [(\boldsymbol{C_{BA}})(\%_{\boldsymbol{BA}}) + (\boldsymbol{C_{Agg}})(\%_{\boldsymbol{Agg}})] \quad (1)$$

C_{Blend} = *predicted concentration of COPC in blended product (mg/kg-dry)*

C_{BA} = *measured concentration of COPC in BA (mg/kg-dry)*

C_{Agg} = *measured concentration of COPC in natural/recycled aggregate (mg/kg-dry)*

Full direct exposure results, including theoretical calculations for constituent concentrations in the proposed BA-aggregate blends, are outlined in Chapter 5. In addition to the asphalt pavement layer which will encapsulate the waste material in the road base, any contaminants present in the BA are expected to be reduced in the final material through blending with the aggregate materials and will likely pose a lower risk of direct exposure than unblended BA. After wetting, compaction, and confinement by the asphalt pavement layer, the direct exposure risk will be significantly reduced during the service life of the road. Worker exposure will be controlled through proper construction techniques, such as wetting the BA to control dust (OSHA, 1970).

4.2 Leaching-to-Groundwater

Assessment of leaching-to-groundwater risk involves examining the leaching behavior of various constituents from the waste material and road base blends and modeling the mobility from the placement site to a target compliance point. For the beneficial use of a waste material in road base, a theoretical description of the contaminant pathway is as follows: upon contact with infiltrating water through the surficial pavement layer, constituents leach out of the road base, travel vertically through the subbase and vadose zone, and enter the aquifer. Once inside the saturated zone, they are horizontally transported via groundwater movement. Dilution and attenuation of the constituent is expected at each stage, suggesting concentrations will decrease. An illustration of this process is included in Figure 4-2.

To identify the constituents that require further site-specific modeling, the proposed blends were leached according to EPA Method 1316 (EPA, 2017) and concentrations were compared to Florida's Groundwater Cleanup Target Levels (GCTL). The materials leached for this test were representative or proposed road base segments, including 15-85 blends of BA-LR, and 15-85 blends of BA-RCA (by mass). While the final road base design may contain less than 15% BA, these blends will provide a conservative estimate of the leaching-to-groundwater risk. Additional information about EPA Method 1316 test may be found in Section 6.1. The leaching test values are compared to health-based GCTLs, and initial values (C_0) that exceed the GCTL are used to calculate target dilution and attenuation factors (DAF), as displayed in equation 2. The DAF are tools implemented to understand the dilution and attenuation in the soil and aquifer matrix beneath the base required to bring the predicted leachate concentrations to a selected regulatory threshold. Elements with a DAF of 1 or less indicate that leaching concentrations do not exceed respective water quality thresholds. Elements with a DAF greater than 1 are further investigated to understand the element fate and transport at the specific site.

$$DAF = \frac{C_0}{GCTL} \qquad (2)$$

The fate and transport model chosen for this risk assessment is the EPA's Industrial Waste Management Evaluation Model (IWEM). This model is commonly used to evaluate potential groundwater impacts resulting from beneficial use material applications and requires site-specific parameters such as infiltration through the pavement, depth to groundwater, and soil-attenuation values. To provide the most accurate site-specific assessment, these characteristics were determined by calculating site-specific partitioning coefficients, proposed road base permeability, estimating soil and aquifer depth based on existing site data, and using the Hydrologic Evaluation of Landfill Performance (HELP) model to develop realistic, conservative pavement infiltration rates. Using these inputs, IWEM predicts a conservative estimate (90th percentile) of groundwater concentrations which are then used to assess potential groundwater impacts from the reuse scenario. These experiments and models are described thoroughly in the following sections.

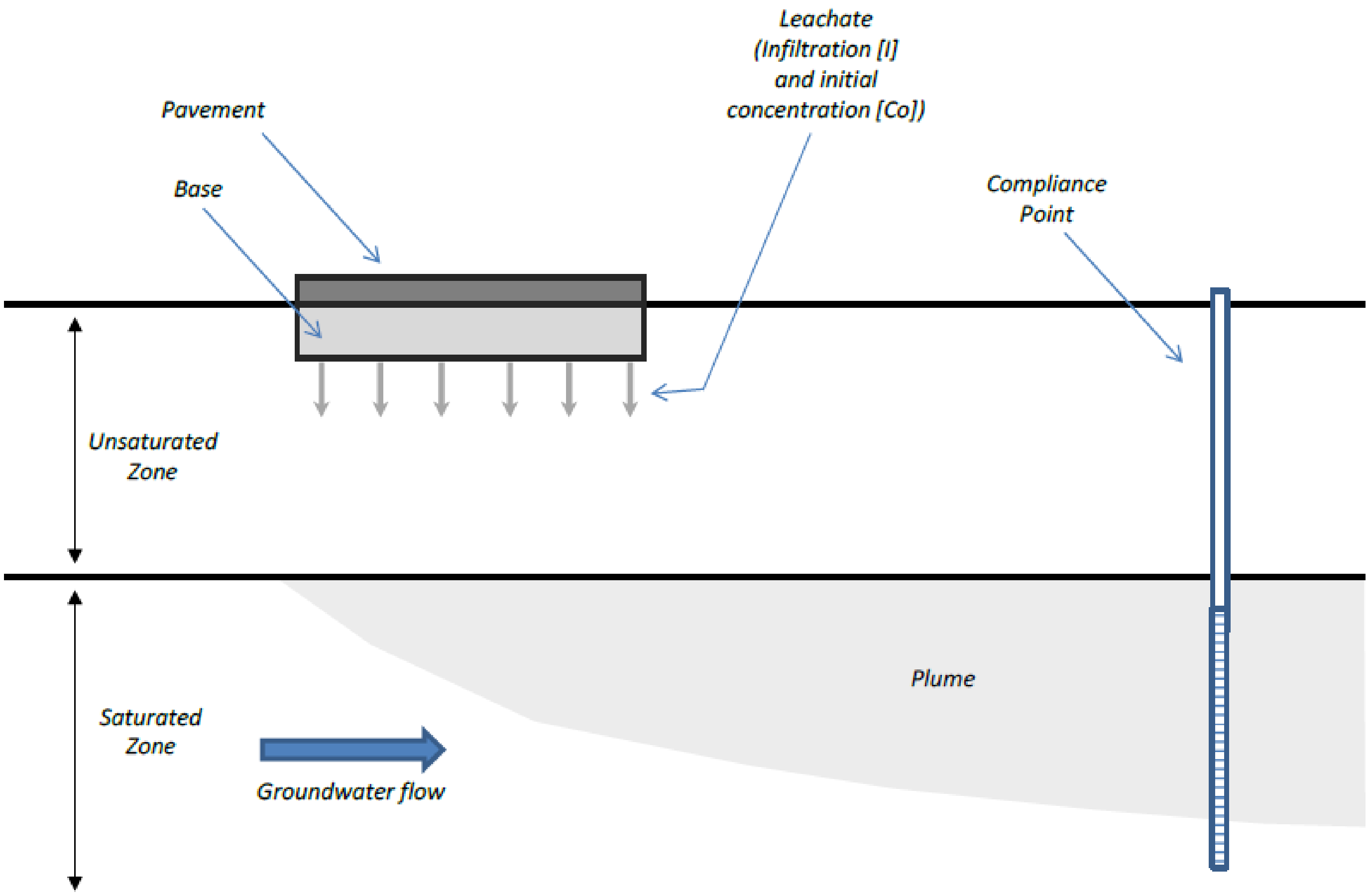

Figure 4-2: Illustration of constituent transport from the placement site to a point of compliance.

5.0 Direct Exposure Assessment

As discussed previously, direct exposure pathways include ingestion, inhalation, and dermal contact. While much of the direct exposure risk for BA will be mitigated by engineering controls in the road base application, understanding the chemical composition of unblended BA and aggregate materials is important for determining if any constituents require attention when designing the road base blends. The BA, LR, and RCA were analyzed for total inorganic elements and results were compared to Florida's risk-based commercial and industrial direct exposure SCTL (FDEP, 2005).

Five replicates of each sample (BA, LR, and RCA) were digested according to EPA Method 3050B to dissolve complex matrices and extract environmentally available elements (US EPA, 2019b). The samples were then analyzed with ICP-AES in accordance with EPA Method 200.7 to determine total element concentrations. The results in Table 5-1 compare the total element concentrations found in the BA and aggregate materials to Florida's SCTL. Mean concentrations of As, Ba, Cu, and Pb exceeded the residential SCTL in all daily samples. Additionally, Sb exceed the residential target level in four of the fourteen daily samples.

While the residential SCTL exceedances reflect potential direct exposure risk, worker exposure during ash processing, transport, and recycling will be limited and controlled through proper construction techniques, such as dust control and proper Personal Protective Equipment (PPE). It is important to recall that the BA-amended base will be encapsulated under an asphalt pavement layer, so its direct exposure risk will be mitigated during normal road usage. Furthermore, blending BA with LR or RCA will reduce BA content and reduce total element concentrations provided by the BA, as seen in Tables 5-2 and 5-3. In the BA:RCA and BA:LR 15:85 blends, theoretical total Ba, Pb, and Sb concentrations are reduced and no longer exceed the residential SCTL compared to BA alone. Theoretical total Cu concentration, while still exceeding the residential SCTL (150mg/kg), is also reduced in these blends. Furthermore, the Cu SCTL is based on acute exposure, which would be mitigated in the encapsulated nature of the road base. When compared to the EPA Regional Screening Level for residential soil of 3,100 mg/kg, none of the blends exceed the level.

Table 5-1: Total element concentrations (mg/kg-dry) in daily samples. Bolded numbers indicate an exceedance in the residential SCTL.

Sample	Res SCTL	Com SCTL	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 8	Day 9	Day 10	Day 11	Day 12	Day 13	Day 14
Al	80,000	*	36,100	25,400	27,700	29,500	33,600	48,900	33,200	35,500	35,300	23,000	29,500	42,400	38,300	25,200
As	2.1	12	**5.76**	**6.91**	**5.72**	**3.38**	**7.03**	**3.70**	**9.65**	**8.47**	**4.22**	**7.50**	**4.59**	**4.65**	**8.64**	**5.59**
B	17,000	430,000	162	195	166	160	271	179	177	223	145	156	207	185	223	159
Ba	120**	130,000	**373**	**351**	**252**	**414**	**539**	**409**	**420**	**314**	**247**	**401**	**320**	**324**	**351**	**245**
Be	120	1400	0.302	0.259	0.227	0.246	0.326	0.516	0.283	0.252	0.246	0.230	0.225	0.267	0.312	0.217
Ca			121,000	110,000	100,000	100,000	148,000	108,000	115,000	108,000	94,300	85,400	91,900	113,000	132,000	94,000
Cd	82	1700	11.2	11.0	7.23	4.49	3.63	4.42	4.87	15.5	4.63	6.27	5.89	3.90	8.81	3.93
Co	1,700	42,000	229	51.5	49.9	56.1	134	38.7	30.4	33.8	44.6	29.3	106	29.6	48.8	44.4
Cr	210	470	88.0	71.8	74.1	204	79.1	760	102	78.9	59.3	70.2	853	198	82.6	85.4
Cu	150**	89,000	**4,110**	**2,650**	**2,750**	**4,380**	**4,920**	**1,970**	**2,170**	**2,950**	**3,730**	**2,340**	**2,980**	**2,350**	**12,200**	**1,750**
Fe	53,000	*	45,700	34,800	41,600	47,800	39,700	36,000	49,300	52,100	37,000	43,500	46,400	34,500	48,000	30,400
K			3,940	3,050	1,870	1,710	2,140	1,940	2,350	2,360	1,940	2,210	2,210	2,170	2,610	1,660
Mg			6,260	5,300	5,680	5,490	6,400	6,290	6,160	2,480	5,250	4,990	4,680	6,380	6,970	5,430
Mn	3,500	43,000	1,050	981	736	852	1,040	2,690	545	685	489	480	521	1,670	660	434
Mo	440	11,000	8.84	7.42	9.47	9.27	8.35	11.4	7.55	9.21	4.66	5.71	6.56	7.33	9.50	7.78
Na			9,920	8,940	6,770	7,110	8,140	6,970	8,380	9,290	6,730	7,720	8,170	7,550	9,210	6,520
Ni	340**	35,000	86.1	130	116	108	288	401	85.1	97.6	80.4	77.1	60.5	161	124	68.5
Pb	400	1400	**1,670**	**1,510**	**561**	**1,900**	**2,250**	**1,570**	**10,000**	**4,900**	**1,210**	**1,260**	**2,080**	**1,140**	**1,640**	**1,130**
Sb	27	370	21.6	**30.1**	19.5	17.0	15.8	**39.3**	24.1	**59.2**	13.7	16.0	**31.0**	19.1	21.5	16.6
Se	440	11,000	1.12	1.20	0.502	0.553	0.751	1.306	0.721	0.981	0.302	0.354	0.821	0.781	0.298	0.213
Sn	47,000	880,000	96.9	104	64.5	55.6	80.8	51.2	103	152	242	152	93.0	42.9	127	42.0
Sr	52,000	*	309	311	268	234	397	302	276	295	222	338	239	310	463	232
Ti			1,200	827	1,340	1,090	1,450	1,000	1,180	1,340	1,000	1,460	1,170	1,020	1,140	759
V	67**	10,000	15.8	17.6	13.4	15.1	32.7	45.5	15.9	17.2	11.7	12.1	15.7	20.2	16.7	12.3
Zn	26,000	630,000	4,050	2,670	2,750	2,630	2,710	5,660	2,330	3,270	2,470	2,910	3,270	2,600	3,470	4,000

* Contaminant is not a health concern for this exposure scenario

** Direct exposure value based on acute toxicity considerations. This criterion is applicable in scenarios where children might be exposed to soils (e.g. residences, schools, playgrounds)

Table 5-2: Theoretical total element concentrations (mg/kg-dry) in BA:RCA blends, calculated according to Equation 1. Bolded numbers indicate an exceedance in the residential SCTL.

Theoretical Total Values (mg/kg-dry)								
Sample	**Res SCTL**	**Com SCTL**	**BA:RCA 15:85**	**BA:RCA 20:80**	**BA:RCA 35:65**	**BA:RCA 50:50**	**BA:RCA 65:35**	**BA:RCA 80:20**
Al	80,000	*	8,780	10,200	14,500	18,800	23,100	27,400
As	2.10	12.0	**7.58**	**7.49**	**7.24**	**6.98**	**6.73**	**6.47**
B	17,000	430,000	39.1	47.8	73.7	100.	126	152
Ba	120**	130,000	85.2	101	**148**	**196**	**243**	**291**
Be	120	1400	0.256	0.258	0.262	0.266	0.270	0.274
Ca			206,000	200,000	183,000	166,000	149,000	131,000
Cd	82.0	1,700	1.20	1.53	2.53	3.52	4.52	5.51
Co	1,700	42,000	11.6	14.8	24.4	34.0	43.6	53.3
Cr	210	470	42.9	52.1	79.9	108	136	163
Cu	150**	89,000	**569**	**751**	**1,300**	**1,840**	**2,390**	**2,930**
Fe	53,000	*	14,000	17,500	27,800	38,200	48,600	**58,900**
K			723	816	1,090	1,370	1,650	1,930
Mg			3,870	3,970	4,270	4,560	4,860	5,160
Mn	3,500	43,000	203	245	371	497	623	749
Mo	440	11,000	5.47	5.62	6.08	6.54	7.00	7.46
Na			1,710	2,070	3,180	4,280	5,380	6,490
Ni	340**	35,000	24.7	31.1	50.5	69.9	89.3	109
Pb	400	1400	266	354	**616**	**879**	**1142**	**1405**
Sb	27.0	370	4.12	5.32	8.94	12.6	16.2	19.8
Se	440	11,000	0.298	0.322	0.394	0.466	0.539	0.611
Sn	47,000	880,000	16.7	21.6	36.4	51.2	66.0	80.8
Sr	52,000	*	522	509	469	430	391	352
Ti			386	431	564	697	830	964
V	67.0**	10,000	18.5	18.5	18.5	18.6	18.6	18.7
Zn	26,000	630,000	523	680	1,150	1,630	2,100	2,570

* Contaminant is not a health concern for this exposure scenario

** Direct exposure value based on acute toxicity considerations. This criterion is applicable in scenarios where children might be exposed to soils (e.g. residences, schools, playgrounds)

Table 5-3: Theoretical total element concentrations (mg/kg-dry) in BA:LR blends, calculated according to Equation 1. Bolded numbers indicate an exceedance in the residential SCTL.

Theoretical Total Values (mg/kg-dry)									
Sample	**Res SCTL**	**Com SCTL**	**BA:LR 15:85**	**BA:LR 20:80**	**BA:LR 35:65**	**BA:LR 50:50**	**BA:LR 65:35**	**BA:LR 80:20**
Al	80,000	*	5,590	7,210	12,100	16,900	21,800	26,600
As	2.10	12	1.27	1.56	**2.42**	**3.27**	**4.13**	**4.99**
B	17,000	430,000	29.5	38.8	66.4	94.0	122	149
Ba	120**	130,000	56.7	74.2	**127**	**179**	**232**	**284**
Be	120	1,400	0.127	0.136	0.163	0.190	0.217	0.244
Ca			219,000	212,000	193,000	173,000	154,000	134,000
Cd	82.0	1700	1.11	1.45	2.46	3.47	4.48	5.49
Co	1,700	42,000	10.4	13.7	23.5	33.4	43.2	53.0
Cr	210	470	36.5	46.1	75.1	104	133	162
Cu	150**	89,000	**550**	**733**	**1,280**	**1,830**	**2,380**	**2,930**
Fe	53,000	*	11,300	14,900	25,800	36,600	47,500	**58,300**
K			393	505	841	1,180	1,510	1,850
Mg			3,150	3,300	3,720	4,140	4,570	4,990
Mn	3,500	43,000	147	193	328	464	600	736
Mo	440	11,000	1.47	1.86	3.02	4.19	5.36	6.52
Na			1,410	1,800	2,950	4,110	5,260	6,420
Ni	340**	35,000	21.1	27.8	47.8	67.8	87.8	108
Pb	400	1400	264	351	**615**	**878**	**1,140**	**1,400**
Sb	27.0	370	3.95	5.16	8.81	12.5	16.1	19.7
Se	440	11,000	0.277	0.302	0.378	0.454	0.530	0.606
Sn	47,000	880,000	16.7	21.6	36.4	51.2	66.0	80.8
Sr	52,000	*	392	387	371	354	338	322
Ti			175	232	402	573	743	914
V	67.0**	10,000	7.25	7.92	9.94	12.0	14.0	16.0
Zn	26,000	630,000	482	642	1,120	1,600	2,080	2,560

* Contaminant is not a health concern for this exposure scenario

** Direct exposure value based on acute toxicity considerations. This criterion is applicable in scenarios where children might be exposed to soils (e.g. residences, schools, playgrounds)

6.0 Leaching-to-Groundwater Assessment

While the concentrations for assessing the direct risk of exposure were theoretically calculated, the leaching behavior primarily relies on the interaction between the components, the ratio of liquid to solid (LS), and the pH of the material and leachate. Various leaching experiments were conducted to evaluate the mobility of elements from the BA both fresh and aged, and aggregates alone including the Synthetic Precipitation Leaching Procedure (SPLP) as per EPA Method 1312 (US EPA, 1994b) and EPA Method 1316 at an LS of 10. Several leaching tests were performed on the BA-aggregate blends, including a modified version of EPA Method 1316 based on BA addition, EPA Method 1316 considering LS ratio, and EPA Method 1313 considering pH (US EPA, 2017, 2019a).

For each daily sample of fresh BA, SPLP was performed in duplicate in accordance with the EPA guidelines (EPA, 1994b). The leaching data obtained from SPLP offered insights into the behavior of inorganic elements found in the ash. In this procedure, a 100-gram representative sample was combined with 2 liters of Extraction Fluid #1 as specified by the method. Each sample was rotated at room temperature, at 30 revolutions per minute for 18 hours. Subsequently, the SPLP pH was recorded for each sample, followed by filtering the samples through the designated glass fiber filter. These filtered samples were digested using EPA Method 3010A to prepare for ICP-AES analysis (EPA, 1992).

After the aging process described in the previous sections, SPLP was carried out on several representative samples of aged BA. EPA Method 1316 at an LS of 10 was conducted on each aggregate, aged BA, and aged BA blended with LR or RCA (EPA, 2017). Each sample was combined in a 1 L bottle, and nanopure water was added at an LS of 10. The mixture was rotated for 72 hours, filtered, and preserved for ICP-AES analysis. The samples were digested using EPA Method 3010A, and the concentrations of trace elements were determined using ICP-AES technology. The mix designs tested for leached constituents ranged from 10% to 80% aged BA by mass, blended with LR or RCA at varying proportions (10%, 15%, 20%, 35%, 50%, 65%, and 80% BA).

6.1 Leaching as a Function of LS Ratio

Following testing of each blend and discussions with WIN, the 15-85 BA-aggregate blends were selected for further analysis. These blends were selected based on ash availability and initial data collected from total element concentrations, however the mobility of constituents of concern were further examined and described in this section. To determine the leaching characteristics of the 15% BA blends with LR and RCA in relation to the LS ratio, EPA Method 1316, Liquid-Solid Partitioning as a Function of Liquid-to-Solid Ratio in Solid Materials Using a Parallel Batch Procedure was employed (EPA, 2017). For each sample, a 1 L bottle was utilized, and nanopure water was added at LS ratios of 2, 5, 10, 15, and 20. The mixture was then rotated for 72 hours, filtered, and preserved for subsequent ICP-AES analysis. The samples were digested following EPA Method 3010A, and the concentrations of trace elements were determined using ICP-AES technology.

While the LS ratio of 10 in the leaching process helps identify COPCs, it does not represent the conditions that would be encountered by an asphalt-encapsulated road base. Asphalt pavement is generally considered impermeable, making it burdensome to conduct a leaching test using a realistic LS ratio. However, this method can still offer valuable insights into the trends of element mobility as the LS ratio varies and may be extrapolated to predict leaching behavior under site-specific conditions.

6.2 Leaching as a Function of pH

To investigate the movement of trace elements under different pH conditions, EPA Method 1313, Liquid-solid partitioning as a function of extract pH using a parallel batch extraction procedure was conducted on the 15%-85% BA-aggregate blends (US EPA, 2017). For each sample, a 1 L of nanopure water was added to the blended samples at an LS ratio of 10. The eluent pH was modified by introducing varying concentrations of nitric acid or sodium hydroxide to meet target pH values including 1, 3, 5, 7, 9, 11, and 12.5 ± 0.5. After rotating the samples for 72 hours, they were filtered and preserved for subsequent ICP-AES analysis. The samples were digested following EPA Method 3010A, and the concentrations of trace elements were determined using ICP-AES technology.

As the leachate from the road base blend migrates through the site-soil and reaches the groundwater, the pH can be influenced by site-specific conditions, potentially impacting the mobility of the elements. While other factors such as soil partitioning coefficients or ion exchange capacity may also influence the movement of elements, this test method offers valuable insights into the behavior of the elements as a function of pH.

6.3 Leaching Behavior Results

6.3.1 Fresh BA and Aggregate

The SPLP leached elemental concentrations were analyzed and compared to the residential GCTLs. Table 6-1 displays the SPLP concentrations, with those exceeding the residential GCTL indicated in bold. Al, Pb, and Sb exceeded the residential GCTL in all daily samples, and Na exceeded the target level in half of the fourteen total daily samples. The greatest GCTL exceedance is Pb by a factor of 11.3 – 201 times above the GCTL (0.015 mg/L). The Florida residential GCTL for Al (2.0 mg/L) is an aesthetic guideline corresponding to the secondary drinking water standard. This target level is in place for taste and odor as opposed to health; thus, the EPA RSL for Al (20 mg/L) is included in Figure 6-1. Leaching concentrations from the LS10 leaching test (mg/L) were analyzed for LR and RCA samples and compared to the residential GCTLs, as displayed in Table 6-2. The only exceedance was Sr in RCA at 4.58 mg/L, compared to the residential GCTL of 4.2 mg/L.

Table 6-1. Average SPLP Results (mg/L) from each daily BA sample (n=2). Concentrations that exceed the residential GCTL are indicated in bold.

Element	Res. GCTL	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 8	Day 9	Day 10	Day 11	Day 12	Day 13	Day 14
SPLP pH		11.9	12.0	12.0	12.1	11.8	12.0	12.1	12.1	12.0	12.1	12.2	12.3	12.2	12.2
Al	0.2	**93.7**	**60.0**	**35.1**	**48.5**	**104**	**33.4**	**49.4**	**70.0**	**84.9**	**10.7**	**20.4**	**27.4**	**27.6**	**33.1**
As	0.01	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008
B	1.4		0.020	0.020	0.020	0.020	0.020	0.020	0.020	0.020	0.020	0.020	0.020	0.020	0.020
Ba	2	0.579	0.673	0.463	0.696	0.230	0.688	0.583	0.791	0.407	0.460	0.533	1.19	0.586	0.551
Ba	0.004	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
Ca	-	513	603	346	674	327	534	631	624	560	532	620	805	607	728
Cd	0.005	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
Co	0.14	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012
Cr	0.1	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004
Cu	1	0.158	0.336	0.084	0.210	0.261	0.187	0.327	0.180	0.471	0.173	0.363	0.107	0.167	0.228
Fe	0.3	0.041	0.033	0.035	0.043	0.055	0.047	0.103	0.089	0.029	0.032	0.028	0.035	0.190	0.030
K		63.8	110	64.8	40.9	29.9	56.4	55.5	61.4	70.6	94.7	88.6	58.8	60.4	42.7
Mg	-	0.134	0.143	0.143	0.140	0.162	0.125	0.130	0.142	0.088	0.120	0.131	0.113	0.244	0.110
Mn	0.050	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
Mo	0.035	0.011	0.014	0.017	0.011	0.012	0.014	0.012	0.011	0.011	0.013	0.014	0.007	0.020	0.012
Na	160	148	**216**	150	121	95.7	**161**	147	**169**	**174**	**196**	**214**	148	**161**	108
Ni	0.1	0.002	0.004	0.002	0.002	0.003	0.003	0.003	0.002	0.004	0.002	0.004	0.002	0.002	0.002
Pb	0.015	**0.458**	**0.991**	**0.175**	**0.900**	**0.170**	**0.822**	**0.493**	**0.519**	**0.968**	**3.013**	**0.652**	**1.13**	**0.682**	**0.438**
Sb	0.006*	**0.007**	**0.006**	**0.006**	**0.006**	**0.007**	**0.006**	**0.006**	**0.006**	**0.010**	**0.006**	**0.008**	**0.006**	**0.006**	**0.006**
Se	0.05	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004
Sn	4.2	0.006	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004
Sr	4.2	0.507	0.584	0.363	0.404	0.331	0.444	0.543	0.484	0.467	0.683	0.551	0.776	0.527	0.440
Ti		0.010	0.012	0.009	0.012	0.007	0.011	0.013	0.012	0.012	0.011	0.011	0.014	0.014	0.012
V	0.049	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
Zn	5	0.245	0.523	0.084	0.606	0.101	0.323	0.300	0.301	0.226	0.365	0.352	0.318	0.260	0.190

*Detection limit for Sb is equivalent to the GCTL (0.006 mg/L)

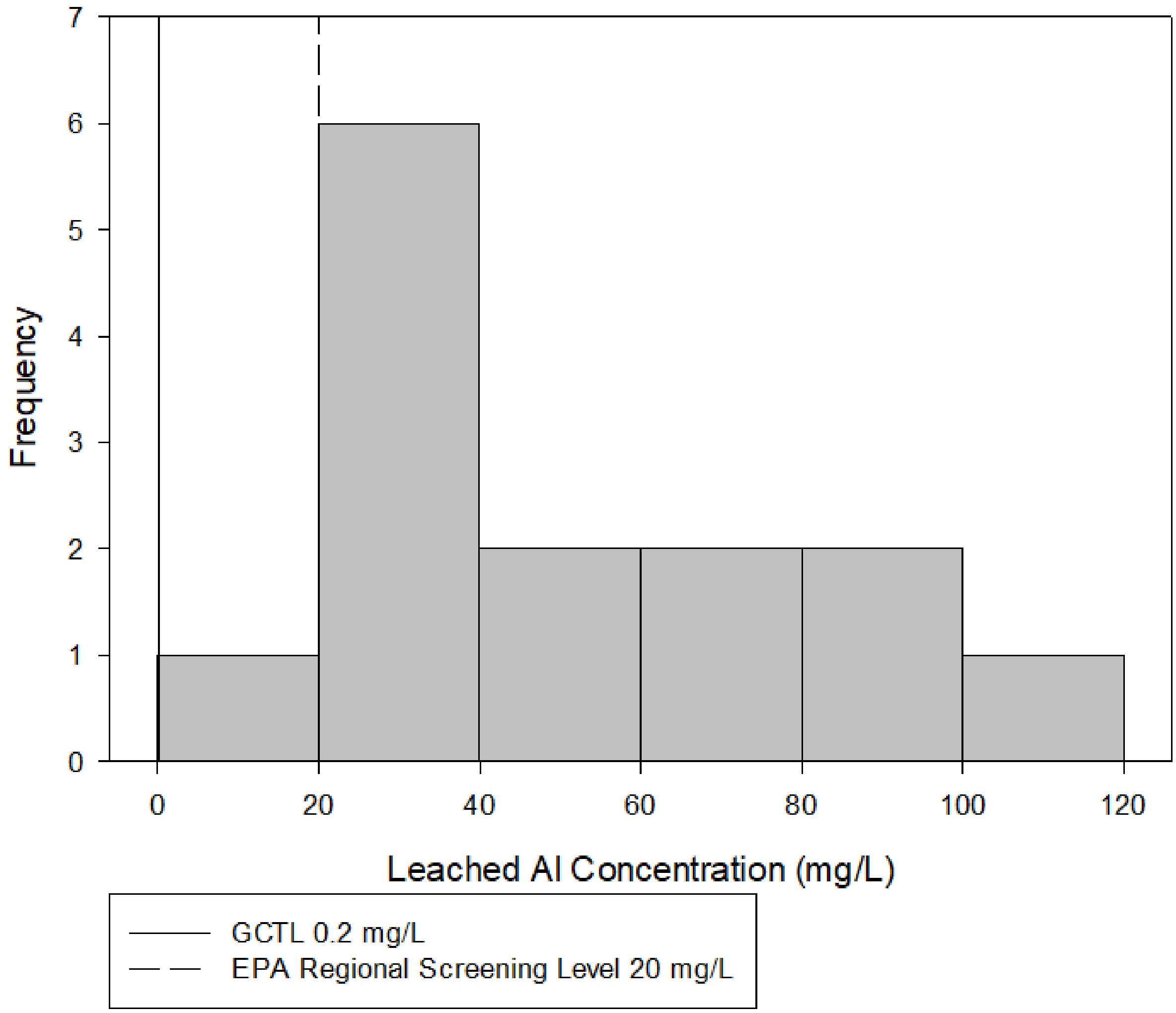

Figure 6-1. Distribution of leached SPLP Al concentrations (mg/L) from the daily South Broward BA samples (n=14) compared to the GCTL (0.2 mg/L) and the EPA Regional Screening Level (20 mg/L)**.**

Table 6-2. Average leached LS10 concentrations (mg/L) from RCA and LR sources (n=2) compared to the residential SCTL (mg/L). Concentrations that exceed the residential GCTL are indicated in bold.

	Res. GCTL	RCA	LR
pH		12.2	9.04
Al	20*	0.121	0.01
As	0.01	0.004	0.004
B	1.4	0.01	0.01
Ba	2	0.872	0.004
Be	0.004	0.001	0.001
Ca	-	560	8.56
Cd	0.005	0.001	0.001
Co	0.14	0.006	0.006
Cr	0.1	0.024	0.002
Cu	1	0.010	0.003
Fe	0.3	0.035	0.015
K	-	35.6	0.430
Mg	-	0.0215	1.40
Mn	0.05	0.001	0.001
Mo	0.035	0.0479	0.003
Na	160	11.1	1.32
Ni	0.1	0.001	0.001
Pb	0.015	0.008	0.005
Sb	0.006	0.003	0.003
Se	0.05	0.003	0.002
Sn	4.2	0.002	0.002
Sr	4.2	**4.58**	0.204
Ti	-	0.0191	0.002
V	0.049	0.001	0.008
Zn	5	0.014	0.013

*compared to the risk-based EPA RSL 20 mg/L

6.3.2 Aged BA

The BA was stored outside in lined windrows and mixed daily to allow for natural carbonation as a way to control Pb leaching. This practice is common globally and statewide, as Pb is typically the limiting factor on BA reuse scenarios (Oehmig et al., 2015). The SPLP concentrations associated with aged BA are compared to the residential GCTLs and reported in Table 6-3. Concentrations exceed the GCTL or RSL in all samples for Al and Sb, and in all but one sample for Pb. However, the Pb leached concentration has been reduced from up to 201 times the GCTL in fresh ash to only about 1.2 times (or less) above the GCTL for aged BA. This reduction in Pb leaching is coupled with an increase in Sb leaching for the aged BA, due to a decrease in pH and reduction of Ca necessary for Sb binding (Schafer et al., 2019). The Sb leached concentrations increased to approximately 7.5 times the residential GCTL from aged BA (0.40-0.045 mg/L).

Table 6-3. SPLP Concentrations for five grab samples of aged BA (mg/L) compared to the GCTL. Concentrations that exceed the residential GCTL are indicated in bold (n=2).

SPLP Concentration (mg/L)						
SPLP pH	Res GCTL	10.5	10.5	10.6	10.6	10.6
Al	20*	**50.4**	**64.5**	**65.1**	**63.0**	**58.4**
As	0.01	0.008	0.008	0.008	0.008	0.008
B	1.4	6.24	0.145	0.116	0.118	0.133
Ba	2	0.118	0.118	0.139	0.133	0.127
Be	0.004	0.002	0.002	0.002	0.002	0.002
Ca	-	123	131	148	147	136
Cd	0.005	0.002	0.002	0.002	0.002	0.002
Co	0.14	0.012	0.012	0.012	0.012	0.012
Cr	0.1	0.004	0.004	0.004	0.0049	0.004
Cu	1	0.212	0.229	0.308	0.311	0.288
Fe	0.3	0.022	0.022	0.021	0.021	0.025
K	-	25.4	26.4	35.9	36.2	32.5
Mg	-	0.129	0.134	0.113	0.115	0.125
Mn	0.050	0.002	0.002	0.002	0.002	0.002
Mo	0.035	0.024	0.025	0.034	0.034	0.032
Na	160	69.7	70.3	95.8	95.8	86.9
Ni	0.1	0.002	0.002	0.002	0.002	0.002
Pb	0.015	0.012	**0.017**	**0.018**	**0.018**	**0.016**
Sb	0.006	**0.042**	**0.045**	**0.040**	**0.041**	**0.041**
Se	0.05	0.004	0.004	0.004	0.0042	0.004
Sn	4.2	0.004	0.004	0.004	0.004	0.004
Sr	4.2	0.483	0.554	0.669	0.655	0.592
Ti	-	0.008	0.008	0.010	0.009	0.009
V	0.049	0.025	0.032	0.031	0.030	0.028
Zn	5	0.017	0.011	0.012	0.013	0.014

*Al compared to the EPA RSL risk-based threshold of 20 mg/L

6.3.3 Blended Road Base: Leaching as a Function of BA Addition

The aged BA was mixed with RCA or LR at concentrations of up to 80% BA (10%, 15%, 20%, 35%, 50%, 65%, and 80% BA), and leaching tests were conducted using nanopure water at an LS ratio of 10, as outlined in Section 6.1. Among the elements analyzed, Al, Mo, Pb, Sb, and V were found to leach above the EPA RSL or the Florida GCTL. Figures 6-2 to 6-7 illustrate the leaching behavior of each element as the BA concentration increases in LR and RCA blends compared to the respective leaching thresholds. The leaching concentrations for all analyzed elements at each blend ratio can be found in Appendix C.

The aged BA, LR, and RCA exhibit pH levels around 10.3, 9.0, and 12.2, respectively, consistent with the literature and previous studies (Schafer et al., 2019). The pH of the blends decreases with the addition of LR and increases with the addition of RCA, ranging from 9.7 to 10.2 and 10.6 to 12.1, as depicted in Figure 6-2. In the preliminary screening of each material individually, BA was found to leach Al above the RSL (20 mg/L), while LR and RCA leaching levels remained well below the RSL. Al concentrations fell below the EPA RSL of 20 mg/L in RCA blends containing up to 20% BA, but remained above the RSL in RCA blends above 20% BA and all LR blends. The concentrations increased with increasing BA content, as shown in Figure 6-3, indicating that the mobility of Al depends largely on the availability of BA and pH. Figure 6-4 displays the Mo concentrations for each blend, with LR blends consistently exhibiting lower concentrations compared to RCA blends at every ratio. Mo concentrations in LR blends remained below the Florida GCTL (0.035 mg/L) for LR blends up to 35% BA, but exceeded the GCTL for all RCA blends and LR blends containing 50% BA or more. All blends leached Mo concentrations below the EPA RSL (0.1 mg/L).

Pb exceeded the RSL (0.015 mg/L) when leached from BA alone, as well as in all BA-aggregate blends. All LR blends appeared to leach lower levels of Pb compared to RCA blends, likely due to lower pH. The aging process, as described in Section 2.2, should reduce the mobility of Pb by lowering the pH, particularly in LR blends. However, it is possible that the South Broward BA may not have been aged for a sufficient duration to achieve complete carbonation. Sb exceeded the GCTL (0.006 mg/L) when leached from fresh and aged BA alone (0.006-0.008 and 0.040-0.045 mg/L) but remained at or below the RSL in RCA mixes containing up to 35% BA. All LR blends and RCA blends with 50% BA or more leached Sb at concentrations above the RSL, as shown in Figure 6-7. The mobility of Sb from BA and BA blends is highly dependent on pH and other chemical interactions, necessitating further investigation. The leaching behavior of trace elements, the strength performance, and the availability of South Broward BA were contributing factors in selecting the 15% BA blends for further analysis. The results described in this section suggest that with a 15% BA replacement, the leaching of Al and Sb can be reduced below screening thresholds with RCA blends, while Mo and Pb can be reduced with LR blends.

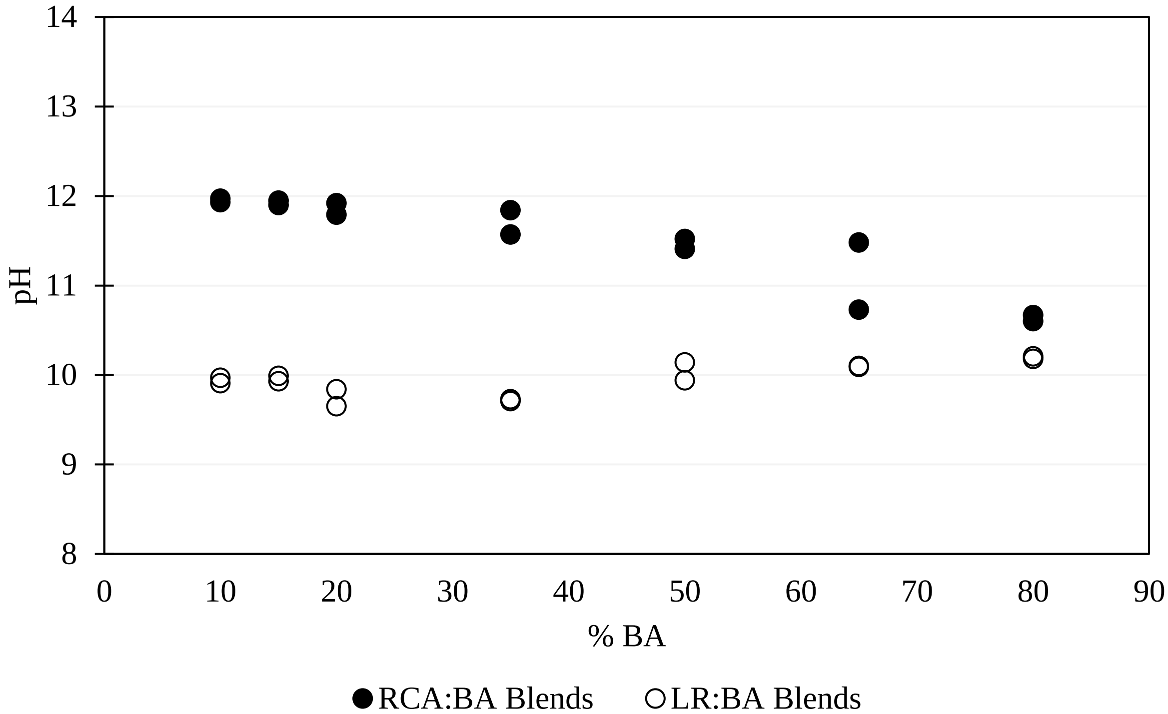

Figure 6-2. pH of the RCA:BA and LR:BA blends as BA % increases from 10-80% by mass.

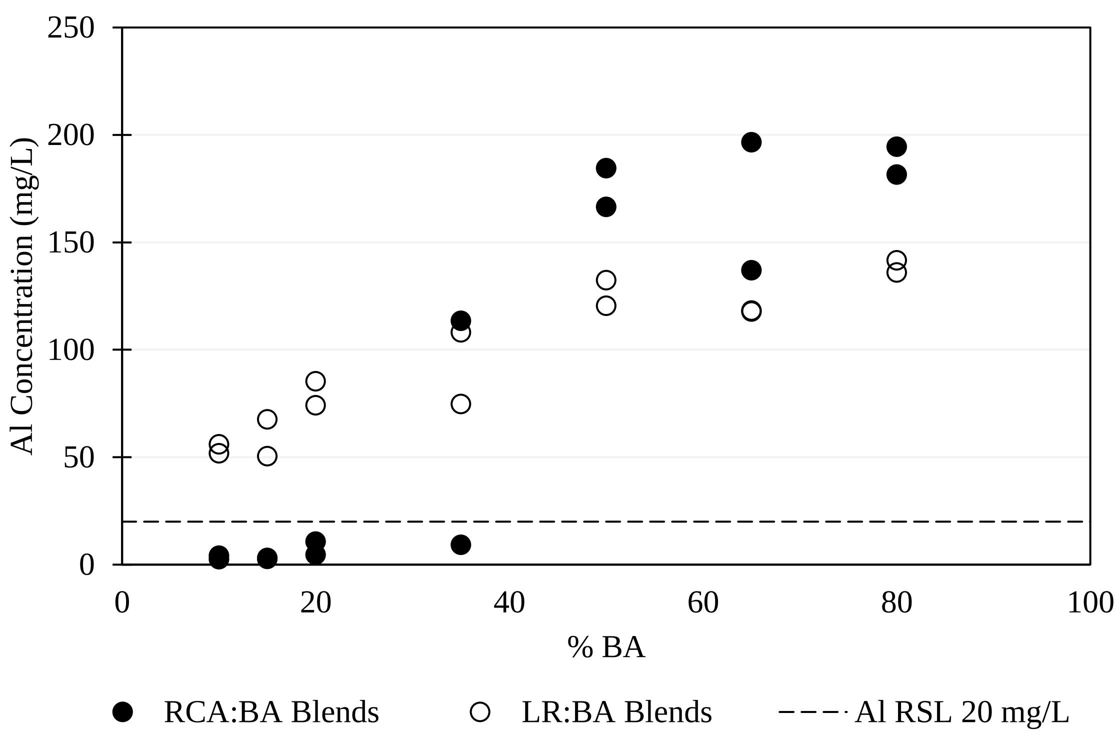

Figure 6-3. Leached Al concentration of the RCA:BA and LR:BA blends as BA % increases from 10-80% by mass compared to the EPA RSL for Al of 20 mg/L.

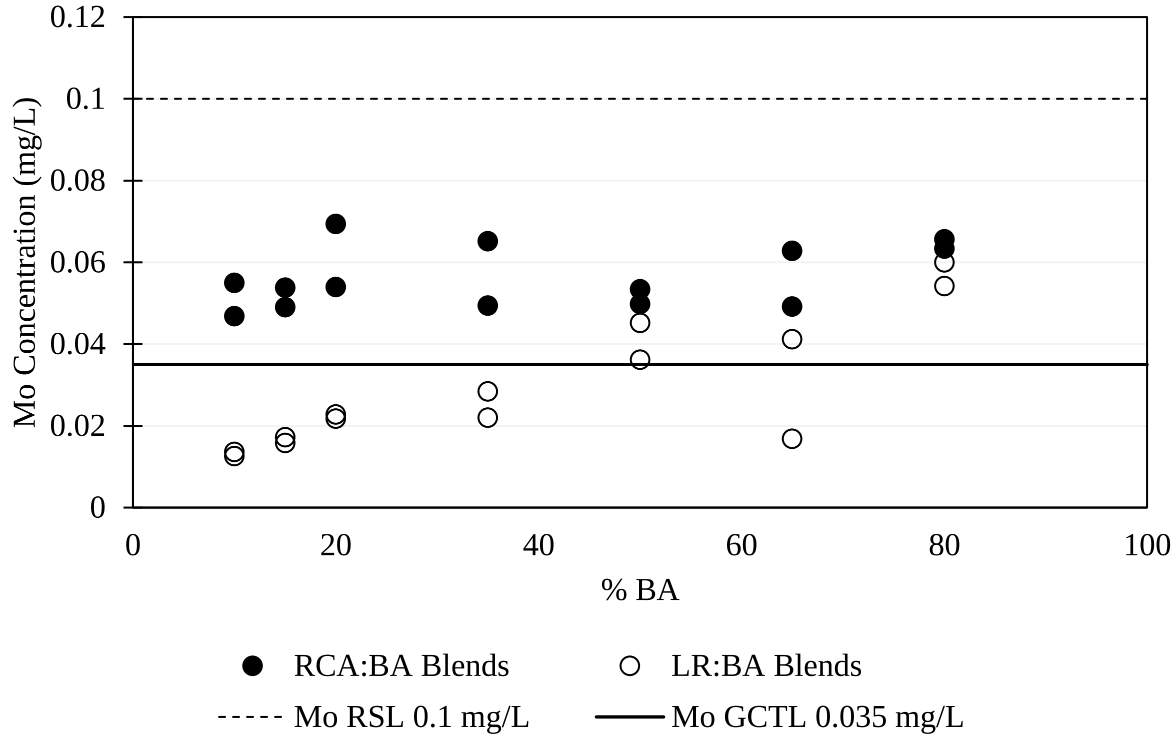

Figure 6-4. Leached Mo concentration of the RCA:BA and LR:BA blends as BA % increases from 10-80% by mass compared to the EPA RSL for Mo of 0.1 mg/L and the Florida GCTL of 0.035 mg/L.

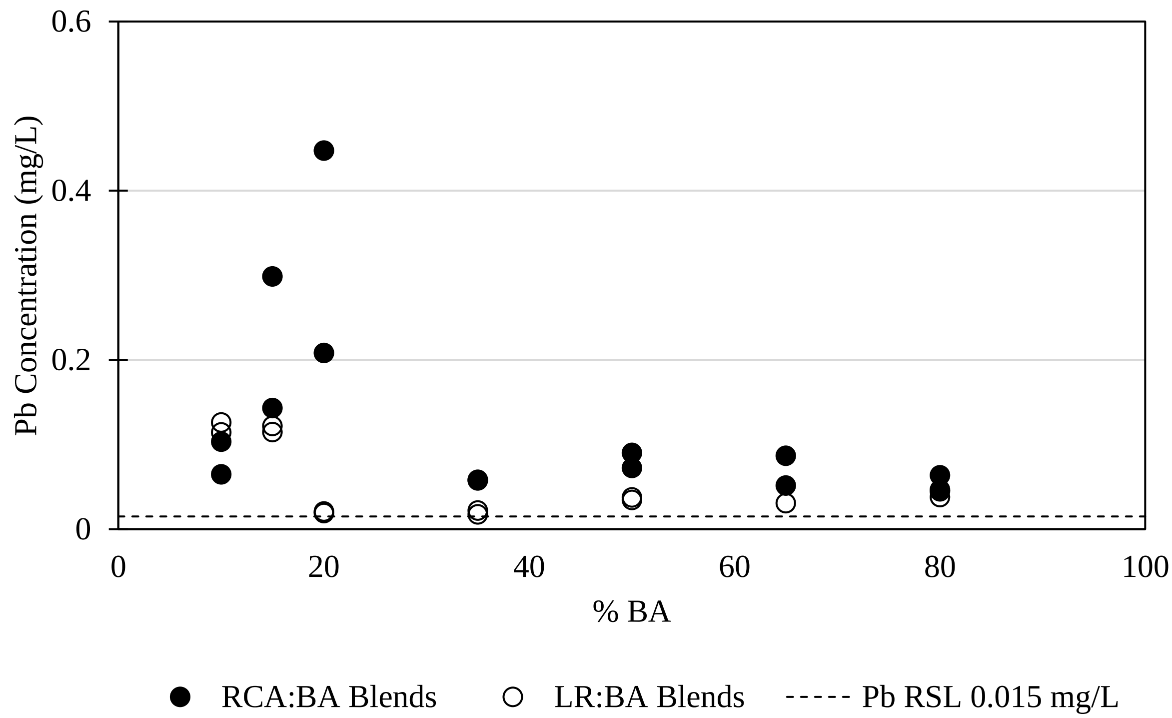

Figure 6-5. Leached Pb concentrations of the RCA:BA and LR:BA blends as BA % increases from 10-80% by mass compared to the EPA RSL for Pb of 0.015 mg/L.

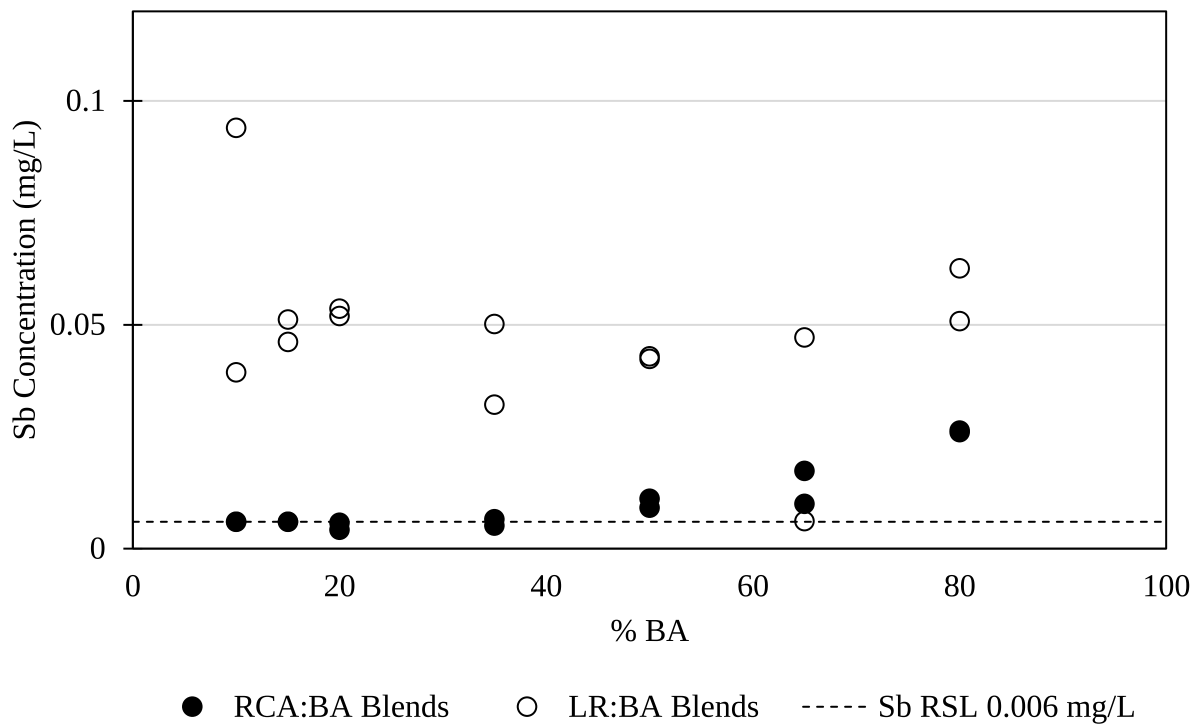

Figure 6-6. Leached Sb concentrations of the RCA:BA and LR:BA blends as BA % increases from 10-80% by mass compared to the EPA RSL for Sb of 0.006 mg/L.

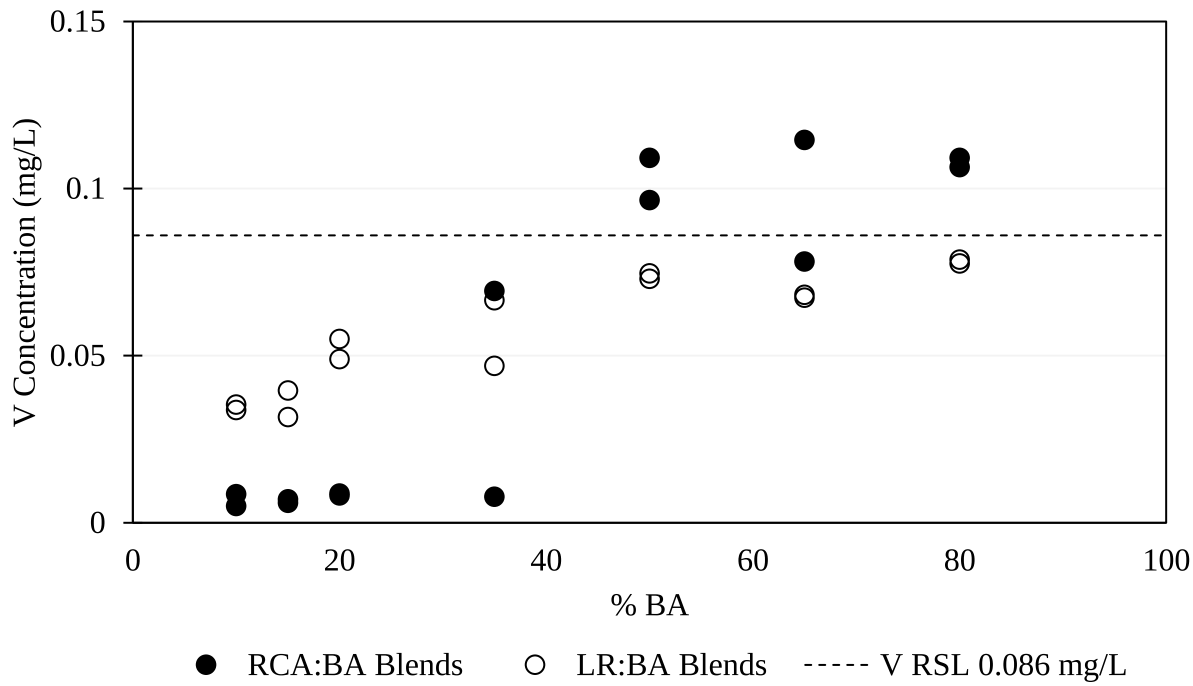

Figure 6-7. Leached V concentrations of the RCA:BA and LR:BA blends as BA % increases from 10-80% by mass compared to the EPA RSL for V of 0.086 mg/L.

6.3.4 Blended Road Base: Leaching as a Function of LS

The 15%-85% BA-aggregate blend was selected for further analysis based on leaching data and recommendations from WIN. Leaching as a function of LS was conducted at LS ratios of 2, 5, 10, 15, and 20 (n=2) by incorporating 15% BA by mass with LR or RCA and contacting with nanopure water. The leaching behavior of each element as a function of LS ratio is presented in Figures 6-8 to 6-12. The elements Al, Mo, Pb, and Sb all leached above the EPA RSL or Florida GCTL for at least one LS ratio tested. The leaching concentrations for all analyzed elements are included in Appendix C.

It is onerous to perform leaching tests at LS ratios likely exhibited in scenarios where road base is encapsulated by asphalt pavement (LS < 1), however the leaching behaviors here provide insight on the availability or solubility leaching of several elements of concern. For example, Al leaching decreases with increasing LS ratio in BA-LR blends, exhibiting surface availability-controlled leaching. However, Al mobility increases with increasing LS ratio from BA-RCA blends, suggesting another mechanism (such as pH) influences the leaching behavior. The influence of pH on element mobility is further discussed in the following section.

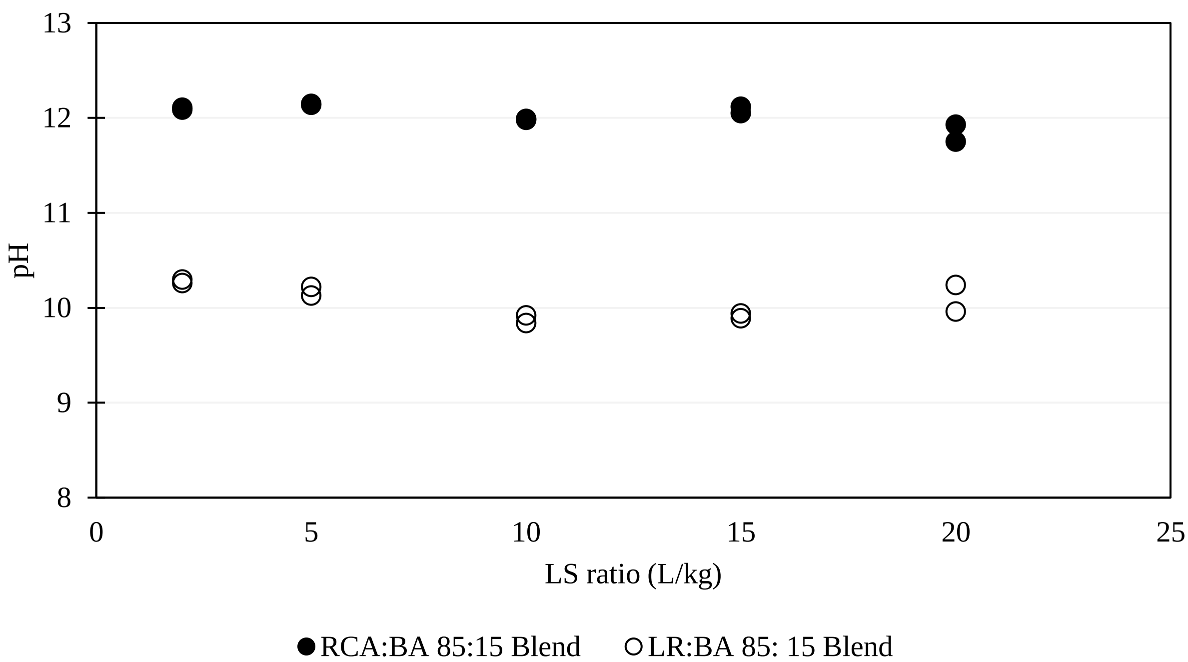

Figure 6-8. pH values from 15% BA blends with RCA and LR as a function of LS ratio.

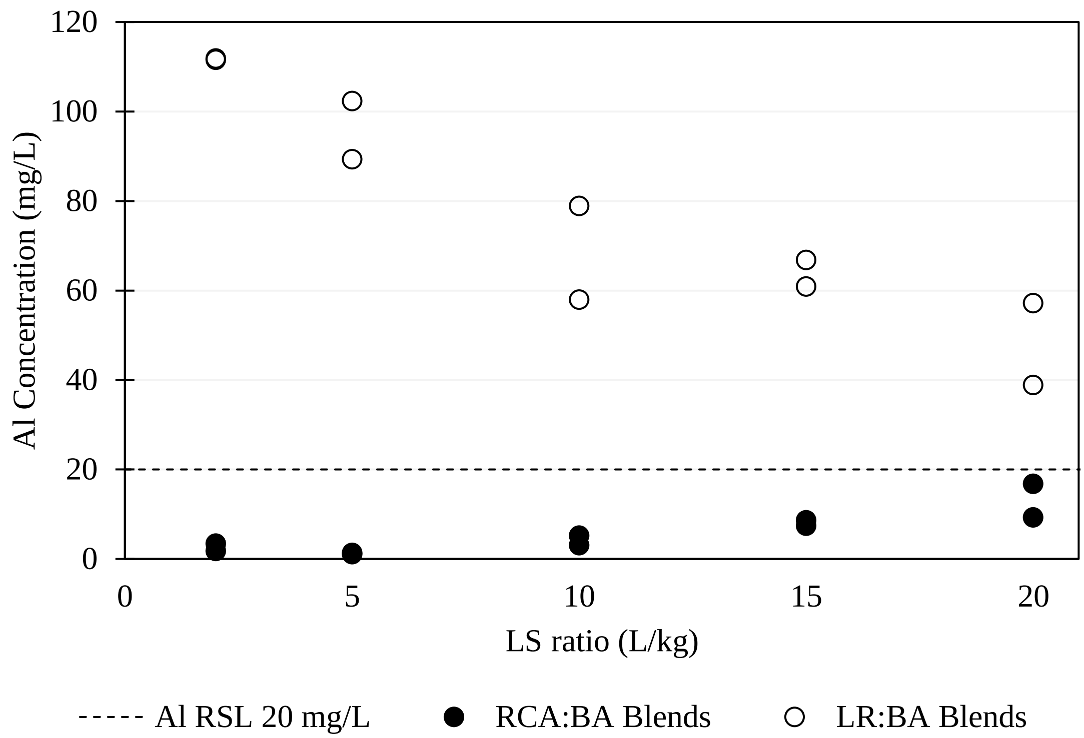

Figure 6-9. Leached Al concentrations from 15% BA blends with RCA and LR as a function of LS ratio compared to the Al RSL of 20 mg/L.

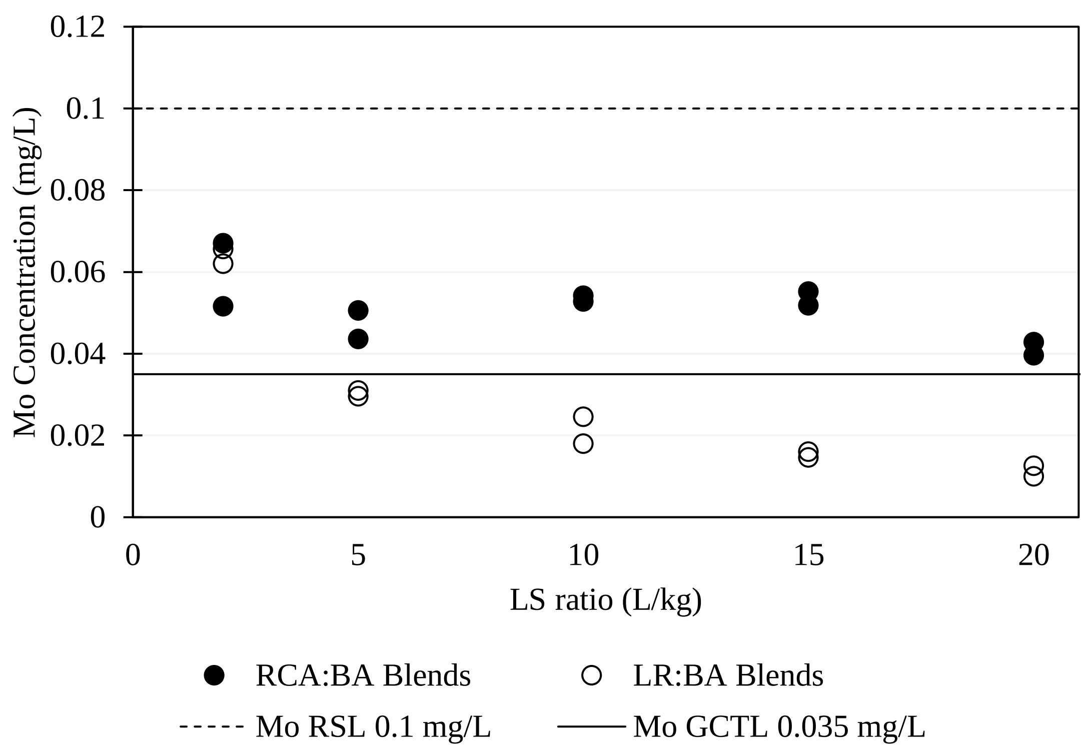

Figure 6-10. Leached Mo concentrations from 15% BA blends with RCA and LR as a function of LS ratio compared to the Mo RSL of 0.1 mg/L and GCTL of 0.035 mg/L.

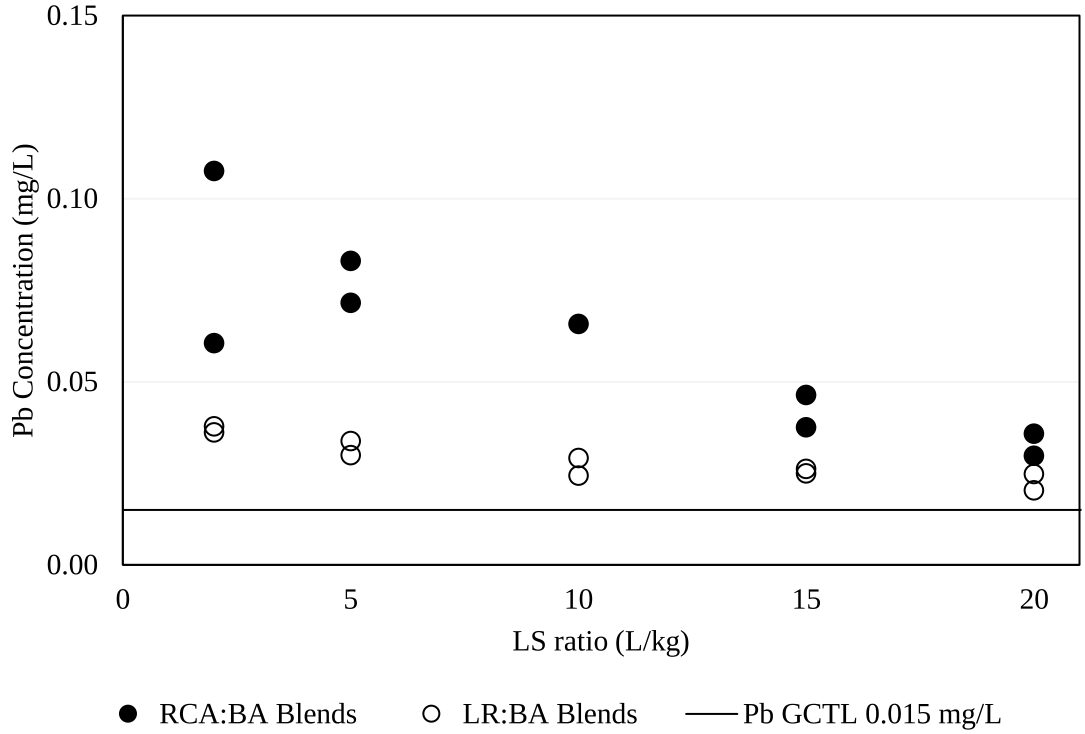

Figure 6-11. Leached Pb concentrations from 15% BA blends with RCA and LR as a function of LS ratio compared to the Pb GCTL of 0.015 mg/L.

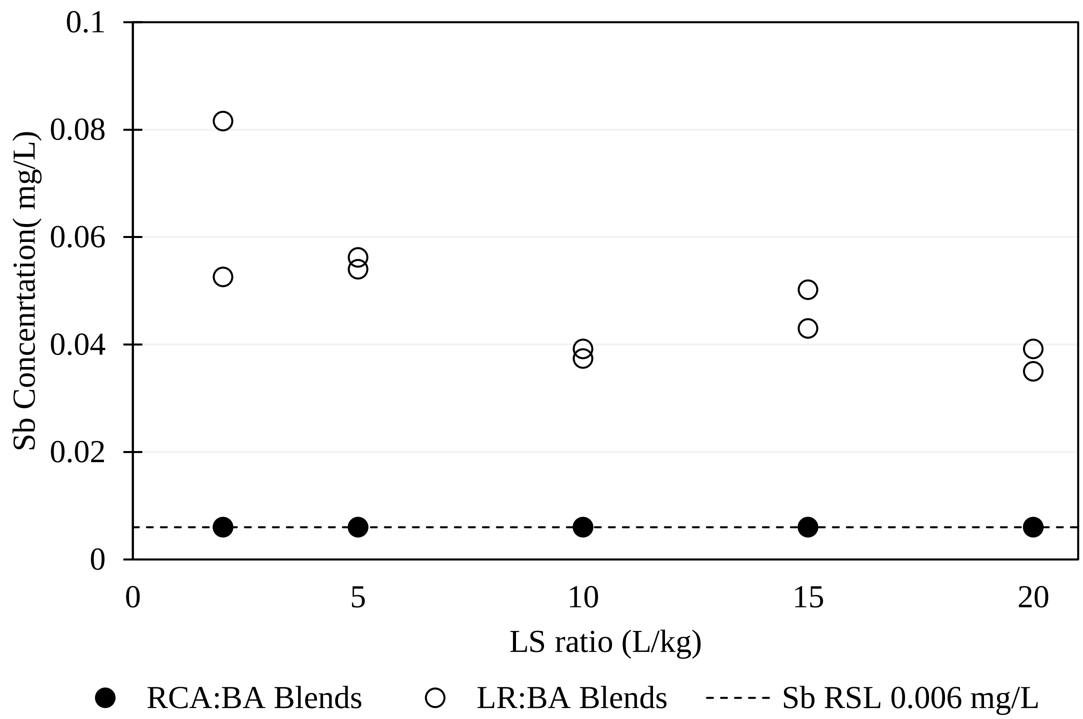

Figure 6-12. Leached Sb concentrations from 15% BA blends with RCA and LR as a function of LS ratio compared to the Sb RSL of 0.006 mg/L.

6.3.5 Blended Road Base: Leaching as a Function of pH

Blends were created using LR or RCA with 15% BA addition, leached at an LS of 10 with nitric acid and sodium hydroxide added to manipulate the extract pH. Each target pH was obtained in duplicate, but only one replicate was obtained for LR blends at pH 1 and 3, and for RCA at pH 3 due to the complicated buffering capacities of the materials at such a low pH. The leaching behavior of each element as a function of pH is displayed in Figures 6-13 to 6-16. Al, Mo, Pb, and Sb leached above the EPA RSL or Florida GCTL from at least one blend and pH point, but were subsequently reduced below the respective target level in another blend and pH point. The natural blend concentrations (no acid or base added) are indicated in the figures for further comparison. Leaching concentrations of all elements as a function of pH are included in Appendix C.

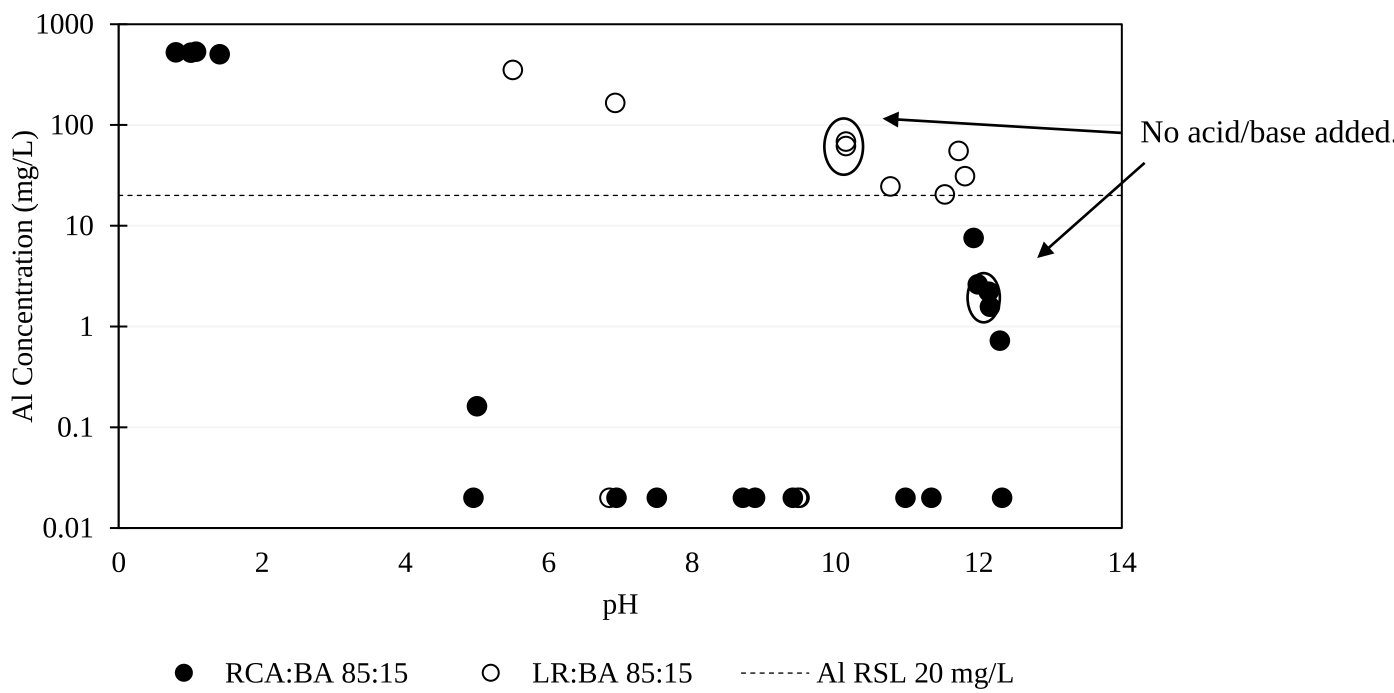

Figure 6-13. Al leaching from 15% BA 85% aggregate blends (mg/L) as a function of pH compared to the EPA RSL 20 mg/L. Samples without acid or base addition are indicated for comparison.

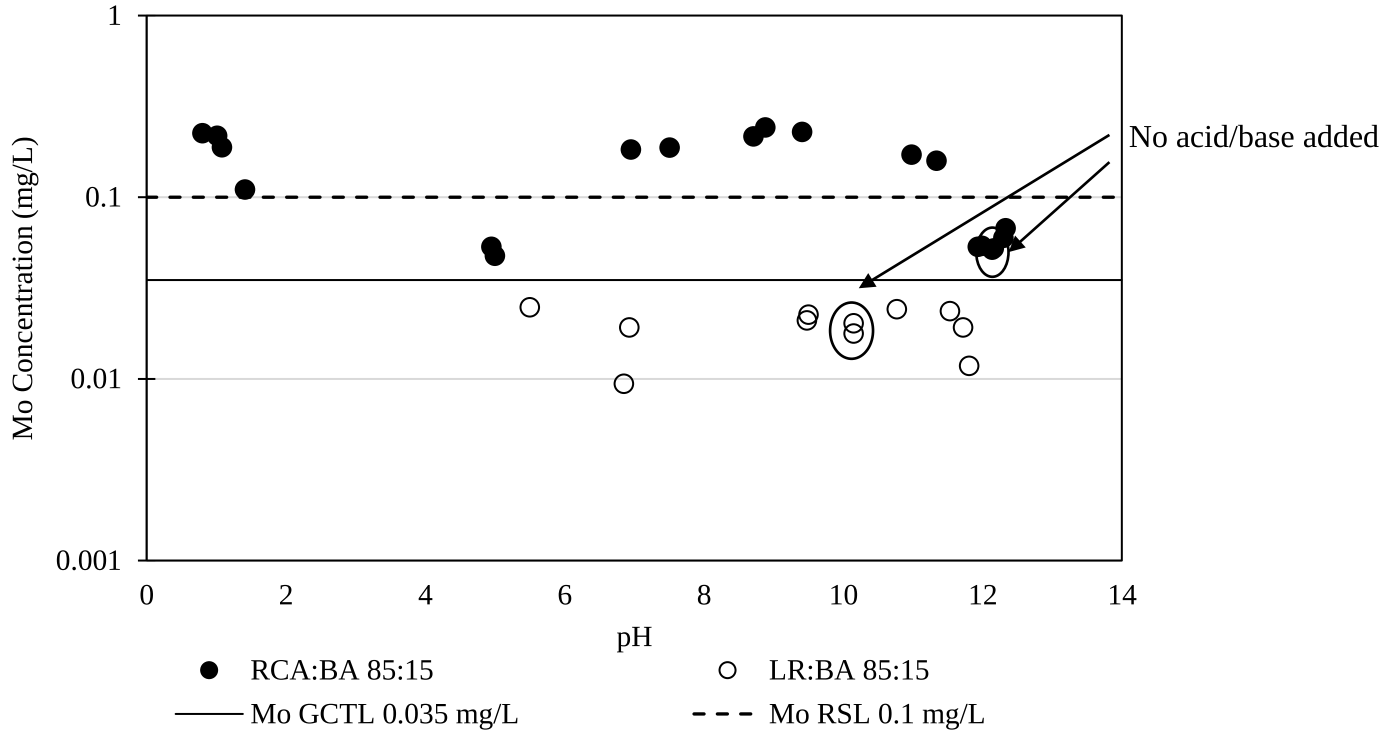

Figure 6-14. Mo leaching from 15% BA 85% aggregate blends (mg/L) as a function of pH compared to the EPA RSL 0.1 mg/L and FDEP Residential GCTL of 0.035 mg/L. Samples without acid or base addition are indicated for comparison.

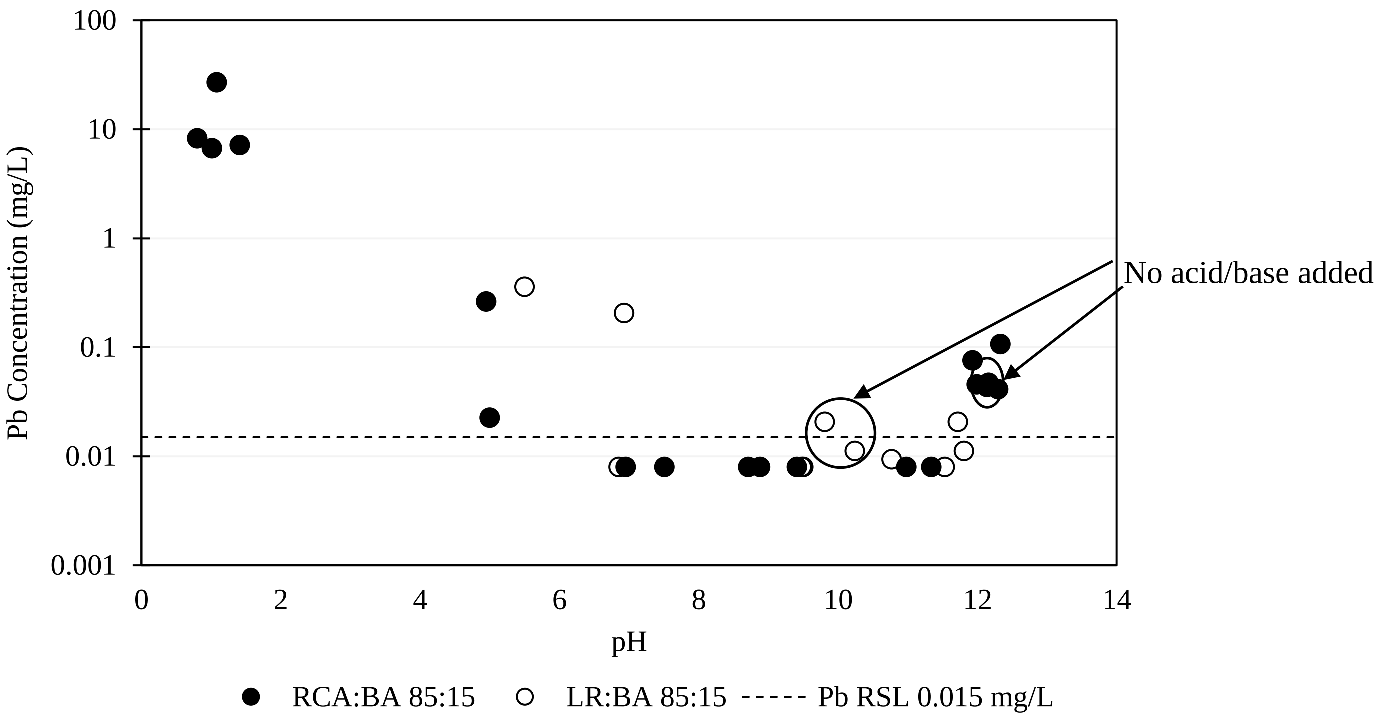

Figure 6-15 . Pb leaching from 15% BA 85% aggregate blends (mg/L) as a function of pH compared to the EPA RSL 0.015 mg/L. Samples without acid or base addition are indicated for comparison.

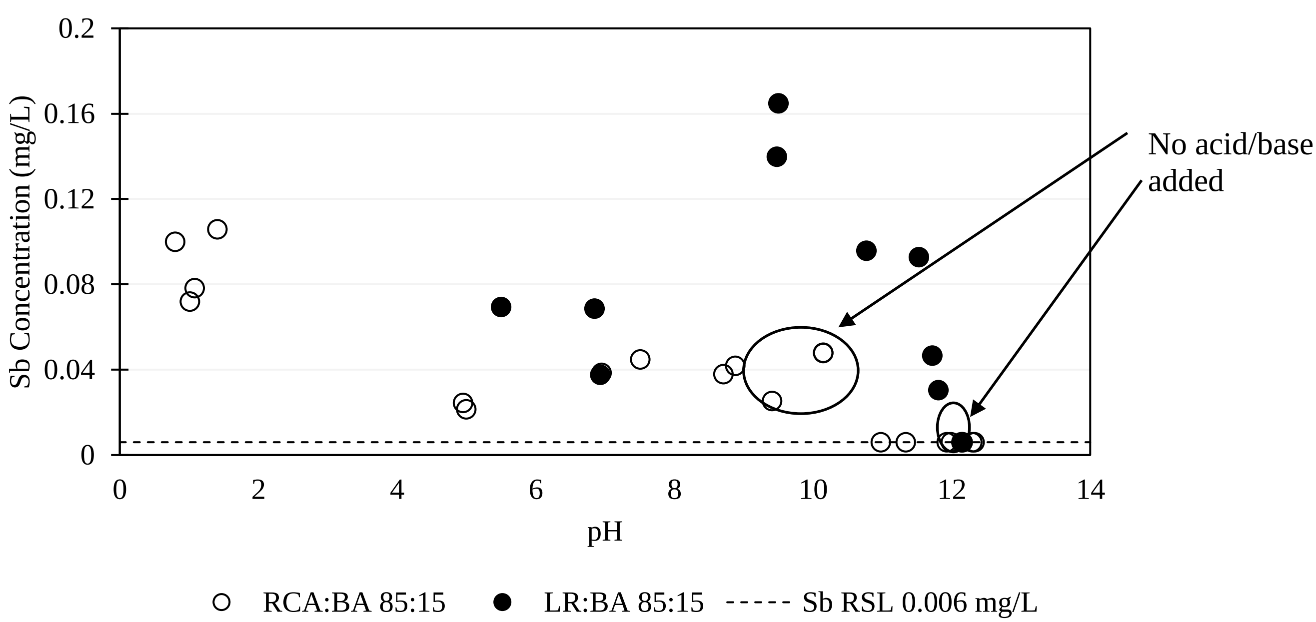

Figure 6-16. Sb leaching from 15% BA 85% aggregate blends (mg/L) as a function of pH compared to the EPA RSL 0.006 mg/L. Samples without acid or base addition are indicated for comparison.

6.3.6 Blending Road Base: Extended Aging Results

While EPA Method 1313 provides valuable information on the impact of pH on the mobility of elements, the weathering process of BA not only alters the pH, but also changes the composition of BA (Ai et al., 2019). Aging BA, also known as carbonation, leads to compositional changes in the material, and pH has been used in previous analyses as an indicator of carbonation progress. In previous studies, a pH range of 9.5-10.5 was identified as optimal for carbonation, indicating desired changes in the BA composition. However, it was observed that the WIN BA contained higher concentrations of leached Pb than expected from optimally carbonated ash. As a result, a representative sample of WIN BA was set aside to undergo further aging (referred to as extra-aged) until a natural pH of 8.6 was reached. Subsequently, leaching tests were performed on a 15% BA and 85% RCA or LR blend at an LS ratio of 10 (n=2), and the results are presented in Table 6-4.

The leaching of Pb in both blends incorporating the extra-aged ash demonstrated a decrease compared to the blends containing the aged ash. Although the concentrations were still above the residential GCTL, the leaching of Pb from RCA blends decreased from 0.202 mg/L in the aged ash blend to 0.043 mg/L in the extra-aged ash blend. In LR blends, Pb leaching decreased from 0.0268 mg/L in the aged ash blend to levels below the GCTL in the extra-aged ash blend. On the other hand, Sb leaching remained below the thresholds for water quality in RCA blends but exceeded the limits in LR blends. It is important to note that exceedance of the screening threshold do not necessarily prohibit a material from reuse, but instead identify the elements that may require engineering controls in a beneficial use application.

Table 6-4. Leached element concentrations (mg/L) from extra-aged WIN BA blended with 85% LR or RCA at an LS10 (n=2). Concentrations exceeding the residential GCTL are in bold.

LS10 Concentration (mg/L)			
Sample	Res GCTL	RCA	LR
LS10 pH		11.9	9.88
Al	20*	5.98	**27.9**
As	0.01	0.004	0.004
B	1.4	0.010	0.095
Ba	2	0.560	0.043
Be	0.004	0.001	0.001
Ca	-	166	56.1
Cd	0.005	0.001	0.001
Co	0.14	0.006	0.006
Cr	0.1	0.005	0.002
Cu	1	0.055	0.046
Fe	0.3	0.026	0.007
K		23.6	5.05
Mg	-	0.009	0.103
Mn	0.050	0.001	0.001
Mo	0.035	0.031	0.010
Na	160	24.9	15.3
Ni	0.1	0.001	0.001
Pb	0.015	**0.043**	0.005
Sb	0.006	0.003	**0.025**
Se	0.05	0.002	0.002
Sn	4.2	0.002	0.002
Sr	4.2	2.15	0.477
Ti		0.014	0.008
V	0.049	0.005	0.018
Zn	5	0.028	0.002

*Al compared to the risk-based threshold of 20 mg/L

7.0 Infiltration Analysis

7.1 Approach

The primary route of constituent transport from a road base is the infiltration of water through the pavement and base layers into the subsurface environment. Consequently, the infiltration rate of water through the roadway is a key parameter in assessing the risk of constituent release to groundwater. It can be expected that precipitation will primarily run off rather than infiltrate through the pavement, as asphalt pavement is typically low in permeability, with laboratory and field values for saturated hydraulic conductivity of new pavement ranging from 4 x 10^{-4} m/s to 4 x 10^{-8} m/s. As traffic further compacts the pavement the hydraulic conductivity is expected to fall, with values of 10^{-10} m/s being measured for older pavements. (Carter and Bentley, 1991). Roadways are typically sloped to shed water and maintain safe driving conditions, further reducing liquid available to infiltrate through to the base. The infiltration rate is a required input for the chosen fate and transport model in this risk analysis, IWEM.

The UF team presented a range of potential infiltration rates through a paved road in a past risk analysis conducted for a demonstration project using WTE BA in Pasco County (University of Florida, 2015). These values were calculated using the HELP model, a model developed for the EPA to predict the migration of water into and out of landfills and other solid waste containment structures that is meant to evaluate the hydrological environment of a landfill, though it may be adapted to fit other situations. The model performs a water balance analysis of a given scenario, relying on meteorological data and site-specific parameters to solve for predicted quantities of runoff, evapotranspiration, and infiltration. In this past analysis the UF team used the HELP model to represent the paved road as a multi-layer system subject to precipitation, solar radiation, and wind. Using a combination of two configurations, the team determined the estimated infiltration rates.

7.2 Infiltration Rate Selection

An infiltration rate equal to 4% of the precipitation was determined to be a conservative high-end estimate for an asphalt road. In the 2015 assessment, this rate corresponded to an asphalt road with hydraulic conductivity of 5 x 10^{-4} cm/s (University of Florida, 2015). For this analysis, a set of scenarios was modeled using infiltration rates ranging from 0.5% to 4% of precipitation, using the precipitation data collected from the area of the proposed demonstration project. Past research efforts have measured infiltration rates through a paved area as less than 4% of precipitation (Hjelmar et al. 2007). The infiltration rates used in the modeling effort are tabulated below in Table 7-1.

Table 7-1: Infiltration rates considered in risk analysis presented as percentage of precipitation and in mm/yr.

Infiltration (% Precipitation)	Infiltration (mm/yr)
0.5%	8.24
1%	16.5
2%	33.0
2.5%	41.2
3%	49.4
4%	65.9

8.0 Fate and Transport Modeling

8.1 Modeling Approach

As discussed in Section 4, constituents that leach from the road base could continue to migrate through the soil and into the groundwater; in each stage, the chemicals in the leachate could be attenuated by the soil or diluted by the ground water. The DAF (See Equation 1 in Section 4) for each element that leached above the respective threshold is displayed in Table 8-1. The concentrations used to calculate the DAF are based on the highest leaching values received over all LS ratios from the EPA Method 1316 analysis, resulting in the most conservative estimates for the DAF presented in Tables 8-1 and 8-2.

Table 8-1: Dilution and attenuation factor requirements for BA-LR Blend compared to the GCTL or other drinking water standard.

Element	GCTL or DWS (mg/L)	Highest leached concentration (mg/L)	Calculated DAF
Lead	0.015	0.037	2.47
Antimony	0.006	0.0671	11.17

Table 8-2: Dilution and attenuation factor requirements for BA-RCA Blend compared to the GCTL or other drinking water standard.

Element	GCTL or DWS (mg/L)	Highest leached concentration (mg/L)	Calculated DAF
Lead	0.015	0.0841	5.61

To predict if the elements leached from the road base demonstration project meet target DAFs and are below groundwater thresholds at an assumed compliance point, IWEM was used to model the fate and transport of contaminants in this assessment. A series of 72 IWEM runs were conducted for each BA-amended road base section using 6 infiltration rates, seasonal high and low groundwater gradients and depths, at three receptor distances (10 ft, 50 ft, 100 ft). All inputs can be found in Tables 8-3 and 8-4 and model results are listed in Section 8.3. IWEM is often used in state and federal beneficial use decision-making efforts to determine the impact of constituents leaching to groundwater. As mentioned previously, inputs include site-specific parameters such as pollutant concentration, roadway geometry, distance to point of compliance, and rate of water infiltration to pavement. IWEM hosts a national database of hydrogeologic conditions, including depth to groundwater, aquifer pH and thickness, and soil-chemical partitioning coefficients, that the user may select for the model based on site characteristics. Additionally, the database contains climatic information, including annual precipitation and aquifer recharge, for the site under consideration.

To model the emission of constituents from a roadway, the user enters site-specific parameters such as the rate of water infiltration through the pavement, initial constituent concentrations leaching from the waste material, and distance to the point of compliance. To accurately model contaminant transport through the subsurface, IWEM uses a national database of hydrogeologic conditions, including depth to groundwater, aquifer pH and thickness, and soil-chemical partitioning coefficients (see Figure 4-2). Additionally, the database contains climatic information, including annual precipitation and aquifer recharge, for the site under consideration. If a parameter is unknown, IWEM will use a distribution of values from its database. The model is a stochastic model, and the output concentration is the upper 90th percentile value, meaning the results are very conservative. A detailed list of inputs used in the IWEM runs for this risk assessment are included in Section 8.2.

8.2 IWEM Inputs

IWEM allows the user to input values for parameters such as leachate concentration, total constituent content, and infiltration rate. The leachate concentration used was the constituent concentration measured in the 1316 leaching procedure at an LS ratio of 2. It should be noted that the ash used in the 1316 experiment did not undergo "extended aging" described in Section 6.2.6. The extended aging of ash reduced the release of Pb from the blends but increased the release of Sb. Total concentration inputs are derived from the measured values in the direct exposure risk analysis described in Section 4.2. A series of infiltration rates was used in the model, ranging from 0.5% to 4% of precipitation.

Apart from the listed parameters, IWEM also allows the user to define the subsurface environment by inputting values for depth to groundwater, soil type, aquifer thickness, hydraulic gradient, hydraulic conductivity, and recharge rate. Subsurface environment parameters were taken from a hydrogeological investigation performed at the South Broward site in 2020. In the report, the hydraulic gradient and depth to groundwater are reported as corresponding to either the seasonal high or seasonal low groundwater flow periods. Two sets of IWEM runs were performed using either the seasonal high or low groundwater flow values for hydraulic gradient and depth to groundwater, referred to hereafter as the high-dilution scenario and the low-dilution scenario, respectively (Geosyntec, 2020). IWEM uses the chosen soil type and a "climate-center" to define the aquifer's recharge rate.

To account for attenuation of constituents by soil, IWEM uses partition coefficient (K_d) values. Partition coefficients describe the distribution of a constituent between two phases at equilibrium, soil and water in this case. IWEM contains a catalog of default K_d values based on leachate pH and subsurface environment conditions. However, it is widely understood that relying on default partition coefficients from the literature, which contains a broad range of values for each constituent, is less accurate than using site- and material-specific values (EPA, 1999). For Sb, a partition coefficient was taken from the average value reported in a study using MSWI BA contacted with a variety of soils (Blaisi et al., 2019). Tables 8-3 and 8-4 summarize the inputs used for the BA-LR blend and the BA-RCA blend, respectively.

Table 8-3: IWEM model input parameters and justification for BA-LR road base

Input	**Selection**	**Justification**
Model Source Type	Roadway	-
Test Strip Width	6.096 m (20 ft)	Standard
Number of Layers in Road	1 (base)	
Layer Thickness	0.254 m (10 in) [base]	Typical layer thickness
Layer Hydraulic Conductivity	31.536 m/yr [base]	(Muhunthan et al., 2012)
Layer Bulk Density	2.045 g/cm3 (127.6 PCF) [base]	Laboratory test results
Roadway Segment Length	182.88 m (600 ft)	Proposed parameter
Distance to Point of Compliance	3.05 m (10 ft), 15.24 m (50 ft), 30.5 m (100 ft)	Assumption
Groundwater Flow Angle with Respect to Road	90°	Assumption
Subsurface Environment	Unconsolidated and Semi-consolidated Shallow Aquifer	IWEM default - most representative of shallow surficial aquifer present at South Broward Site
Depth to Groundwater, Groundwater pH	(1.524 m) 5 ft	Geosyntec
Hydraulic Conductivity	173.45 m/yr	Geosyntec
Aquifer Thickness	18.288 (60ft)	Geosyntec
Hydraulic Gradient	0.00019 ft/ft (seasonal high) 0.00008 ft/ft (seasonal low)	Geosyntec
Soil Type	Coarse Grained Soil	IWEM default -most representative of soil type at South Broward Site
Aquifer Recharge Rate	0.2201 m/yr	IWEM default
Infiltration Rate	0.01658 m/yr, 0.0415 m/yr, 0.0829 m/yr, 0.1244 m/yr, 0.1658 m/yr	Percentages of Precipitation (University of Florida, 2015)
COPC Input C_o Values	EPA Method 1316 (leaching) (mg/L) Lead 0.037 Antimony 0.045 EPA Method 3050B (totals) Lead 264 Antimony 4	Laboratory test results
Partitioning Coefficients (Kd in L/kg)	Antimony 10 L/Kg	(Blaisi et al., 2019)
Reference Groundwater Concentrations	EPA Regional Screening Levels or National Primary Drinking Water Standards	Most applicable and current risk-based drinking water thresholds

Table 8-4: IWEM model input parameters and justification for BA-RCA road base

Input	**Selection**	**Justification**
Model Source Type	Roadway	-
Test Strip Width	6.096 m (20 ft)	Proposed dimension
Number of Layers in Road	1 (base)	Base layer is the focus of the analysis
Layer Thickness	0.254 m (10 in) [base]	Proposed layer thickness
Layer Hydraulic Conductivity	31.536 m/yr [base]	(Muhunthan et al., 2012)
Layer Bulk Density	2.045 g/cm3 (127.6 PCF) [base]	Laboratory test results
Roadway Segment Length	182.88 m (600 ft)	Proposed parameter
Distance to Point of Compliance	3.05 m (10 ft), 15.24 m (50 ft), 30.5 m (100 ft)	Assumption
Groundwater Flow Angle with Respect to Road	90°	Assumption
Subsurface Environment	Unconsolidated and Semi-consolidated Shallow Aquifer	IWEM default - most representative of shallow surficial aquifer present at South Broward Site
Depth to Groundwater, Groundwater pH	(1.524 m) 5 ft	Geosyntec
Hydraulic Conductivity	173.45 m/yr	Geosyntec
Aquifer Thickness	18.288 (60ft)	Geosyntec
Hydraulic Gradient	0.00019 ft/ft (seasonal high) 0.00009 ft/ft (seasonal low)	Geosyntec
Soil Type	Coarse Grained Soil	IWEM default -most representative of soil type at South Broward Site
Aquifer Recharge Rate	0.2201 m/yr	IWEM default
Infiltration Rate	0.01658 m/yr, 0.0415 m/yr, 0.0829 m/yr, 0.1244 m/yr, 0.1658 m/yr	Percentages of Precipitation (University of Florida, 2015)
COPC Input C_o Values	EPA Method 1316 (leaching) (mg/L) Lead 0.0841 EPA Method 3050B (totals) Lead 266	Laboratory test results
Partitioning Coefficients (Kd in L/kg)	Default Values	Default
Reference Groundwater Concentrations	EPA Regional Screening Levels or National Primary Drinking Water Standards	Most applicable and current risk-based drinking water thresholds

8.3 IWEM Results

Results of the IWEM analysis for each blend and each dilution scenario are displayed in tables 8-5 through 8-8. Three receptor location scenarios were modeled: 100 ft, 50 ft, and 10 ft from the roadway. IWEM is inherently a conservative model, as it reports the 90th percentile predicted concentration from a range of calculations. Five columns in each table correspond to the five chosen infiltration rates. Variance in results reported by the model can be expected due to the stochastic approach the model uses. Bolded values indicate predicted concentrations that exceed the regulatory guidelines.

Table 8-5: IWEM 90th percentile concentrations for BA-LR blend in road base at receptor distances of 10, 50, and 100-ft for the High Dilution scenario. Residential GCTL benchmark exceedances are indicated in bold.

Modeled Infiltration Rate:	0.5% Precipitation	1% Precipitation	2% Precipitation	2.5% Precipitation	3% Precipitation	4% Precipitation
10 ft to Receptor						
Lead (mg/L)	0.00016	**0.0162**	**0.0321**	**0.0335**	**0.0346**	**0.0356**
Antimony (mg/L)	0.0042	**0.0347**	**0.0395**	**0.0357**	**0.0327**	**0.0281**
50 ft to Receptor						
Lead (mg/L)	0.0002	0.0048	0.0091	0.0130	**0.0162**	**0.0214**
Antimony (mg/L)	0.0043	**0.0093**	**0.0098**	**0.0112**	**0.0113**	**0.0107**
100 ft to Receptor						
Lead (mg/L)	0.0002	0.0016	0.0048	0.0064	0.0079	0.0107
Antimony (mg/L)	0.0031	0.0043	0.0051	0.0055	0.0055	0.0056

Table 8-6: IWEM 90th percentile concentrations for BA-LR blend in road base at receptor distances of 10, 50, and 100 ft for the Low Dilution scenario. Residential GCTL benchmark exceedances are indicated in bold.

Modeled Infiltration Rate:	**0.5% Precipitation**	**1% Precipitation**	**2% Precipitation**	**2.5% Precipitation**	**3% Precipitation**	**4% Precipitation**
10 ft to Receptor						
Lead (mg/L)	0.0041	**0.0239**	**0.03201**	**0.0327**	**0.0342**	**0.0354**
Antimony (mg/L)	**0.0144**	**0.0450**	**0.0351**	**0.0308**	**0.0285**	**0.0242**
50 ft to Receptor						
Lead (mg/L)	0.00093	0.0048	0.0114	0.0149	**0.0176**	**0.0234**
Antimony (mg/L)	**0.0060**	**0.0093**	**0.0126**	**0.0131**	**0.0126**	**0.0113**
100 ft to Receptor						
Lead (mg/L)	0.0005	0.0028	0.0062	0.0078	0.0097	0.0132
Antimony (mg/L)	0.0042	**0.0068**	**0.0072**	**0.0071**	**0.0071**	**0.0069**

Table 8-7: IWEM 90th percentile concentrations for BA-RCA blend in road base at receptor distances of 10, 50, and 100 ft using for the High Dilution scenario. Residential GCTL benchmark exceedances are indicated in bold.

Modeled Infiltration Rate:	**0.5% Precipitation**	**1% Precipitation**	**2% Precipitation**	**2.5% Precipitation**	**3% Precipitation**	**4% Precipitation**
10 ft to Receptor						
Lead (mg/L)	0.0009	**0.0377**	**0.0741**	**0.0773**	**0.0789**	**0.0810**
50 ft to Receptor						
Lead (mg/L)	0.00139	0.0080	**0.0225**	**0.0321**	**0.0391**	**0.0493**
100 ft to Receptor						
Lead (mg/L)	0.0008	0.0044	0.01139	**0.0154**	**0.0189**	**0.0258**

Table 8-8: IWEM 90th percentile concentrations for BA-RCA blend in road base at receptor distances of 10, 50, and 100 ft for the Low Dilution scenario. Residential GCTL benchmark exceedances are indicated in bold.

Modeled Infiltration Rate:	**0.5% Precipitation**	**1% Precipitation**	**2% Precipitation**	**2.5% Precipitation**	**3% Precipitation**	**4% Precipitation**
10 ft to Receptor						
Lead (mg/L)	**0.0031**	**0.0569**	**0.0740**	**0.0358**	**0.0783**	**0.0807**
50 ft to Receptor						
Lead (mg/L)	0.0136	0.0112	**0.0278**	**0.0351**	**0.0432**	**0.0563**
100 ft to Receptor						
Lead (mg/L)	0.0018	0.0065	**0.0152**	**0.0190**	**0.2258**	**0.03122**

8.4 Comparison to GCTLs

The modeled scenarios described in the previous section are conservative. The chosen infiltration rates range from 0.5% to 4% of precipitation. This range was selected based on past work performed by the UF team and others. The previous analysis had determined that infiltration through the base is likely to be below 10%, with field data from the literature reporting as 4% and lower (University of Florida, 2015). It is important to consider that IWEM is a stochastic model presenting the 90th percentile predicted concentration, with 90% of simulations yielding lower concentrations than the reported value. Risk to groundwater will be managed through an environmental monitoring plan including soil sampling, the existing monitoring well network, and the lysimeters introduced in Section 2.3. The lysimeters will allow infiltration rates to be quantified through the road's service life and offer insight into the degree of constituent migration.

Predicted concentrations using the seasonal high groundwater values for depth to groundwater and hydraulic gradient were lower than those using the seasonal low values. For the BA-LR road sections, predicted concentrations of Sb and Pb fell below their Residential GCTLs at 100-ft from the road using the seasonal high values. For the simulations using seasonal high values with the BA-RCA blend, the 90th percentile predicted Pb concentrations exceeded residential GCTLs at infiltration rates equal to 2.5% of total precipitation and above. The input leachate concentration was derived from laboratory leaching tests on ash that had not undergone the "extended aging" previously mentioned.

Using the seasonal low groundwater values as inputs for the BA-LR blend resulted in predicted 90th percentile concentrations exceeding the limit of 0.006 mg/L at a receptor distance 100 ft from the road with infiltration rates over 2.5% of precipitation. However, these predicted concentrations were not far above the 0.006 mg/L value. Similarly, at a receptor distance 100-ft from the road, Pb narrowly exceeded the water quality threshold of 0.015 mg/L at 2.5% infiltration. This can be attributed to the variability of the stochastic model with the exceeding concentrations being close to the limit for the lower infiltration rates (0.007 compared to 0.006 and 0.0152 compared to 0.015 mg/L).

9.0 Bottom Ash Management Plan

To mitigate any potential risk and ensure the proposed application is protective of human health and the environment, UF proposes an Ash Management plan for WIN WTE BA used in road base for the current pilot project. This design is intended for a blended approach where BA is blended with aggregates and is encapsulated by covered asphalt pavement. This plan will detail mechanisms like required aging, storage, and specified usages. The material for this project will be obtained, treated, and stored at the WIN Waste South Broward Facility.

The screening process requirements are:

- The BA will be screened to remove particles greater than 1.5”.
- This screening process will take place on top of or in a lined Class I landfill cell, inside a permitted ash-processing building.
- The amount of BA in the blended material will not exceed a total of 15% by mass of the total aggregate.

The required aging specifications include:

- BA used for a blended base coarse aggregate will be aged for a minimum of 90 days prior to recycling and reuse.
- This process will occur on top of or in a lined Class I landfill cell, or inside a permitted ash-processing building.
- The BA piles should remain no greater than 20 ft in height during the entire treatment period.

The storage requirements are:

- Any ash-derived aggregate will remain within the lined section of the landfill prior to implementation as a road base within the proposed road base segments.

Other specified usages that are important to consider post treatment and construction include:

- Dust emissions from the storage, treating, and transporting will be controlled by wetting process, covering with a tarp, or covering with a protective material.
- The blended BA will be covered by a pavement layer (asphalt).
- Any blended BA not used for the project site will be removed and returned to the WIN monofill, a Class I landfill, or other approved FDEP site.

10.0 Monitoring

Monitoring for potential contamination from the construction of the road will be fully addressed through an environmental monitoring plan. Background concentrations will be established by sampling soil and groundwater adjacent to the road prior to construction. Additional soil samples will be taken periodically to assess the mobility of COPC, if any. The site is within an existing groundwater monitoring well network, allowing for the detection of any changes in water quality after the installation of the road. The existing groundwater monitoring well network is depicted in Figure 10-1 with the addition of another groundwater monitoring well downgradient of the proposed pilot project. These wells will be sampled semi-annually and analyzed for parameters listed in the South Broward Power Plant Citing Certificate (PA 85-21H).

The release of COPC into groundwater would likely require some time to be detected through monitoring well concentrations or soil sampling. To give a more direct evaluation of COPC mobility and quantify infiltration rates, a catchment system or lysimeter will be installed under a portion of each test section as described in Section 2. The lysimeters include a drainage layer installed underneath the road base, consisting of drainage media underlaid by impermeable liner. Leachate will be diverted by this drainage layer outwards to a reservoir for quantification and chemical analysis. Figure 2-4 depicts the proposed lysimeter design. Lysimeter leachate will be recorded for volume produced and constituents of potential concern for at least one year following construction.

The integrity and performance of the road will be evaluated through a set of physical tests to be performed during and after construction. Proposed physical testing includes density checks, field LBR tests, and falling weight deflectometer (FWD) testing. The road will also be monitored throughout the lifespan for visual performance indicators such as cracking, rutting, and shoving.

Figure 10-1: Existing groundwater wells configuration with the addition of a proposed groundwater well.

11.0 Summary of Proposed Demonstration Project and Risk Mitigation

WIN proposes to further investigate the reuse potential of WTE BA from its South Broward Facility by constructing a demonstration roadway. The 2,400-foot roadway will be constructed around WIN's Cell 1C1 monofill and will serve as an access road to the cell. The proposed demonstration roadway will be built in four segments: 15-85 BA-LR and BA- RCA and their respective controls (0% BA). Based on results from past testing, the proposed demonstration project will incorporate aged BA. Aged ash required the lowest DAF to reduce constituent concentrations to below risk-based thresholds and met road base material standards when blended with the chosen materials (LR, RCA) in preliminary LBR testing. Ash will be stockpiled outdoors for 90 days at the WIN Waste facility to allow for natural carbonation before being used in the pilot project. The aggregate materials used for this research were sourced from FDOT-approved vendors proximal to the demonstration site.

WIN Waste has chosen a location for demonstrating the feasibility of recycling its BA as a road base material. A 2,400 ft paved access road on the north side of WIN Waste's South Broward facility is the proposed site for the demonstration project, with BA incorporated into the base layer beneath the asphalt pavement. The road will be composed of four test strips, with lengths between 300-750 ft, with one strip each of BA-LR, BA-RCA, and corresponding control strips with LR and RCA without BA.

BA, like other waste materials, has constituent contents which can pose a risk to human health and the environment. Two risk pathways were assessed: direct exposure and leaching-to-groundwater. The site location and the method of BA reuse (encapsulation under pavement and blending with aggregates) mitigate the direct exposure pathway. The average concentrations of As, Ba, Cu, and Pb exceeded the residential SCTL in all daily samples. Additionally, Sb exceeded the residential target level in four of the fourteen daily samples. Leaching-to-groundwater risk was assessed using a combination of established laboratory leaching procedures and fate and transport modeling. Leaching tests indicated that most constituents leached from the BA-LR, BA-RCA at concentrations below FDEP's risk-based GCTL or EPA RSL. The two elements that leached above the GCTL for one or more mixes are Pb and Sb. For blends made with 15% BA and leached as a function of LS, LR:BA blends exceeded the RSL for Al and Sb, RCA:BA blends exceeded the GCTL for Mo, and both blends exceeded the GCTL for Pb.

Fate and transport modeling was performed using IWEM to assess leaching risk to the surrounding environment. This modeling effort incorporated site-specific data on the subsurface environment and climate. The models predict Pb and Sb will be attenuated to some degree in both the underlying soil and diluted during their transport through the aquifer. Fate and transport modeling with IWEM using aquifer conditions typical of Broward County indicate that it is likely that constituent concentration will not exceed risk thresholds at 100ft from the road given infiltration rates less than 1% of precipitation. Any impacts to groundwater from the road construction would also be detected by the existing groundwater monitoring well network on-site. The lysimeters enable the measurement of infiltration rate and leachate COPC concentration, providing a close look at constituent transport.

The results of this evaluation demonstrate that BA sourced from WIN Waste South Broward, when combined at a 15-85 ratio with LR, RCA, and when recycled in a manner consistent with the procedures and constraints identified in this report, will not pose a significant threat to human health and the environment. Direct exposure risk should not be a concern because the BA is encapsulated under a paved surface and blended with common aggregate material, reducing estimated total element concentration. While some elements leach above health-based thresholds, based on modeling efforts using site-specific information including climate data and aquifer conditions, these elements should be diluted and attenuated to safe concentrations at distances 100-ft or less from the roadway. Furthermore, the chosen site location is on the WIN monofill, which has an existing groundwater monitoring network and is distanced from potable water wells and bodies of water. The protective site location and proposed monitoring efforts reduce any potential risk to the environment.

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Appendix A: Additional Physical Performance Testing Results

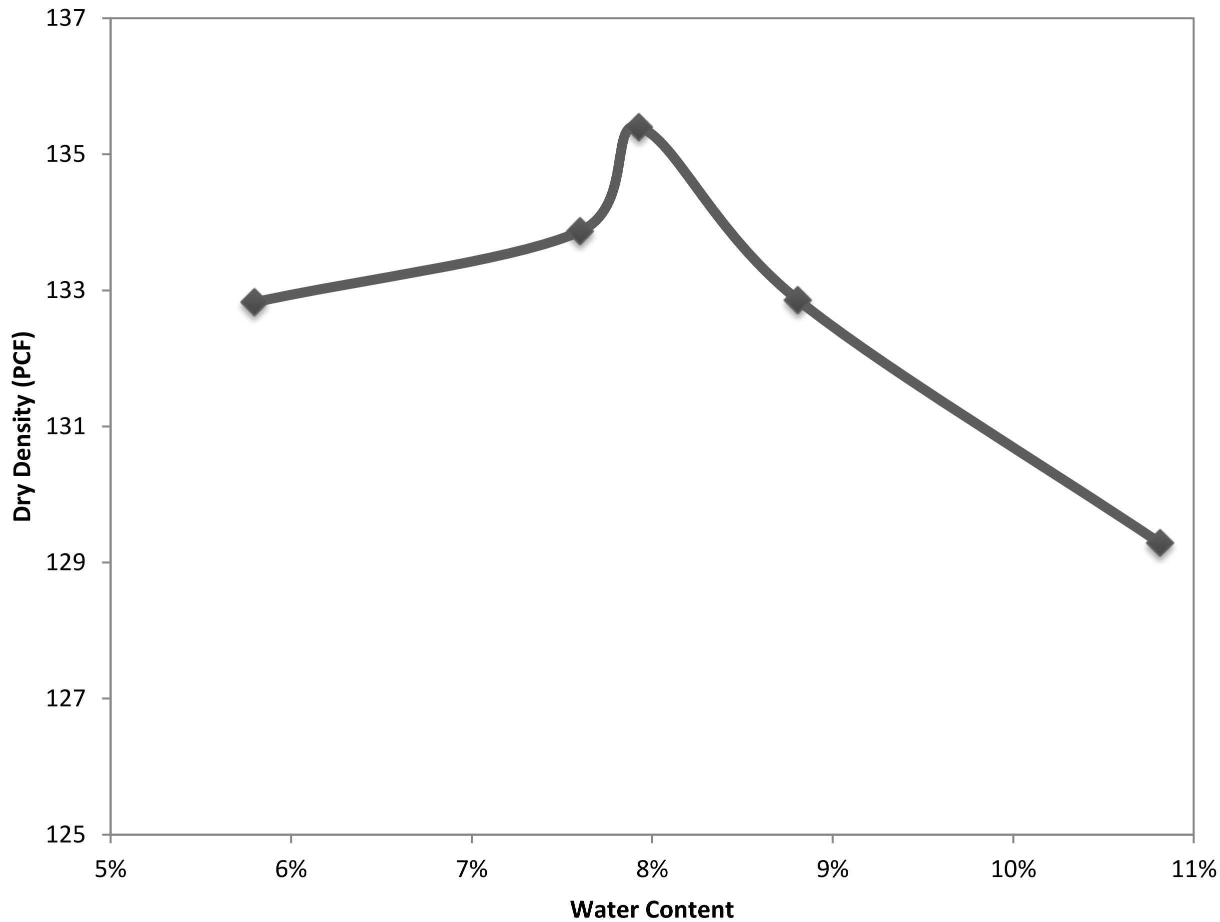

Figure A-1. Moisture-density relationship of LR

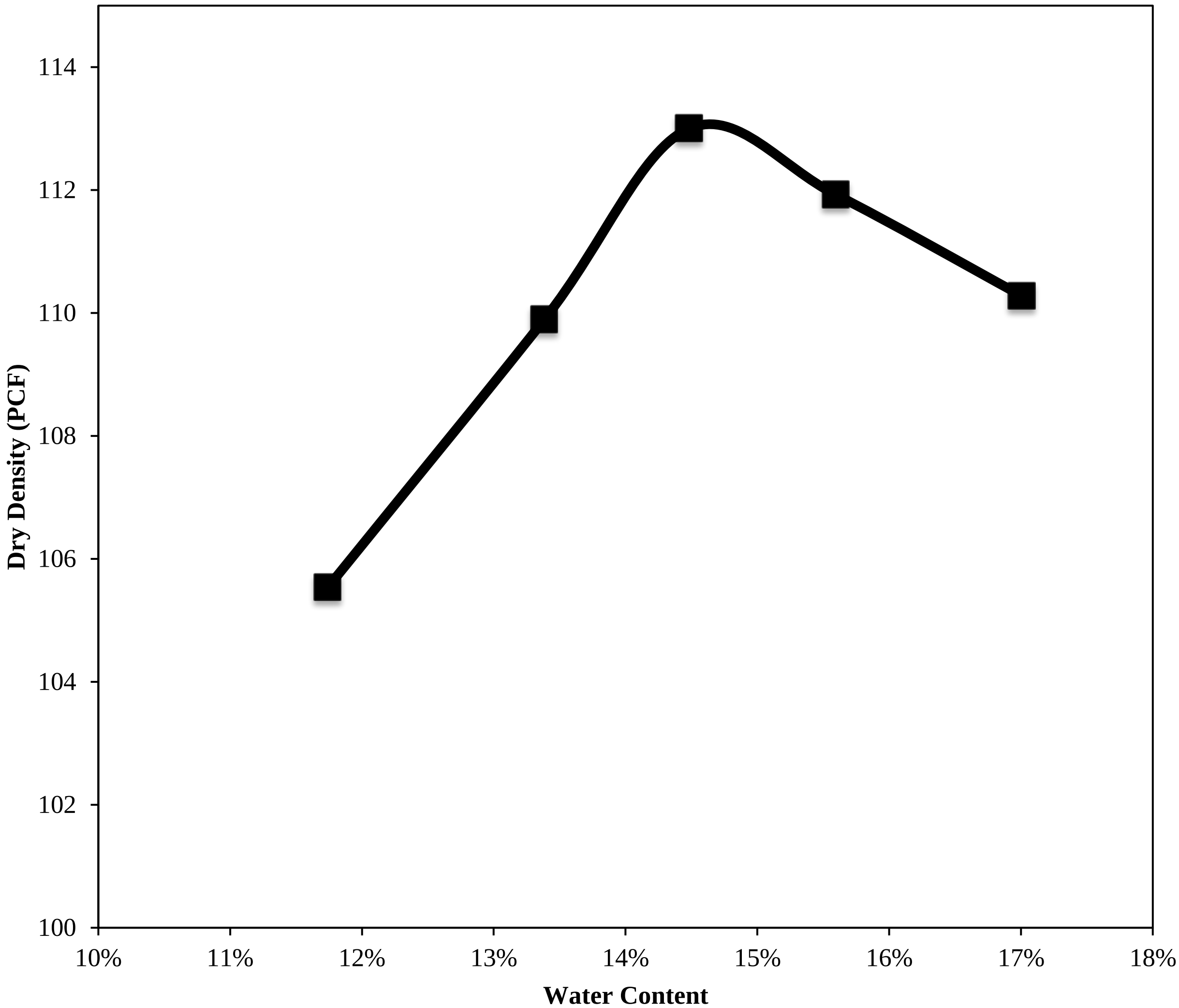

Figure A-2. Moisture-density relationship of RCA

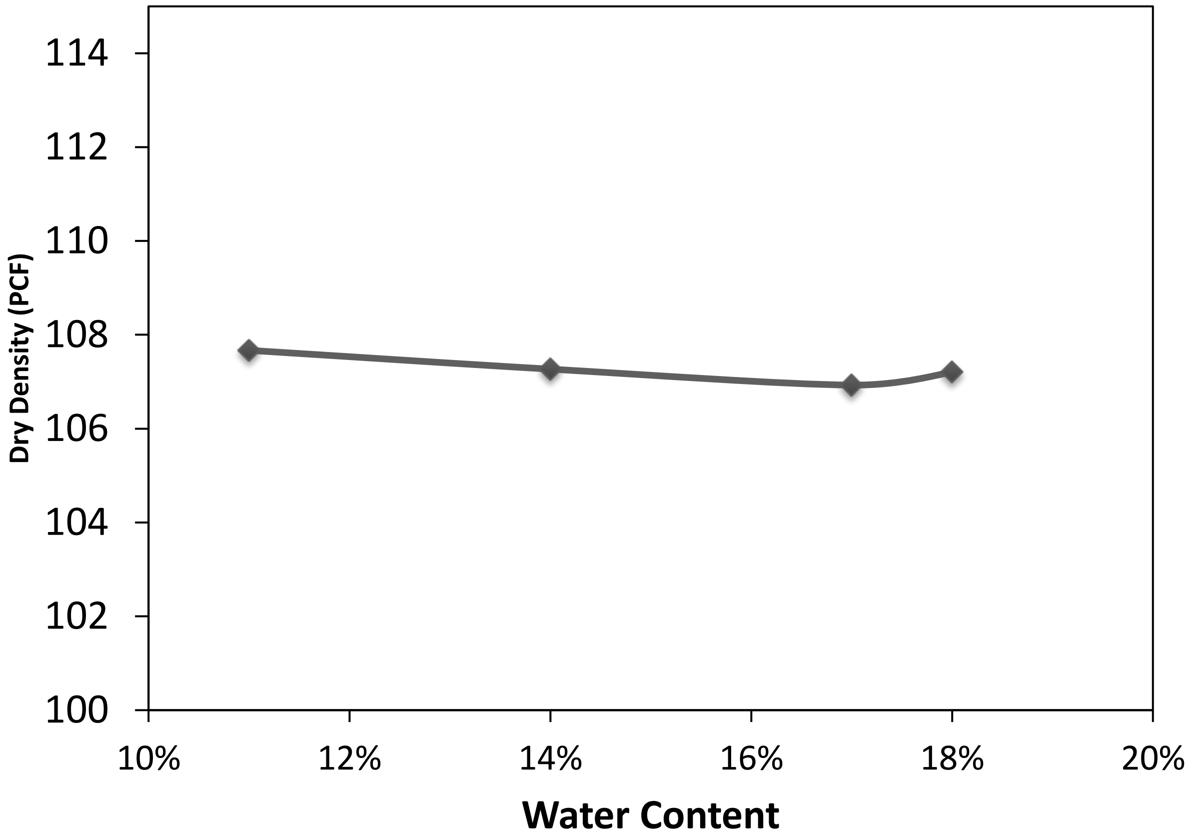

Figure A-3. Moisture-density relationship of BA15-RCA85 blend

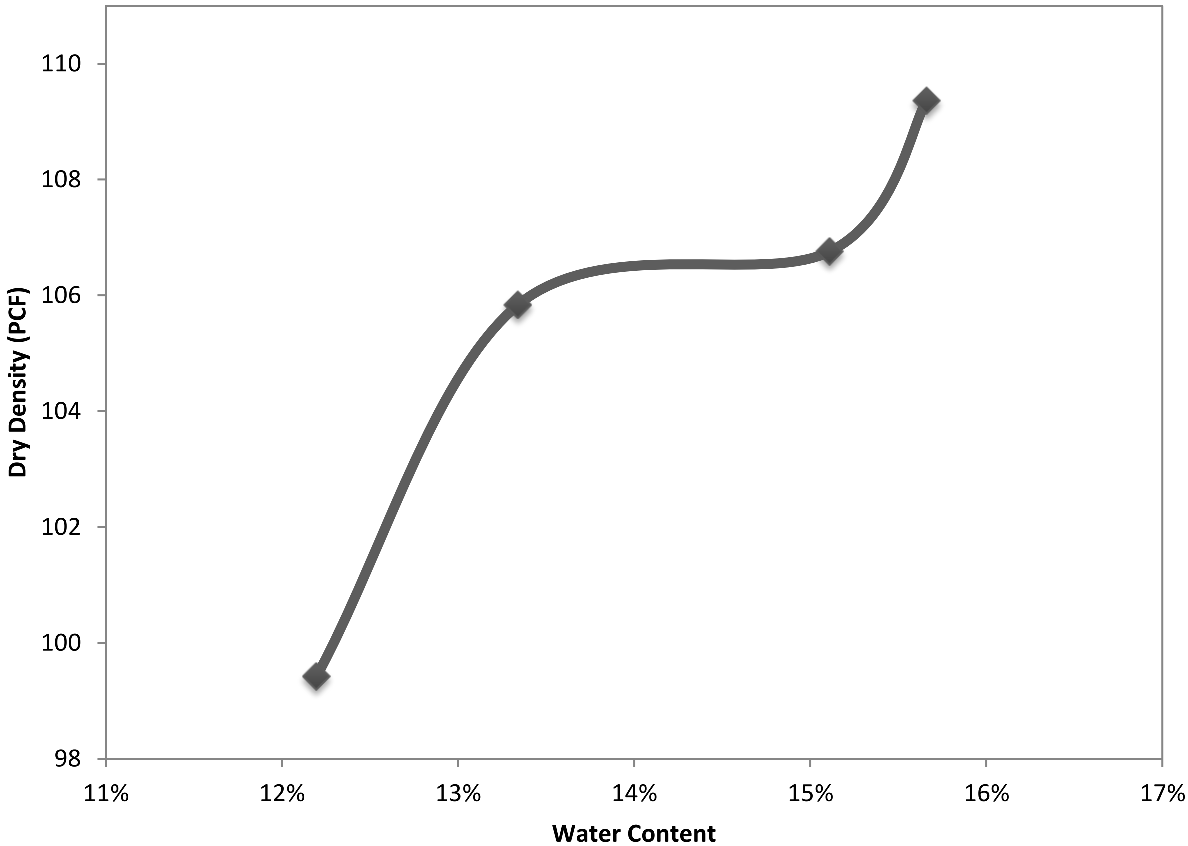

Figure A-4. Moisture-density relationship of BA35-RCA65 blend

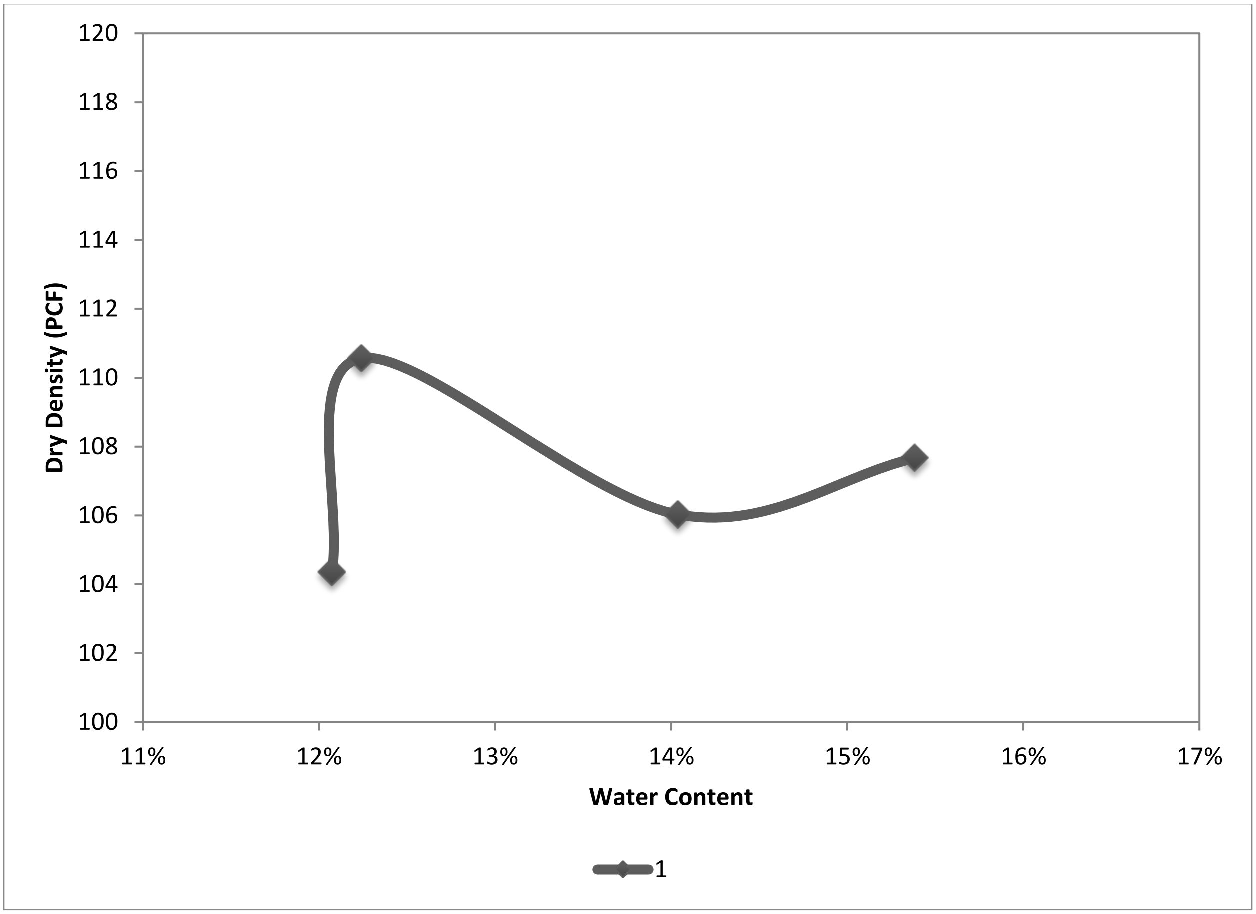

Figure A-5. Moisture-density relationship of BA50-RCA50 blend

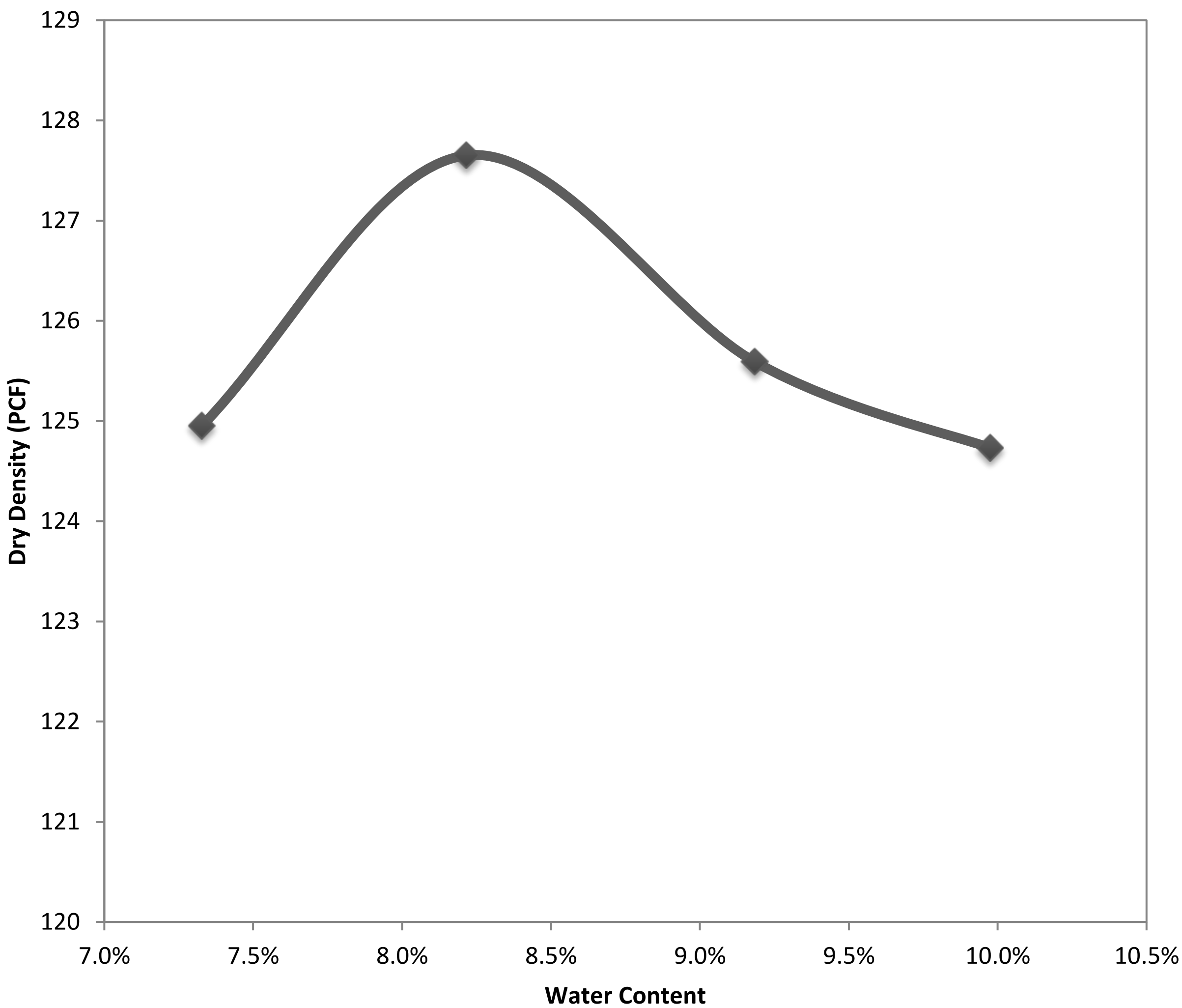

Figure A-3. Moisture-density relationship of BA15-LR85 blend

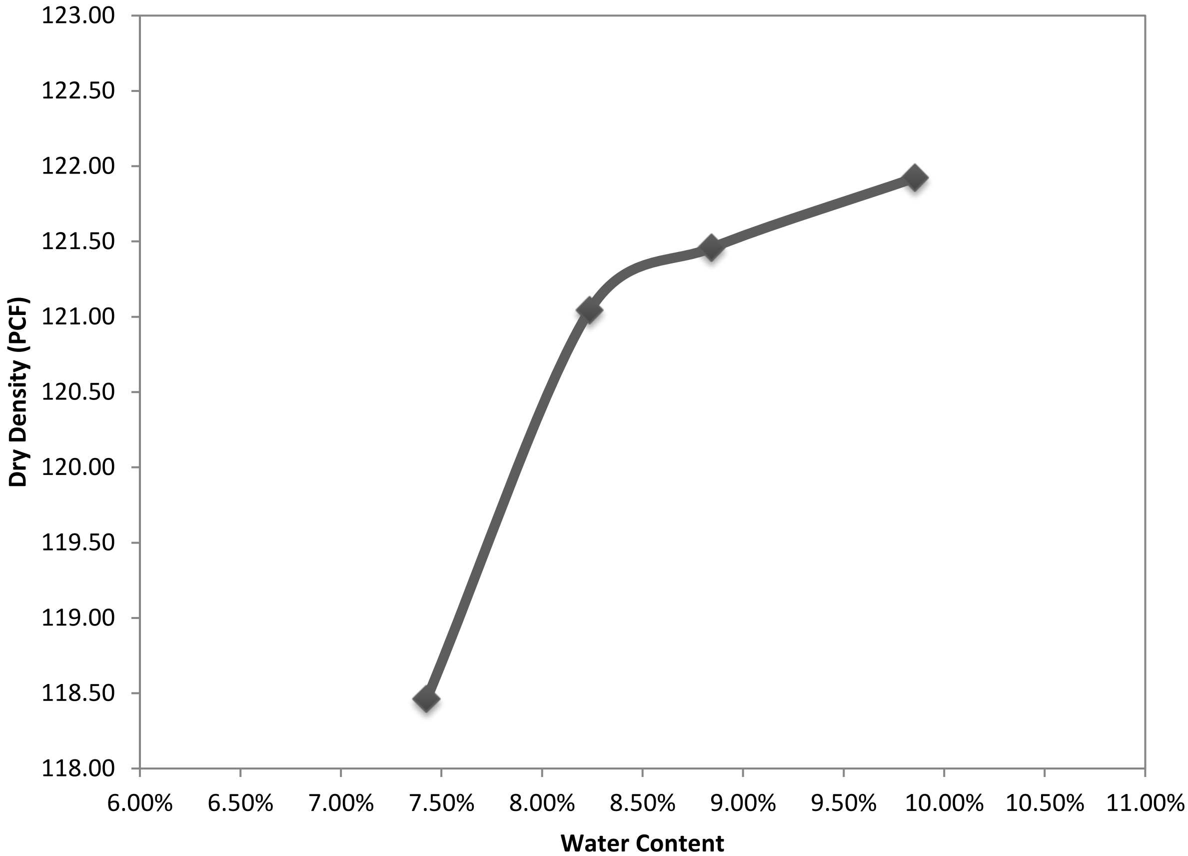

Figure A-4. Moisture-density relationship of BA35-LR65 blend

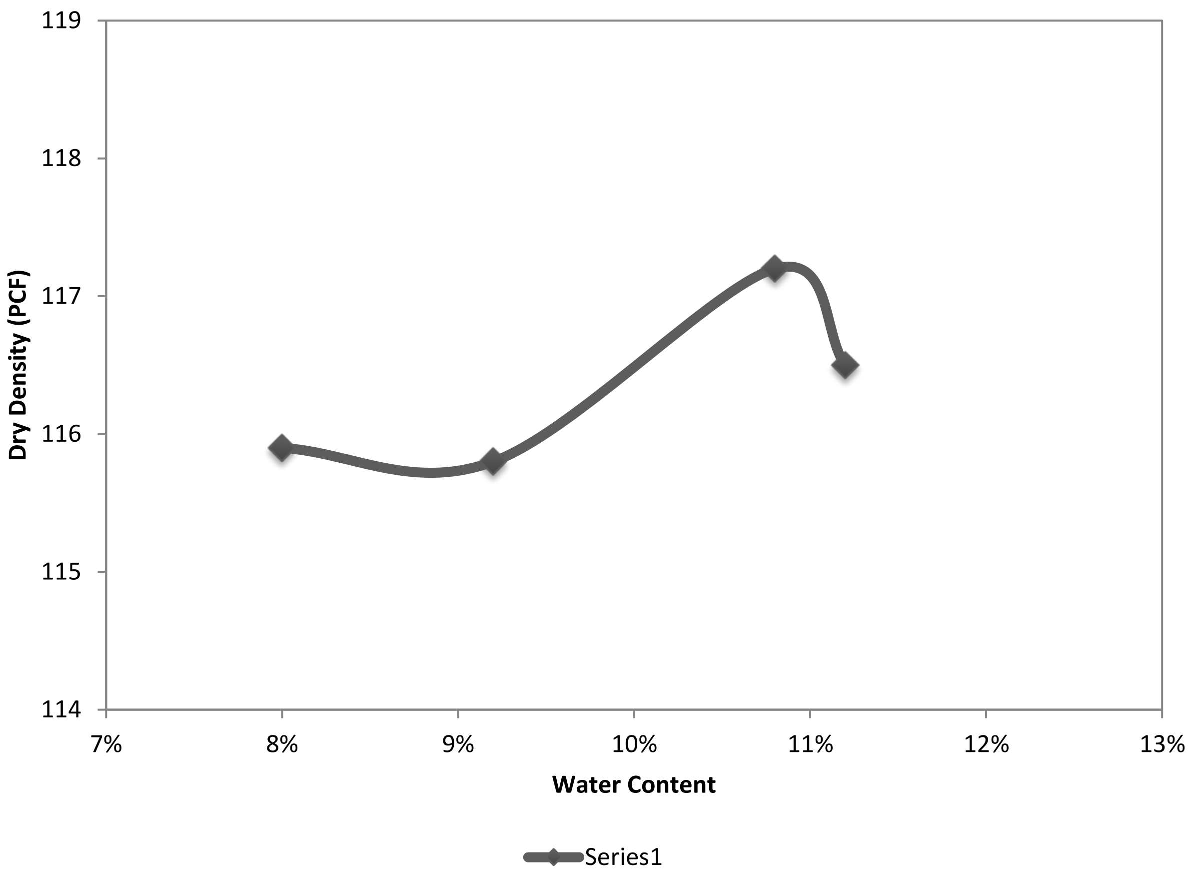

Figure A-5. Moisture-density relationship of BA50-LR50 blend

Appendix B: Additional Leaching Analysis for BA Blends

Table B-1. Trace element leaching concentrations (mg/L) from BA:RCA blends as a function of BA addition (%)

	Res GCTL	**EPA RSL (mg/L)**	**Trace element concentration (mg/L)**						
% BA			**10**	**15**	**20**	**35**	**50**	**65**	**80**
pH			12	11.9	11.9	11.7	11.5	11.1	10.6
Al	**20***	**20**	3.37	2.85	7.63	61.3	176	167	188
As	**0.01**	**0.01**	0.008	0.008	0.008	0.008	0.008	0.008	0.008
B	**1.4**	**4**	0.02	0.02	0.01	0.01	0.01	0.012	0.041
Ba	**2**	**2**	1.1	1.42	1.24	0.94	0.902	0.41	0.253
Be	**0.004**	**0.004**	0.002	0.002	0.001	0.001	0.001	0.001	0.001
Ca	**-**		381	395	283	237	215	187	204
Cd	**0.005**	**0.005**	0.002	0.002	0.001	0.001	0.001	0.001	0.001
Co	**0.14**	**0.006**	0.012	0.012	0.006	0.006	0.006	0.006	0.006
Cr	**0.1**	**0.1**	0.0133	0.0125	0.0132	0.0101	0.0038	0.0029	0.0025
Cu	**1**	**1.3**	0.084	0.107	0.125	0.173	0.257	0.304	0.439
Fe	**0.3**	**14**	0.278	0.275	0.042	0.048	0.065	0.036	0.024
K			34.3	39.5	44.6	48.8	54.3	50.8	68.4
Mg	**-**		0.048	0.048	0.031	0.03	0.034	0.049	0.057
Mn	**0.050**	**0.43**	0.002	0.002	0.001	0.0012	0.0012	0.0013	0.001
Mo	**0.035**	**0.1**	0.051	0.051	0.062	0.057	0.052	0.056	0.065
Na	**160**		29.9	40.5	51.7	66.8	92	95.6	146
Ni	**0.1**	**0.1**	0.002	0.002	0.002	0.002	0.007	0.002	0.002
Pb	**0.015**	**0.015**	0.084	0.221	0.328	0.058	0.081	0.069	0.054
Sb	**0.006**	**0.006**	0.006	0.006	0.005	0.006	0.01	0.014	0.026
Se	**0.05**	**0.05**	0.004	0.004	0.002	0.004	0.004	0.002	0.006
Sn	**4.2**	**12**	0.004	0.004	0.001	0.002	0.005	0.004	0.003
Sr	**4.2**	**12**	3.62	3.84	3.25	2.56	2.09	1.63	1.41
V	**0.049**	**0.086**	0.007	0.007	0.009	0.039	0.103	0.096	0.108
Zn	**5**	**6**	0.151	0.16	0.035	0.1	0.093	0.06	0.02

Table B-2. Trace element leaching concentrations (mg/L) from BA:LR blends as a function of BA addition (%).

	Res GCTL	EPA RSL (mg/L)	Trace element concentrations (mg/L)						
% BA			**10**	**15**	**20**	**35**	**50**	**65**	**80**
pH			**9.9**	**10**	**9.7**	**9.7**	**10**	**10.1**	**10.2**
Al	**20***	**20**	53.9	59.1	79.7	91.4	126	118	139
As	**0.01**	**0.01**	0.008	0.008	0.008	0.008	0.008	0.008	0.008
B	**1.4**	**4**	0.126	0.179	0.175	0.176	0.161	0.14	0.177
Ba	**2**	**2**	0.096	0.083	0.102	0.094	0.137	0.146	0.132
Be	**0.004**	**0.004**	0.002	0.002	0.001	0.001	0.001	0.001	0.001
Ca	**-**		85	96	119	139	185	219	230
Cd	**0.005**	**0.005**	0.002	0.002	0.001	0.001	0.001	0.001	0.001
Co	**0.14**	**0.006**	0.012	0.012	0.006	0.006	0.006	0.006	0.006
Cr	**0.1**	**0.1**	0.004	0.004	0.0029	0.0022	0.0021	0.004	0.003
Cu	**1**	**1.3**	0.082	0.121	0.134	0.142	0.279	0.202	0.41
Fe	**0.3**	**14**	0.263	0.266	0.01	0.011	0.006	0.011	0.017
K			6.9	10.9	16.5	22.5	40.2	45.7	65.2
Mg	**-**		0.173	0.148	0.138	0.116	0.105	0.103	0.103
Mn	**0.050**	**0.43**	0.002	0.002	0.001	0.001	0.0012	0.0011	0.001
Mo	**0.035**	**0.1**	0.013	0.017	0.022	0.025	0.041	0.029	0.057
Na	**160**		19.1	28.7	38.6	54.1	92.4	105	151
Ni	**0.1**	**0.1**	0.002	0.002	0.002	0.002	0.002	0.002	0.002
Pb	**0.015**	**0.015**	0.12	0.118	0.02	0.02	0.036	0.779	0.042
Sb	**0.006**	**0.006**	0.067	0.049	0.053	0.041	0.043	0.027	0.057
Se	**0.05**	**0.05**	0.004	0.004	0.003	0.004	0.003	0.001	0.004
Sn	**4.2**	**12**	0.005	0.004	0.002	0.002	0.003	0.002	0.002
Sr	**4.2**	**12**	0.58	0.589	0.696	0.721	1.12	1.15	1.14
V	**0.049**	**0.086**	0.035	0.036	0.052	0.057	0.074	0.068	0.078
Zn	**5**	**6**	0.15	0.152	0.005	0.004	0.006	0.006	0.006

Table B-3. Trace element leaching concentrations (mg/L) from 15: 85 BA:RCA blends (by mass) as a function of LS ratio

LS Ratio	**Res GCTL**	**EPA RSL (mg/L)**	**2**	**5**	**10**	**15**	**20**
pH			12.1	12.145	11.985	12.085	11.84
Al	**20***		2.6404	1.2247	4.168	8.058	13.022
As	**0.01**	**20**	0.008	0.008	0.008	0.008	0.008
B	**1.4**	**0.01**	0.02	0.02	0.02	0.02	0.0104
Ba	**2**	**4**	2.269	2.374	1.5575	1.1672	0.6061
Be	**0.004**	**2**	0.002	0.002	0.002	0.002	0.002
Ca	**-**	**0.004**	363.9	540.5	367.5	304.7	280.7
Cd	**0.005**		0.002	0.002	0.002	0.002	0.002
Co	**0.14**	**0.005**	0.012	0.012	0.012	0.012	0.012
Cr	**0.1**	**0.006**	0.0091	0.0141	0.0108	0.0091	0.01
Cu	**1**	**0.1**	0.3984	0.1447	0.1267	0.1014	0.0583
Fe	**0.3**	**1.3**	0.3436	0.2955	0.2993	0.307	0.2985
K		**14**	215.3	78.02	46.59	35	21.59
Mg	**-**		0.0533	0.056	0.0508	0.0491	0.056
Mn	**0.050**		0.002	0.002	0.002	0.002	0.002
Mo	**0.035**	**0.43**	0.0593	0.0471	0.0535	0.0535	0.0412
Na	**160**	**0.1**	233.6	71.39	50.76	35.93	20.65
Ni	**0.1**		0.002	0.002	0.002	0.002	0.002
Pb	**0.015**	**0.1**	0.0841	0.0773	0.2024	0.042	0.0328
Sb	**0.006**	**0.015**	0.006	0.006	0.006	0.006	0.006
Se	**0.05**	**0.006**	0.0063	0.004	0.0041	0.0042	0.0025
Sn	**4.2**	**0.05**	0.004	0.0043	0.004	0.004	0.004
Sr	**4.2**	**12**	10.449	6.57	3.902	3.123	1.9583
Ti		**12**	0.0186	0.0217	0.0185	0.0174	0.0165
V	**0.49**	**0.086**	0.002	0.002	0.0031	0.0022	0.005
Zn	**5**	**6**	0.2091	0.1794	0.1668	0.1532	0.1514

Table B-4. Trace element leaching concentrations (mg/L) from 15: 85 BA:LR blends (by mass) as a function of LS ratio

LS Ratio	Res GCTL	EPA RSL (mg/L)	2	5	10	15	20
pH			10.28	10.175	9.88	9.915	10.1
Al	**20***		111.68	95.86	68.42	63.87	48.05
As	**0.01**	**20**	0.008	0.008	0.008	0.008	0.008
B	**1.4**	**0.01**	0.1563	0.1756	0.1308	0.1352	0.1042
Ba	**2**	**4**	0.1019	0.1077	0.0776	0.0832	0.0691
Be	**0.004**	**2**	0.002	0.002	0.002	0.002	0.002
Ca	**-**	**0.004**	218.3	153.68	101.13	101.46	80.96
Cd	**0.005**		0.002	0.002	0.002	0.002	0.002
Co	**0.14**	**0.005**	0.012	0.012	0.012	0.012	0.012
Cr	**0.1**	**0.006**	0.004	0.004	0.004	0.004	0.004
Cu	**1**	**0.1**	0.3684	0.1762	0.0952	0.0904	0.077
Fe	**0.3**	**1.3**	0.2817	0.2918	0.2803	0.2889	0.2888
K		**14**	56.46	25.53	11.846	10.117	7.465
Mg	**-**		0.1392	0.1537	0.1831	0.1888	0.1412
Mn	**0.050**		0.002	0.002	0.002	0.002	0.002
Mo	**0.035**	**0.43**	0.0638	0.0303	0.0213	0.0153	0.0113
Na	**160**	**0.1**	157.53	68.89	31.94	26.44	18.818
Ni	**0.1**		0.002	0.002	0.002	0.002	0.002
Pb	**0.015**	**0.1**	0.037	0.0319	0.0268	0.0256	0.0226
Sb	**0.006**	**0.015**	0.0671	0.0551	0.0383	0.0466	0.0371
Se	**0.05**	**0.006**	0.004	0.0057	0.0048	0.004	0.0042
Sn	**4.2**	**0.05**	0.006	0.0056	0.0042	0.0047	0.0048
Sr	**4.2**	**12**	1.907	1.3208	0.7591	0.6221	0.4227
Ti		**12**	0.0139	0.0107	0.0071	0.0074	0.0067
V	**0.49**	**0.086**	0.0409	0.0354	0.029	0.0299	0.0234
Zn	**5**	**6**	0.1396	0.1352	0.1367	0.1416	0.133

APPENDIX D- Bottom Ash Use for Pilot Project

1. Purpose: The Bottom Ash Use (BAU) plan outlines the procedures to be utilized by WinWaste (Lincensee) for the beneficial use of bottom ash residue in a pilot project, as defined in Section 62-701.200(7), F.A.C., procured at the South Broward Facility. The authorized application includes blending bottom ash with aggregate and using the blended materials as a base in covered (paved) base course as part of a pilot project at the South Broward WinWaste Facility.

2. Specified Materials: The following materials (Specified Materials) plan to be utilized by the Lincensee's South Broward facility:
    a. Bottom ash: residue that will be blended in specific percentages with aggregate in covered (paved) base courses at replacement percentages up to 15% by mass of total aggregate. Bottom ash is produced as a byproduct of waste to energy (WTE).
    b. Aggregates: material blended with bottom ash to provide structural support and prevent the deformation or settling of the road surface. The chosen aggregates for this pilot project consist of limerock (LR) and Recycled Concrete Aggregate (RCA).

3. Required carbonation: Once approved for use by the Department of Environmental Protection (the Department), the Specified Materials used for blended base course aggregate will be carbonated by the Lincensee in accordance with the following procedure:
    a. The specified materials undergo the carbonation step via aging for a minimum period of 90 days, which will occur in an ash pile either on top of or within a designated Class I landfill cell, within authorized ash-processing facilities, or at locations approved by the Department. The ash piles should not exceed 20 feet in height throughout the treatment period.

4. Conditions for use as blended base course:
    a. Bottom ash used by the Lincensee pursuant to this BAU Plan will be obtained from the South Broward Facility separated from the fly ash stream.
    b. The bottom ash will be aged for at least 90 days, either on top of or within specified Class I landfill cells, in approved ash-processing facilities, or at Department-approved locations.
    c. The bottom ash will undergo screening to eliminate particles larger than 1.5 inches. This screening will occur on or within a designated lined Class I landfill cell, or inside an authorized ash-processing facility.
    d. The amount of ash-derived aggregate incorporated in the blended base course can include up to 15% bottom ash material.
    e. Dust released during the storage, processing, and transportation of bottom ash will be managed by either dampening the ash, using a tarp to cover it, or employing a

similar protective material. Effective dust control measures will be implemented at the aggregate yard.

f. Aggregate derived from blended ash for this project will remain within the lined portion of the Class I landfill site (during staging) or within the groundwater monitoring network (when implemented as base aggregate).

5. <u>Description of Pilot Project:</u>
   a. Location: The pilot project models a full-scale demonstration road at the Licensee's South Broward Facility location. The new roadway will be built on top of an existing 20-foot wide unpaved limerock access path, serving as the outer access route north of the recently expanded Cell 1C1 monofill as depicted in Figure 5-1 below.

Figure 5-1. Location for the designated ash-derived base aggregate pilot project site at the WinWaste South Broward Facility Location (26°04'37"N 80°12'15"W).

   b. Materials: The pilot project will generate approximately 2,400 feet of new asphalt surface, and this length will be divided into four approximate road base sections: (1) 300 ft section made with 100% RCA; (2) 700 ft section made with 15% BA combined with 85% LR; (3) 750 ft section made with 100% LR; (4) 650 ft section made with 15% BA combined with RCA. Sections 2 and 4 are referred to as test sections, and Sections 1 and 3 will be constructed as controls for comparison purposes. Figure 5-2 depicts the site layout for the pilot project and the described sections.

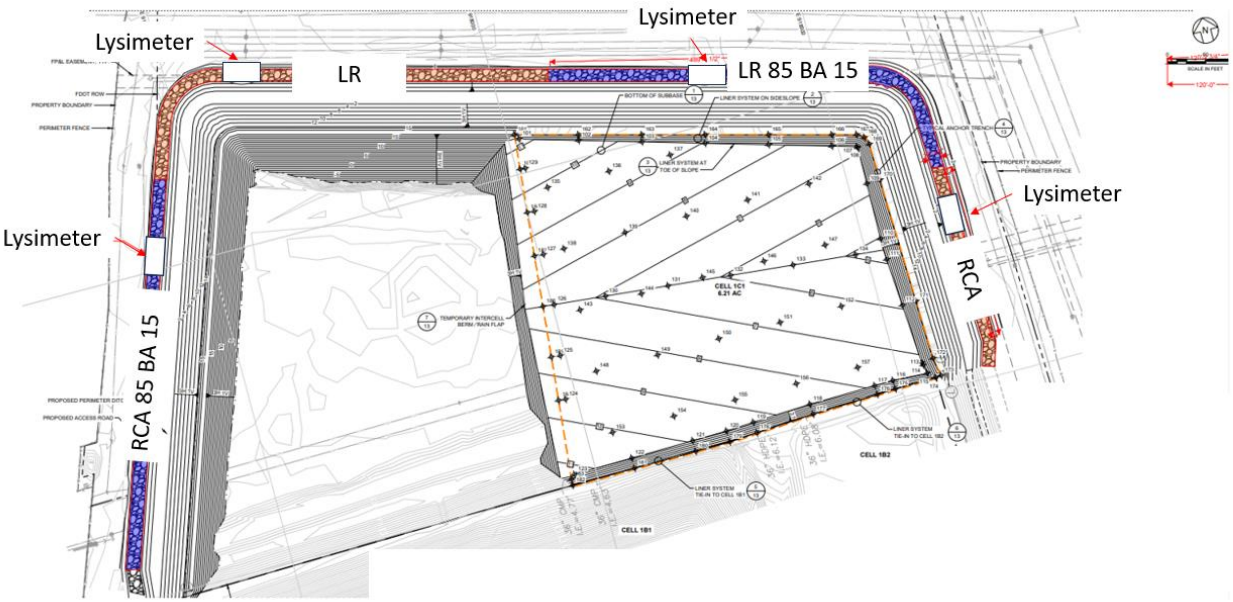

Figure 5-2. Site layout for bottom ash-derived base aggregate pilot project at the South Broward Facility including control and test base sections.

As indicated in Figure 5-3, each of the test and control sections will feature an approximately 10-inch thick (0.83 ft) base layer, confined within the width of the asphalt pavement. The width of the overlying asphalt pavement layer is approximately 3 inches (0.25 ft). There are 2-foot-wide limerock shoulders bordering both sides of the asphalt pavement. Table 5-1 displays the approximate width, depth, and length of each segment and provides an estimation of the amount of each material required for all sections. Considering the dimensions of the base layer in terms of length, depth, and width, along with the allocation of 15% of the base layer for bottom ash, the projected quantity of BA for the pilot road amounts to approximately 2,700 cubic feet.

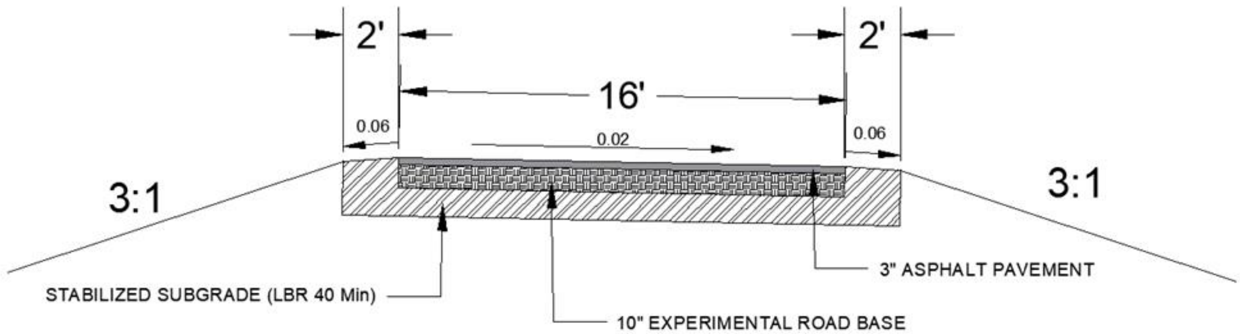

Figure 5-3. Cross section of the pilot project roadway including 3-inch asphalt layer, 10-inch test or control base section, stabilized subgrade and shoulder.

Table 5-1. Dimensions for each section of pilot project road and respective LR, RCA, and BA required for construction.

Section	Width (ft)	Depth (ft)	Length (ft)	LR (tons)	RCA (tons)	BA (tons)
(1) RCA	16	0.83	300	0	271	0
(2) LR:BA	16	0.83	700	615	0	109
(3) LR	16	0.83	750	653	0	0
(4) RCA:BA	16	0.83	650	0	459	81

c. Process: This process entails typical on-site blending of materials, followed by thorough tilling, compaction, and the application of pavement.
   i. On-site blending of materials involves the combining of BA and the aggregate materials (LR, RCA) directly at the location where the road is being built.
   ii. Once the materials are blended, tilled (or equivalent) the mixture is typically compacted. This step involves applying pressure to the blended materials to remove any air gaps, reduce voids, and increase the material's density.
   iii. After the base materials are properly prepared and compacted, the final layer, composed of asphalt, is applied. This layer forms the visible surface of the road.

d. Monitoring:
   i. Groundwater Well Network: The pilot road will be constructed within the South Broward Facility groundwater monitoring well network displayed in Figure 5-4. One additional well will be drilled in the location specified in Figure 5-4 to capture down-gradient concentrations from the pilot project

roadway. The monitoring wells allow groundwater quality assessment before and after base implementation to monitor for potential indications of leaching from the roadway materials. Wells are sampled semi-annually and analyzed for parameters listed in the Power Plant Siting Certificate (PA 85-21H).

Figure 5-4. Existing groundwater wells configuration with the addition of a proposed groundwater well.

ii. Lysimeter Construction: Lysimeters will be installed beneath the demonstration road base layer to collect infiltration through the roadway sections. Figure 5-5 displays the plan and cross-section view of the lysimeters to be implemented beneath each test and control section. Any infiltration will be collected and measured for volume and constituent concentration following roadway construction for at least one year.

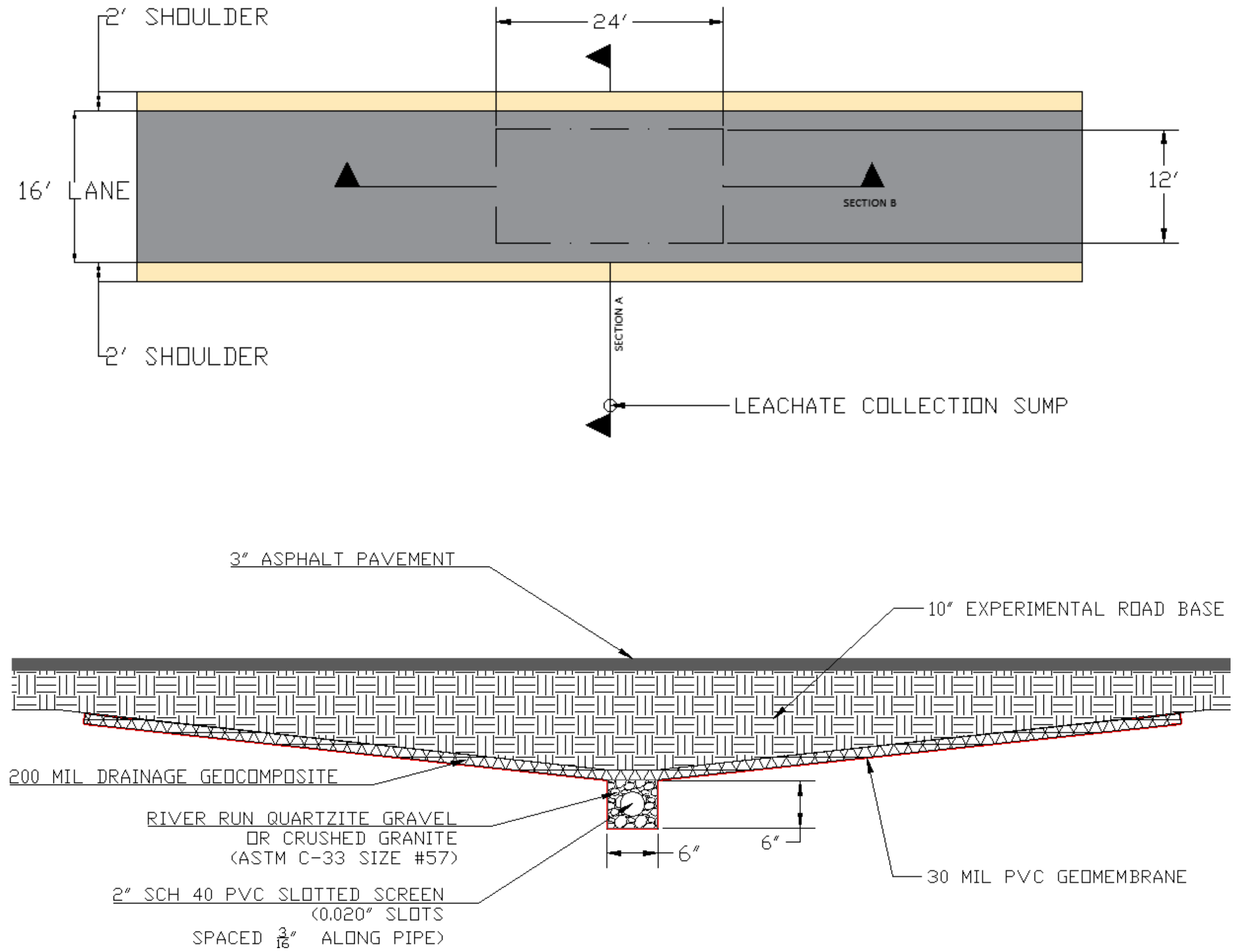

Figure 5-5. Lysimeter and leachate collection sump top and cross-sectional plan for infiltration monitoring.

iii. Physical Monitoring: Various physical tests will be conducted to assess the road's long-term performance, such as Field CBR (ASTM 4429), Falling Weight Deflectometer (FM 5-606), and Rutting Measurement (AASHTO R 88).

6. Definitions: For the purpose of this BAU Plan, the following definitions should be used
   a. **Bottom Ash Use (BAU)** a comprehensive plan describing the measures for the incorporation of bottom ash in the current pilot project.
   b. **Bottom ash (BA)** refers to the coarse, granular material that remains after the combustion of solid waste from an incineration plant, separate from the fly ash fraction. Bottom ash can consist of mineral matter, unburned carbon, and small pieces of metal.

c. **Carbonation** is the process where minerals within the bottom ash interact with atmospheric carbon dioxide, resulting in a modification of the composition of the bottom ash. This, in turn, reduces the pH level and limits mobility of certain hazardous metals.
d. **Groundwater Monitoring Wells** refer to the wells installed at the South Broward Facility to observe groundwater levels and flow conditions, as well as to obtain samples for determining groundwater quality.
e. **Infiltration** represents the liquid (precipitation or other) that permeates through the asphalt and base layer.
f. **Licensee** means the WinWaste South Broward Facility.
g. **Limerock (LR)** refers to a sedimentary rock primarily composed of calcium carbonate minerals, typically calcite or aragonite.
h. **Lysimeters** refer to collection system installed beneath roadway segments designed to capture infiltration through the roadway that can be collected and analyzed.
i. **Municipal solid waste (MSW)** refers to the waste generated by the residential sector that is commonly sent to landfills.
j. **Pavement Layer** is the topmost section of a paved roadway, typically consisting of asphalt or concrete.
k. **Recycled concrete aggregate (RCA)** refers to crushed concrete and masonry waste that is repurposed for use in construction projects. It is obtained by crushing and processing demolished concrete structures, such as buildings.
l. **Road Base** consists of the segment beneath a pavement layer or a roadway that serves to distribute traffic load, often containing compacted, well-graded aggregates.
m. **Shoulder** refers to the graded or surfaced area of the roadway, on the side of and adjacent to the pavement. This segment provides lateral support to the road surface and is appropriately inclined (3:1) to aid in drainage of surface water from the pavement layer surface.
n. **Subgrade** consists of the segment beneath the road base of a roadway and serves to provide additional support and fill to the road. This segment often consists of compacted or stabilized soil.
o. **Waste to Energy (WTE)** refers to the process by which MSW is incinerated to produce energy, and BA is produced as a byproduct.

PROPOSED CONDITION OF CERTIFICATION

SECTION B: SPECIFIC CONDITIONS

I. DEPARTMENT OF ENVIRONMENTAL PROTECTION

* * * * *

B. Solid/Hazardous Waste

* * * * *

5. Ash prior to transport to the landfill shall be stored in an enclosed building on an impervious surface. Final disposal of the ash shall be into the lined landfill or other method approved by the Southeast District Office. Any leachate generated from within the building shall be collected and disposed of by a method approved by the Southeast District Office.

18. Beneficial Use of Ash

a. As an alternative to ash disposal in a landfill, the Licensee is authorized pursuant to Section 403.7045(5), F.S., to use bottom ash residue for specified beneficial uses that are approved in advance by the Department. For example, the Licensee is hereby authorized to blend bottom ash residue with aggregate and then use the blended material in road base pilot project. The Department may authorize the Licensee to use bottom ash residue for other specified purposes, based on the information contained in the Licensee's post-certification submittals, and subject to the conditions established by the Department.

b. The Licensee's use of bottom ash residue shall be conducted in compliance with Bottom Ash Use for Pilot Project that is attached hereto and incorporated herein as APPENDIX D. Updates or changes to APPENDIX D will be reviewed by the Department's Solid Waste Division as post-certification submittals pursuant to Section 403.5113, F.S., unless the Department determines that a modification or amendment pursuant to Section 403.516, F.S., is necessary.

c. The Licensee shall comply with all of the requirements in these Conditions of Certification, including the requirements in APPENDIX D. Any violation of the requirements in APPENDIX D is a violation of this license.

90 Arboretum Drive, Suite 300
Portsmouth, NH 03801
Tel 603.929.3134

Vendor	Vendor ID	Date	Check Number
State of Florida Dept of Environmental	06998102	March 27, 2024	0132370

Invoice No.	Date	Description	Amount	Discount	Paid Amount
011-032024	3/20/2024	011-ALEX KOULET	10,000.00	0.00	10,000.00
		Totals	**10,000.00**	**0.00**	**10,000.00**

Wheelabrator
TECHNOLOGIES

90 Arboretum Drive, Suite 300
Portsmouth, NH 03801
Tel 603.929.3134

PNC Bank, N.A. 060
New Jersey

55-277/312
3482

CHECK NO 0132370

Security features included. Details on back.

DATE: March 27, 2024

PAY EXACTLY
****TEN THOUSAND AND 0/100 US DOLLARS

PAY EXACTLY
$******10,000.00

TO THE ORDER OF

State of Florida Dept of Environmental
Solid Waste Sect Attn Tires
2600 BLAIR STONE ROAD MS 4550
Tallahassee, FL 32399-2400

AUTHORIZED SIGNATURE

⑈0000132370⑈ ⑆031202770⑆ 8026321191⑈