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# Total Maximum Daily Loads and Implementation Plan for Puerto Rico: Copper, Lead, and Mercury

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## ACRONYMS AND ABBREVIATIONS

µg/L	Micrograms per liter
mg/L	Milligrams per liter
BMP	Best Management Practice
CAFO	Concentrated Animal Feeding Operation
Cu	Copper
CWA	Clean Water Act
DMR	Discharge Monitoring Records
Hg	Mercury
HSPF	Hydrologic Simulation Program--FORTRAN
IP	Implementation Plan
LA	Load Allocation(s)
LSPC	Loading Simulation Program C++
MGY	Million gallons per year
MOS	Margin of Safety
MS4	Municipal Separate Storm Sewer System
NCDC	National Climatic Data Center
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NPS	Nonpoint Source
Pb	Lead
PCS	USEPAs Permit and Compliance System
PREQB	Puerto Rico Environmental Quality Board
STORET	USEPAs Storage and Retrieval System
TMDL	Total Maximum Daily Load
USEPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey
WQS	Water Quality Standards
WLA	Waste Load Allocation(s)
WWTP	Waste Water Treatment Plant
WY	Water year



## 1 DESCRIPTION OF WATERBODY, POLLUTANT OF CONCERN, POLLUTANT SOURCES, AND PRIORITY RANKING

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This study is being conducted to develop metal (copper, lead, mercury) Total Maximum Daily Loads (TMDLs) for listed waterbodies in the following Puerto Rico watersheds: Río Grande de Loíza, Río de la Plata, Río Bayamón to Río Hondo, Río Grande de Arecibo, Río Grande de Manatí, Río Grande de Añasco, and Río Culebrinas. The 2016 Puerto Rico 305(b)/303(d) Integrated Report has identified point sources and nonpoint sources of pollution as primary contributors of loading to the listed waters. This TMDL includes an implementation plan that outlines potential strategies for the attainment of the TMDL goals. Puerto Rico waterbodies are an important recreational and natural resource critical to the economic health of the region as well as an important source of drinking water. Consequently, there is a need to identify major contributing sources of metals and identify other environmental factors that contribute to impaired water quality. This investigation will ultimately support the development of decision-making capabilities for implementation of mitigation strategies. This document is focused on quantifying watershed sources of metal loads to receiving waters and determining the required load reductions needed for each watershed to achieve numeric water quality standards (WQS) for establishing TMDLs.

### 1.1 Description of Waterbody and Background Information

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The impaired waterbodies are currently listed on the state and federal Section 303(d) impaired waters list due to high metal (copper, lead, mercury) concentrations. Potential sources identified in the Integrated Report include collection systems failure, onsite wastewater systems, urban runoff/storm sewers, confined animal feeding operations, landfills, major and minor industrial point sources, major and minor municipal point sources, agriculture, architectural materials, automobile components (i.e. brake pads), and historic mining activities.

All impaired waters are classified as SD (Puerto Rico Water Quality Standards Regulation, 2014; Section 1302.2). Because all waterbodies fall within the SD classification, a single set of WQS will be applied for all TMDLs. This TMDL focuses on load reductions that lead to attainment of these WQS and the TMDL Implementation Plan (IP) (see **Section 8**) identifies and prioritizes efforts that will lead to restoration of water quality to WQS.

Watersheds and associated assessment units in this TMDL are as follows:

- ▼ Río Grande de Añasco watershed (PRWR83A): Located in western Puerto Rico, south of Río Culebrinas watershed, and approximately 122,700 acres in area. The landscape is predominately forested land mixed with some agriculture and pasture near the coast. The major urban area is the city of Añasco, which also borders about 1,000 acres of farmland.
- ▼ Río Culebrinas watershed (PRWR95A): Located in northwestern Puerto Rico and approximately 69,500 acres in area. The landscape is predominately forested land mixed with some agriculture and pasture. The major urban areas are Moca and San Sebastián.
- ▼ Río Grande de Arecibo watershed (PRNR7A1, PRNR7A2): Located in the central western portion of Puerto Rico and approximately 152,200 acres in area. The landscape in the upper reaches of the watershed is predominately agriculture transitioning to urban areas of the greater Arecibo metropolitan area along the coast.

- ▼ Río Grande de Manatí watershed (PRNR8A3, PRNR8C2): Located in the center of Puerto Rico with a watershed size of approximately 87,000 acres. The landscape is predominantly forest with gradually steeper slopes toward the southern reaches of the watershed. Little agricultural and urban land exists.
- ▼ Río de la Plata watershed (PRER10A5): Located in the center of Puerto Rico, adjacent to Río Grande de Manatí, and approximately 91,600 acres in area. The landscape is predominately steep-sloped forest intermixed with agriculture. The south-central portion of the watershed contains the most urban areas of Cayey.
- ▼ Río de Bayamón to Río Hondo watershed (PRER12A1, PRER12B1): Located in the northeastern portion of Puerto Rico and approximately 46,800 acres in area. The landscape in the upper reaches of the watershed is predominately low-sloping, as elevation increases further south. The upper reaches are bounded by dense urban areas of the metropolitan cities of Bayamón and Guaynabo, while further south near the city of Cidra, the watershed is predominantly agriculture and forested area.
- ▼ Río Grande de Loíza watershed (PRER14A1, PRER14G1, PRER14G2, PRER14J): Located in the eastern portion of Puerto Rico, and approximately 158,800 acres in area. The western portion of the watershed is characterized by urban areas and major metropolitan areas of Caguas and Carolina, while the eastern part of the watershed is predominantly agriculture, pasture, and forested.

A map showing the locations of listed waterbodies and major watersheds is presented in **Figure 1-1**. A summary of the land uses for each of the major watersheds to be addressed in this TMDL are outlined in **Table 1-1**.

**Table 1-1. Summary of land use by major watershed and category**

Major Watershed	Land Use Total Area (acres)				
	Agriculture	Pasture	Urban	Forest & Natural	Total
Río Grande de Añasco	1,424	470	5,356	114,955	122,205
Río Culebrinas	784	1,134	12,195	55,303	69,416
Río Grande de Arecibo	1,446	1,828	7,236	140,304	150,814
Río Grande de Manatí	375	--	3,240	83,209	86,824
Río de la Plata Watershed	--	521	9,240	79,291	89,052
Río de Bayamón to Río Hondo	55	846	13,922	31,794	46,617
Río Grande de Loíza	233	9,347	31,034	117,643	158,257
<b>Total</b>	<b>4,317</b>	<b>14,146</b>	<b>82,223</b>	<b>622,499</b>	<b>723,185</b>

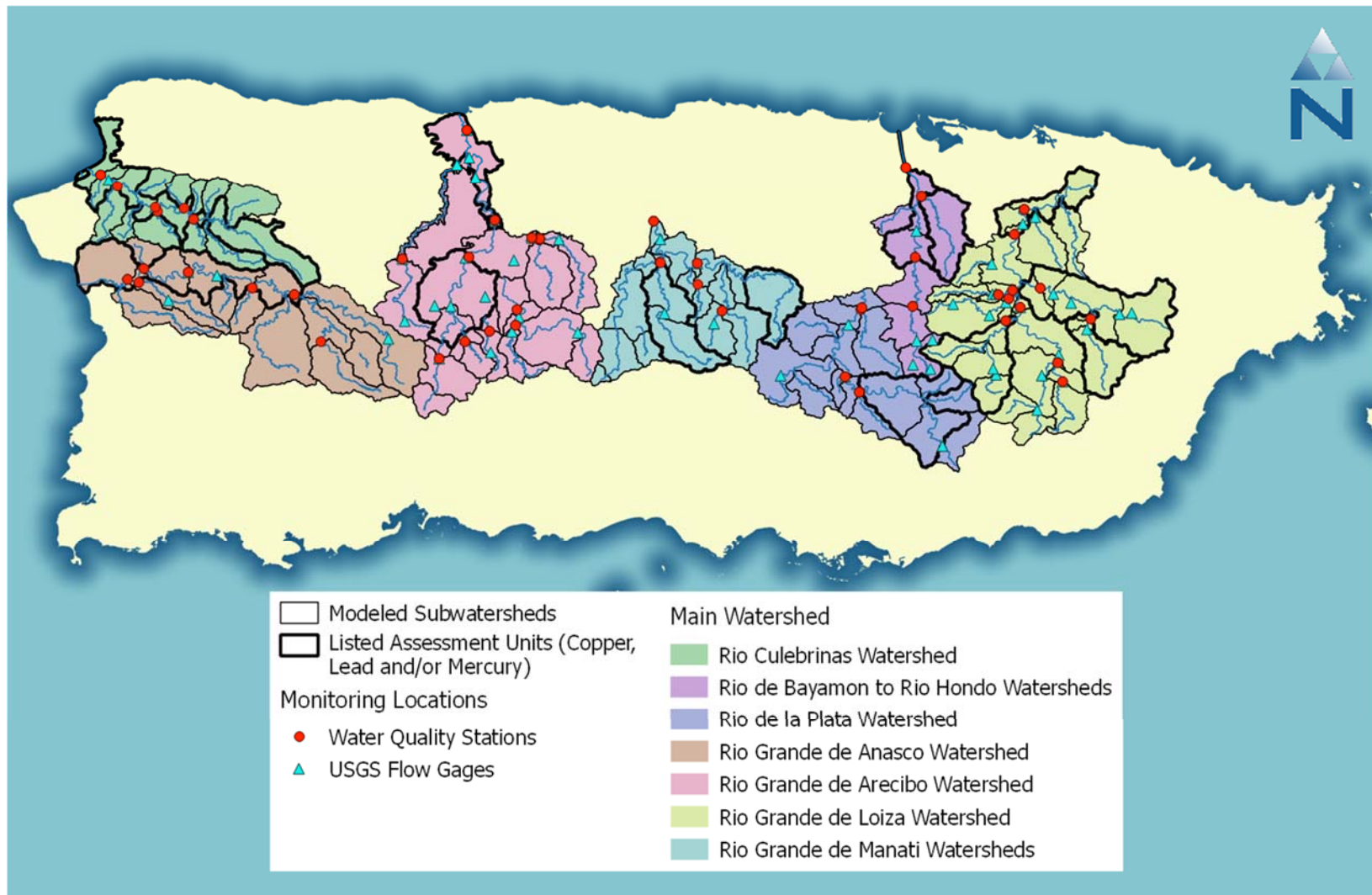


Figure 1-1. Puerto Rico Assessed Watersheds, water quality stations, and flow gages.

## 1.2 Pollutant of Concern

A summary of the waterbodies of concern and the corresponding 303(d) listed impairments are presented in **Table 1-2**. The impairments relate to impacts to the Aquatic Life Use, Raw Sources for Drinking Water, Primary Contact Recreation, and Secondary Contact Recreation designated uses. Probable sources, as indicated in the 2016 Integrated Report include industrial point sources, agricultural operations, municipal point sources, and nonpoint sources like urban stormwater runoff (PREQB 2014a, PREQB 2016). The WQS used to compute copper, lead and mercury exceedances are presented in **Section 1.4**.

Table 1-2. List of waterbodies and pollutants included in the Puerto Rico metals TMDL

Watershed	Waterbody ID	Waterbody Name	303(d) Listed Constituents		
			Copper	Lead	Mercury
Río de La Plata	PRER10A5	Río de La Plata	•	•	•
Río Grande de Manatí	PRNR8A3	Río Grande de Manatí	•		
	PRNR8C2	Río Bauta	•		
Río Grande de Arecibo	PRNR7A1	Río Grande de Arecibo	•		
	PRNR7A2	Río Grande de Arecibo	•	•	
Río Bayamón to Río Hondo	PRER12A1	Río Bayamón	•		
	PRER12B1	Río Guaynabo	•	•	
Río Grande de Loíza	PRER14A1	Río Grande de Loíza	•		
	PRER14G1	Río Gurabo	•		
	PRER14G2	Río Valenciano	•	•	
	PRER14J	Río Turabo	•		
Río Grande de Añasco	PRWR83A	Río Grande de Añasco	•		
Río Culebrinas	PRWR95A	Río Culebrinas	•		

## 1.3 Priority Ranking

Based on the assessment methodology for the 2016 Cycle 305(b)/303(d) Integrated Report, all thirteen (13) assessment units listed in **Table 1-2** were ranked as high priority waterbodies for each of their respective pollutants of concern (PREQB 2016).

## 1.4 Applicable Water Quality Standards

All surface waters are classified SD (Puerto Rico Water Quality Standards Regulation, 2014; Section 1302.2), therefore, all waterbodies in this document are *Class SD* waterbodies. The general condition of the water quality is deemed impaired if it does not meet the requirements for primary and secondary contact recreation and fish propagation. *Class SD* are described in the Puerto Rico Water Quality Standards Regulation as (PREQB 2014b):

*Surface waters intended for use as a raw source of public water supply, propagation and preservation of desirable species, including threatened and endangered species, as well as primary and secondary contact recreation. Primary contact recreation is precluded in any stream or segment that does not comply with the Rule 1303.2 (D) (2) (l) of the PRWQSR until such stream or segment meets the goal of the referred section.*

Summaries of observed data for the listed impairments are presented in **Section 1.5**. These data summaries can be compared to the specific numeric criteria established to support the designated uses for this class of surface waters. The numeric WQS for the determination of the TMDL addressing copper, lead and mercury are based on the applicable WQS listed in **Table 1-3**.

**Table 1-3. Puerto Rico WQS for 303(d) listed constituents in project watersheds (PREQB 2014a)**

Parameter	Criteria	Units	Averaging Period
Copper <sup>1</sup>	$e^{(0.8545 \times [\ln(\text{hardness})] - 1.702)}$	µg/L	single sample maximum
Lead <sup>1</sup>	$e^{(1.273 \times [\ln(\text{hardness})] - 4.705)}$	µg/L	single sample maximum
Mercury	0.050	µg/L	single sample maximum

1. Hardness is expressed as CaCO<sub>3</sub> in mg/L

The WQS for copper and lead are a function of hardness. Because hardness often shows high variability based on location due to site specific conditions of the soil, geology, or certain land use characteristics (ULAR 2016), average hardness values were calculated for each of the seven major watersheds. These values are based on a period of record from October 1, 1980 through September 30, 2016 and were obtained as part of the data set discussed in **Section 1.3**. Hardness assumptions were used as inputs for the equations presented in **Table 1-3** to derive a unique WQS by watershed. **Table 1-4** presents a summary of hardness assumptions and the calculated WQS for copper and lead by watershed.

**Table 1-4. Summary of long-term average hardness values by watershed (1980 – 2016)**

Watershed	Sample Count	Average Hardness (mg/L)	Computed WQS	
			Copper (µg/L)	Lead (µg/L)
Río Grande de Añasco	290	97.21	9.11	3.07
Río Culebrinas	200	139.04	12.36	4.84
Río Grande de Arecibo	746	83.82	8.02	2.54
Río Grande de Manatí	262	104.05	9.65	3.35
Río de La Plata	261	104.81	9.71	3.38
Río Bayamón to Río Hondo	270	124.39	11.24	4.20
Río Grande de Loíza	594	104.34	9.67	3.36

## 1.5 Monitoring Data

Monitoring data for Puerto Rico was compiled from multiple sources including U.S. Environmental Protection Agency's (USEPA's) Storage and Retrieval Data Warehouse (STORET) and data from the Puerto Rico Environmental Quality Board (PREQB). These data were summarized and assessed using

various tabular and graphical methods to evaluate the quality and representativeness of available samples. **Table 1-5** presents a summary of the data included in this data analysis. **Appendix A** includes all water quality monitoring data (in tabular format organized by data source) used for establishing the existing conditions for the Puerto Rico assessment units, and **Appendix B** contains detailed trend analyses of the data. The following subsections provide a general description of each of the pollutants included in the Puerto Rico TMDL including basic information of the impacts and the possible sources for each.

Table 1-5. Summary of available water quality data by assessment unit and data source (WY 2006 – WY 2016).<sup>1</sup>

Waterbody Name	Waterbody ID	Copper sample count		Lead sample count		Mercury sample count	
		USEPA	USGS	USEPA	USGS	USEPA	USGS
<b>Río de la Plata Watershed</b>							
Río de la Plata	PRER10A5	1	8	1	8	--	8
<b>Río Bayamón to Río Hondo Watershed</b>							
Río Bayamón	PRER12A1	--	30				
Río Guaynabo	PRER12B1	--	22	--	22		
<b>Río Grande de Loíza Watershed</b>							
Río Grande de Loíza	PRER14A1	--	22				
Río Gurabo	PRER14G1	1	21				
Río Valenciano	PRER14G2	2	7	2	7		
Río Turabo	PRER14J	1	6				
<b>Río Grande de Arecibo Watershed</b>							
Río Grande de Arecibo	PRNR7A1	--	35				
Río Grande de Arecibo	PRNR7A2	2	21	2	21		
<b>Río Grande de Manatí Watershed</b>							
Río Grande de Manatí	PRNR8A3	1	6				
Río Bauta	PRNR8C2	--	9				
<b>Río Grande de Añasco Watershed</b>							
Río Grande de Añasco	PRWR83A	--	62				
<b>Río Culebrinas Watershed</b>							
Río Culebrinas	PRWR95A	2	58				
<b>Total</b>		<b>10</b>	<b>307</b>	<b>5</b>	<b>58</b>	<b>--</b>	<b>8</b>

*Grey shading indicates that the given pollutant is not listed for that waterbody*

<sup>1</sup> Data from the USEPA’s STORET. Water year (WY) begins on October 1 of the previous year and ends September 30 of the year noted.

### 1.5.1 Total Copper

All thirteen of the 303(d) listed waterbodies in **Table 1-2** are impaired for total copper. Copper is a heavy metal that, in high quantities, can be detrimental to humans and aquatic life through ingestion and direct contact with a contaminated waterbody. Soils and suspended sediments are a major sink for copper once released into the environment, and changes in its chemical form may result in bioconcentration within aquatic organisms. Copper impairments in waterbodies can often be improved by controlling stormwater runoff, industrial point source pollution, and sedimentation, as well as replacing old piping used to transport drinking water and wastewater and limiting use in agricultural operations.

Within the 13 assessment units, there are 42 stations that have recorded copper measurements—most stations (32) have been in operation for more than 10 years. Of those stations, 11 have significant data records (more than 30 observations). Copper concentrations are highest in Río Gurabo (PRER14G1) with a mean concentration of 7.87 µg/L and a maximum concentration of 71.9 µg/L. Copper levels are also high in Río Guaynabo (PRER12) and Río de la Plata (PRER10A5). **Table 1-6** lists copper summary statistics by assessment unit in more detail. The WQS used to compute copper exceedances are presented in **Section 1.4**.

**Figure 1-2** presents the trends in observed copper concentrations in impaired waterbodies annually (last 10 years), seasonally (since beginning of WY 2006), as well as patterns observed based on rainfall and flow data. Yearly trends in the top left graph indicate that exceedances (orange values) were generally higher prior to 2012, with no exceedances in 2015 and 2016. Overall, 9% of the samples exceeded the WQS over the past 11 years (all watersheds/all stations). Seasonal trends from the past 11 years show exceedances during winter and summer months, and none outside of those seasons. Rainfall amount (bottom left graph) appears to be a major contributor to exceedances of copper concentrations in Puerto Rico waters, with exceedance percentages at 40% and 36% during the periods of highest rainfall. The flow duration curve (bottom right graph) shows no exceedances during dry days (0 – 20 percentile), with the number of exceedances increasing as flow increases.

Table 1-6. Summary of available copper ( $\mu\text{g/L}$ ) data by assessment unit (WY 2006 – WY 2016)

Waterbody Name	Assessment Unit	Start Date	End Date	Count	Number of Exceedances	Min ( $\mu\text{g/L}$ )	Mean ( $\mu\text{g/L}$ )	Max ( $\mu\text{g/L}$ )
<b>Río de la Plata Watershed</b>								
Río de la Plata	PRER10A5	2/27/2013	9/8/2016	9	1	0.00	5.61	33.20
<b>Río Bayamón to Río Hondo Watershed</b>								
Río Bayamón	PRER12A1	2/13/2006	9/6/2016	30	2	1.00	3.98	26.40
Río Guaynabo	PRER12B1	2/3/2006	9/6/2016	22	3	2.00	8.31	47.20
<b>Río Grande de Loíza Watershed</b>								
Río Grande de Loíza	PRER14A1	2/9/2006	9/12/2016	22	2	1.10	3.57	21.30
Río Gurabo	PRER14G1	2/7/2006	2/16/2016	22	5	0.00	9.87	71.90
Río Valenciano	PRER14G2	3/2/2013	9/13/2016	9	1	0.00	3.05	16.70
Río Turabo	PRER14J	3/7/2013	2/18/2016	7	1	0.00	2.17	6.80
<b>Río Grande de Arecibo Watershed</b>								
Río Grande de Arecibo	PRNR7A1	2/14/2006	2/18/2016	35	3	0.00	2.79	11.90
Río Grande de Arecibo	PRNR7A2	2/14/2006	2/17/2016	23	2	0.00	3.93	13.80
<b>Río Grande de Manatí Watershed</b>								
Río Grande de Manatí	PRNR8A3	3/22/2006	4/13/2015	7	1	0.00	2.50	10.30
Río Bauta	PRNR8C2	3/21/2006	8/7/2015	9	0	1.10	1.92	3.00
<b>Río Grande de Añasco Watershed</b>								
Río Grande de Añasco	PRWR83A	2/8/2006	9/7/2016	62	4	0.00	2.82	22.30
<b>Río Culebrinas Watershed</b>								
Río Culebrinas	PRWR95A	2/8/2006	9/7/2016	60	4	0.00	3.27	26.80
<b>Total</b>				<b>317</b>	<b>29</b>			

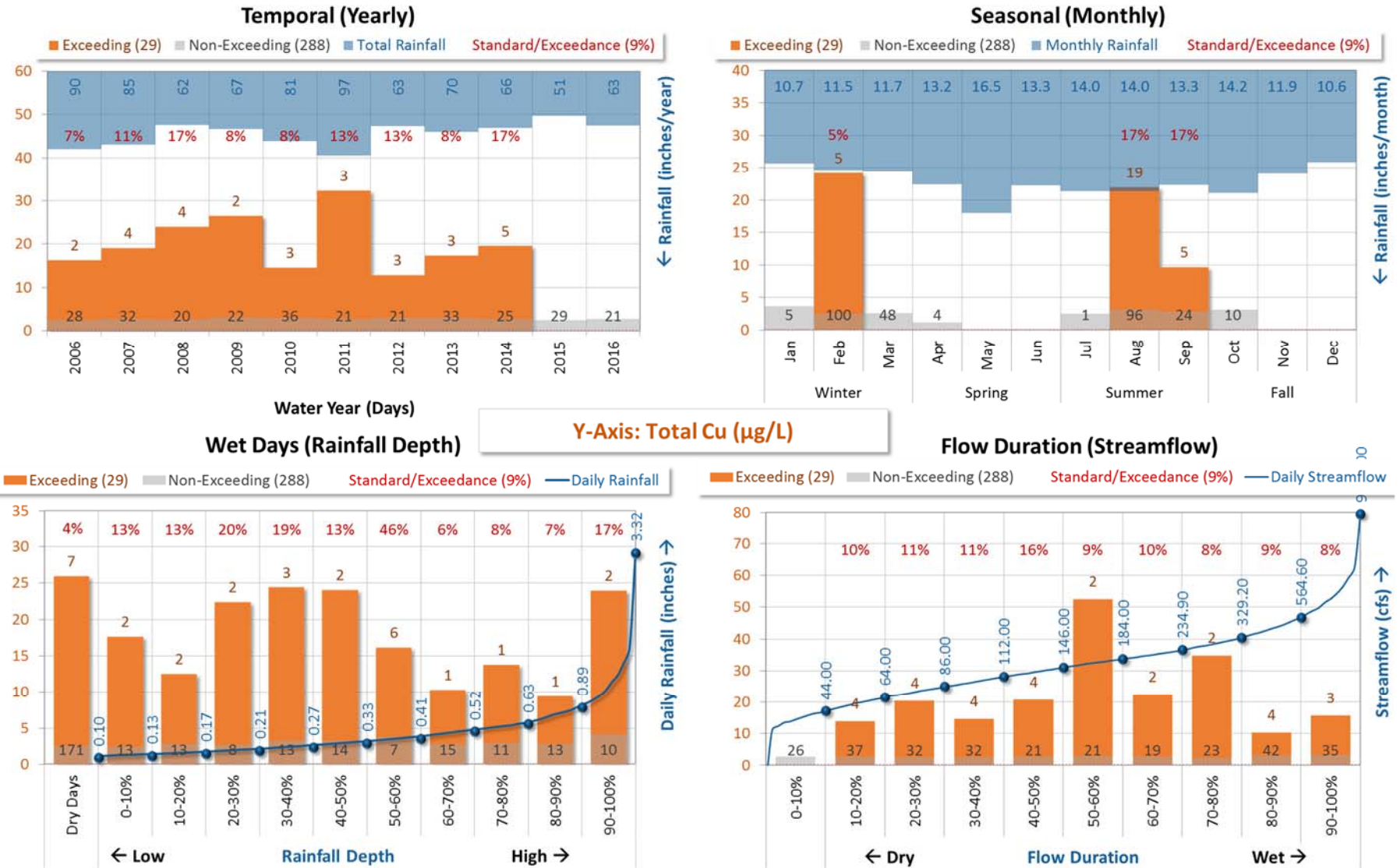
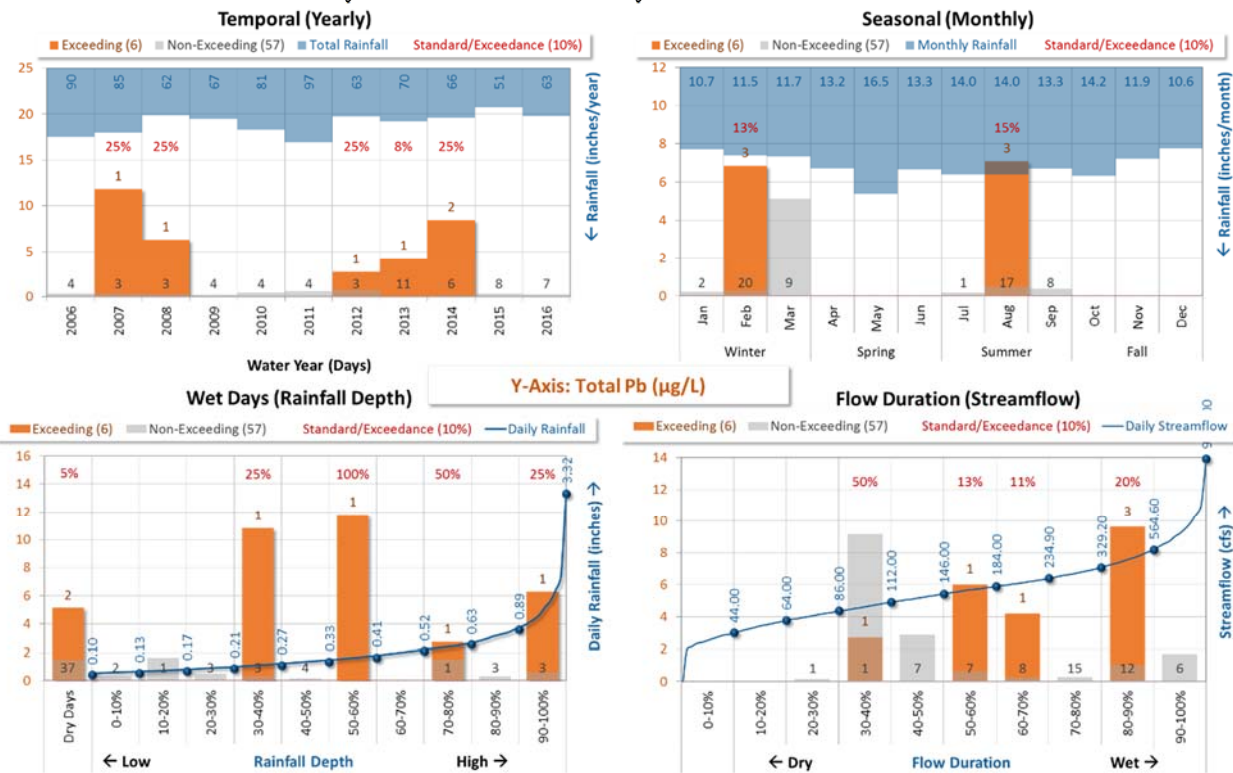


Figure 1-2. Total cooper (Cu) ( $\mu\text{g/L}$ ) in all copper listed waterbodies and stations (WY 2006 – WY 2016).

### 1.5.2 Total Lead

Four of the 303(d) waterbodies in **Table 1-2** are listed as impaired for total lead. Lead is a heavy metal that, in high quantities, can be detrimental to humans and aquatic life when drinking lead-contaminated water or being in direct contact with a contaminated waterbody. In the ambient environment, humans are exposed to lead from a greater variety of sources and at higher levels than those associated with mercury or copper. Soils and suspended sediments are a major sink for lead once released into the environment, and changes in its chemical form may result in bioconcentration within aquatic organisms. Lead impairments in waterbodies can often be improved by controlling industrial & municipal point source pollution and replacing old infrastructure as well as old piping used to transport drinking water and wastewater. The WQS used to compute lead exceedances are presented in **Section 1.4**

Within the four listed assessment units, there are 11 stations that have recorded lead measurements—most stations (9) have been in operation for more than 10 years. Of those stations, two have significant data records (more than 30 observations). Lead concentrations are highest in Río Guaynabo (PRER12B1) with a mean lead concentration of 1.71 µg/L and a maximum of 11.8 µg/L. **Table 1-7** lists lead summary statistics by assessment unit in more



detail.

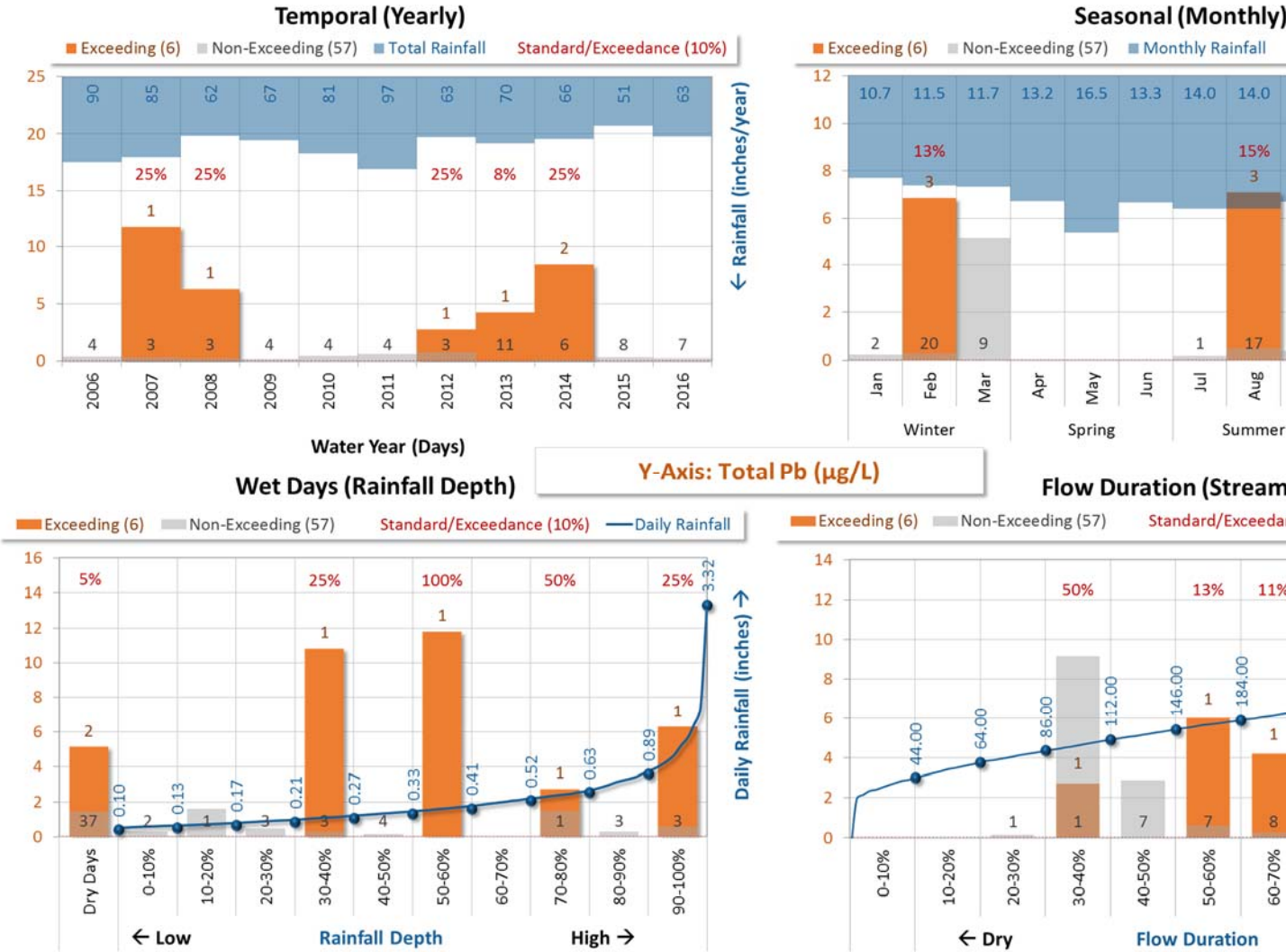


Figure 1-3 presents the trends in observed lead concentrations annually (last 11 years), seasonally (since the beginning of WY 2006), as well as patterns observed based on rainfall and flow data. Yearly trends in the top left graph show exceedances during five out of the last 11 years, but no exceedances during 2015 and 2016. Overall, 10% of the lead samples exceeded WQS over the past 11 years. Seasonal trends show exceedances only during February and August months, though no samples were taken from April – June or October - December. Based on rainfall amount, exceedances appear slightly more frequent during wet days (bottom left graph), though the sample size is small, and the flow duration curve shows exceedances only above a 50-percentile storm, implying that exceedances only occur during events with higher rainfall amounts.

Table 1-7. Summary of available lead (µg/L) data by assessment unit (WY 2006 – WY 2016)

Waterbody Name	Assessment Unit	Start Date	End Date	Count	Number of Exceedances	Min (ug/L)	Mean (ug/L)	Max (ug/L)
<b>Río de la Plata Watershed</b>								
Río de la Plata	PRER10A5	2/27/2013	9/8/2016	9	1	0.00	5.61	33.20
<b>Río Bayamón to Río Hondo Watershed</b>								

Río Guaynabo	PRER12B1	2/3/2006	9/6/2016	22	3	2.00	8.31	47.20
<b>Río Grande de Loíza Watershed</b>								
Río Valenciano	PRER14G2	3/2/2013	9/13/2016	9	1	0.00	3.05	16.70
<b>Río Grande de Arecibo Watershed</b>								
Río Grande de Arecibo	PRNR7A2	2/14/2006	2/17/2016	23	1	0.00	3.93	13.80
<b>Total</b>				<b>63</b>	<b>6</b>			

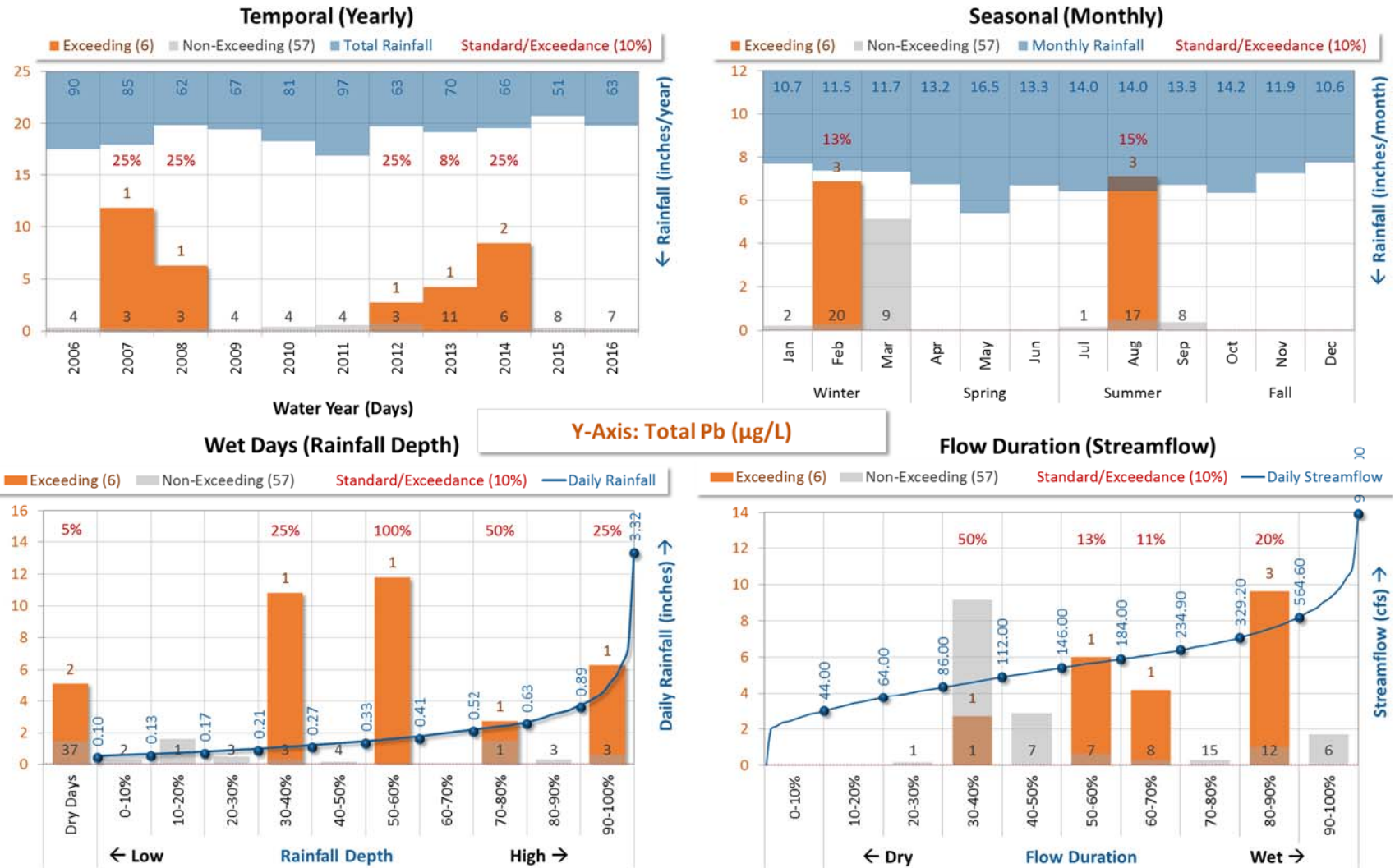


Figure 1-3. Total Pb (µg/L) in all lead listed waterbodies and stations (WY 2006 – WY 2016).

### 1.5.3 Mercury

One of the waterbodies in **Table 1-2** is listed as impaired for total mercury: Río de la Plata (PRER10A5). Mercury is considered one of the most volatile heavy metals and, in high quantities, can be detrimental to humans and aquatic life, especially in its organic form: methylmercury. Soils and suspended sediments are a major sink for mercury once released into the environment, and changes in its chemical form may result in bioaccumulation up the food chain. This bioaccumulation results in concentrations progressively increasing along an ecological food chain, making aquatic organisms with mercury contamination more toxic to humans to ingest. Mercury impairments in waterbodies can often be improved by controlling industrial & municipal point source pollution and as well as removal of batteries, paint, and other sources of mercury from the waste stream. The WQS used to compute mercury exceedances are presented in **Section 1.4**.

Within Río de la Plata, there are two stations that have mercury samples, but only one with samples in the last 10 years. This station has only been in operation since 2013 and contains a total of eight (8) samples. The mean mercury concentration in Río de la Plata is 0.012 µg/L, with a maximum concentration of 0.089 µg/L. **Figure 1-4** displays mercury samples from Río de la Plata over time. **Table 1-8** presents a statistical summary of mercury samples—note that the average concentration for all samples is skewed by the single sample that exceeds the WQS and that the average for the other 7 samples is 0.001 µg/L.

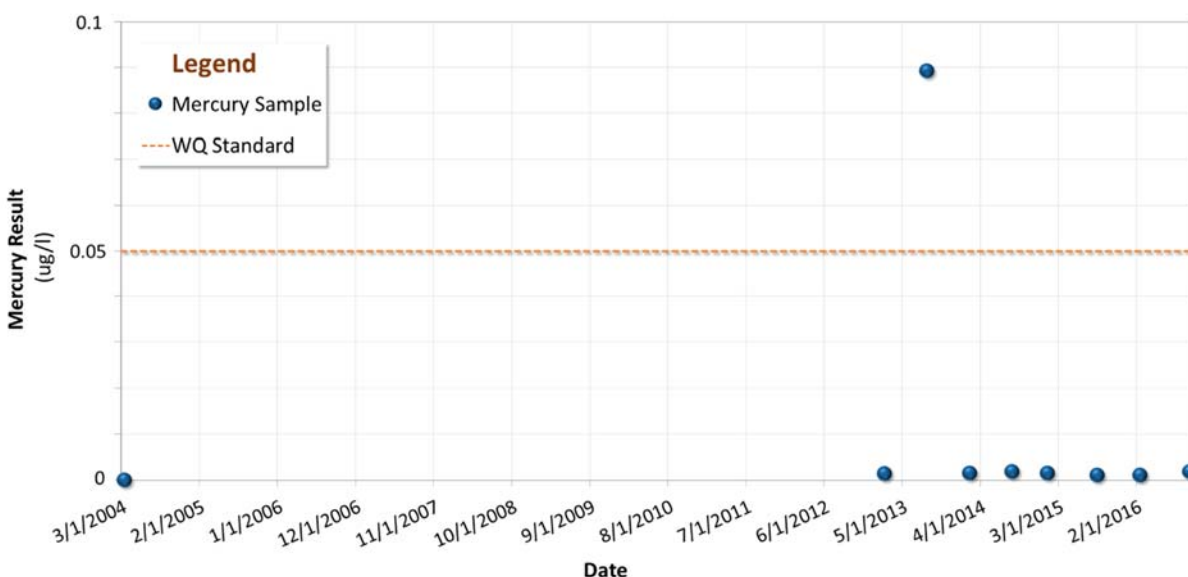


Figure 1-4. Available mercury sampling results for Río de la Plata (WY 2004 – present)

Table 1-8. Summary of mercury sampling across all listed assessment units (WY 2006 – present)

Waterbody	Assessment Unit	Sample Count	# > WQS	Min (ug/L)	Mean (ug/L)	Max (ug/L)
Río de La Plata	PRER10A5	8	1	0.001	0.012	0.089

## 2 POLLUTANT SOURCES

This section summarizes the potential sources for each of the pollutants included on the 2016 303(d) list of impaired waters. Presented in this section are information on types of pollutant sources, when they are most active (i.e., only during rainfall events); and how much is known about the source regarding the ability to characterize and estimate loading to receiving waters. This information will inform the calculation of existing loading of the pollutants and the reductions needed from the sources to attain or maintain WQSSs.

In addition to highlighting the pollutant(s) of concern, the 2016 Integrated Report for Puerto Rico summarizes the possible pollutant sources contributing to impairments in each listed assessment unit. The types of sources range from specific facilities that may report actual discharges to distributed nonpoint sources where contributions are typically rainfall driven and specific sources are more difficult to identify and quantify. **Table 2-1** presents a summary of the potential pollutant sources by assessment unit as documented in the 2016 Integrated Reports (PREQB 2016). The following subsections present discussion of the primary pollutant sources considered in this TMDL.

Table 2-1. Summary of Potential Pollution Sources outlined in the 2016 Integrated Reports

Waterbody Name	Assessment Unit ID	Agriculture	Collection System Failure	Confined Animal Feeding Operations	Landfills	Municipal Point Sources	Industrial Point Source	Onsite Wastewater Systems	Package Plant	Surface Mining	Urban Runoff & Storm Sewers
Río de La Plata	PRER10A5	--	●●●	●●●	--	●●●	●●●	●●●	--	--	●●●
Río Grande de Manatí	PRNR8A3	--	--	●	●	--	--	●	●	--	--
Río Bauta	PRNR8C2	●	--	●	--	--	--	●	--	--	--
Río Grande de Arecibo	PRNR7A1	●	●	●	--	--	●	●	--	--	●
Río Grande de Arecibo	PRNR7A2	●●	●●	●●	●●	●●	●●	●●	--	--	●●
Río Bayamón	PRER12A1	--	●	●	--	--	●	●	--	--	●
Río Guaynabo	PRER12B1	--	●●	●●	●●	--	●●	●●	--	--	●●
Río Grande de Loíza	PRER14A1	--	●	●	--	--	●	●	--	●	●
Río Gurabo	PRER14G1	--	●	●	●	--	●	●	--	●	--
Río Valenciano	PRER14G2	●●	●●	●●	●●	--	●●	●●	●●	--	●●
Río Turabo	PRER14J	●	●	●	--	●	●	●	--	--	●
Río Grande de Añasco	PRWR83A	●	●	●	--	●	●	●	--	--	●
Río Culebrinas	PRWR95A	●	●	●	●	●	●	●	--	--	●

●: Copper

●●: Copper and lead

●●●: Copper, lead, and mercury

## 2.1 Nonpoint Sources

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The following sections provide a summary of what is known about nonpoint sources of copper, lead, and mercury to listed waterbodies. Unlike point sources, which will receive individual wasteload allocations (WLAs), the nonpoint sources are more difficult to identify and quantify. Data analyses and modeling have been conducted to develop loading estimates for known contributing categories of nonpoint sources.

### 2.1.1 Agriculture

Agricultural practices may be a significant source of both copper and lead to the waterbodies listed in **Table 2-1**. Studies have determined that toxic trace metals exist in agricultural soils, many times at larger quantities than non-agricultural soils (Holmgren et al. 1993). Both copper and lead can be found in pesticides and phosphorous-based fertilizers that are applied to agricultural fields. Copper has also been found in high levels in manure, which can be more biologically active than copper in biosolid waste (Hopkins and Ellsworth 2005), and has historically been used as an agricultural fungicide (Apeti et al. 2011). These contaminants may then travel to waterbodies as nonpoint source runoff from agricultural areas either dissolved in runoff or adsorbed to sediment particles. In watersheds where agriculture is a predominant land use, or where agriculture is located adjacent to receiving waters, like Río de Loíza, Río Grande de Arecibo, and Río Culebrinas, application of both pesticides and fertilizers may be a major source of copper and lead to these waterbodies. Details on how agricultural land uses were parameterized and modeled for copper and lead are included in the TMDL Modeling Report (**Appendix C**).

### 2.1.2 Pasture/Animal Feeding and Grazing Operations

Agricultural Feeding Operations (AFO) are agricultural enterprises where animals are raised in confined areas. AFOs, unlike Confined Agricultural Feeding Operations (CAFO), described in Section 2.2.1, operate on smaller areas of land, contain under 1,000 animal units, and are not regulated under the Clean Water Act National Pollutant Discharge Elimination System (NPDES) program, though they may still be impacting the local environment. In this TMDL, these non-NPDES-permitted operations are characterized as pasture/animal feeding and grazing operations. Details on how agricultural land uses were parameterized and modeled for copper and lead are included in the TMDL Modeling Report (**Appendix C**). The existing load will be assigned as a nonpoint source load allocation. Detailed information on each of these operations is not included in this TMDL, as little research is available on the concentrations of metals from animal feeding and grazing operations in Puerto Rico. It is believed that numerous small AFO's exist in the watersheds and that they could represent a source of copper to receiving waters if effluent is not managed properly. This TMDL utilizes a land-use based loading approach using literature values and conservative assumptions. Possible sources of metals at feeding and grazing operations include background metal concentrations (copper and zinc primarily) in native plants as well as metals that are sometimes added as a preservative to animal feed (USEPA 2004). The animal waste generated by these operations could result in higher concentrations of metals available for runoff during storm events or direct deposit to streams.

### 2.1.3 Urban Runoff

The leading cause of water quality issues in Puerto Rico is nonpoint source pollution from urban runoff (NOAA 2000). Upland erosion and sedimentation are also major contributors, as sediment has the potential to transport copper, lead, and mercury to waterbodies, impacting water quality and aquatic life. Watershed runoff and stormwater runoff may carry this sediment to local rivers that originate from either naturally vegetated areas or developed lands. In October 2000, Puerto Rico

received federal approval to aid the commonwealth's new polluted runoff program to address these issues.

Urbanization is highest in Río Bayamón to Río Hondo, Río de Loíza, and Río Culebrinas watersheds. As development and urbanization increases within these watersheds (particularly in the upland areas), various other pollutants (pesticides, heavy metals, organic matter, and trash) will be generated. Stormwater ultimately carries these pollutants with it into rivers, bays, and coastal areas. Sources of sedimentation and runoff are heightened by construction projects, unpaved roads, and large urban areas, especially in areas with high slopes and less vegetation. Loadings from these sources are likely contributing to an exceedance of heavy metal standards but they may also have a longer-term impact associated with the delivery of other pollutants. Copper and lead, specifically, are commonly found in many facets of the urban environment including concrete and automotive components, both of which can deteriorate over time releasing these metals into the surface and groundwater systems (BASMA 2011, ULAR 2016). Details on how unregulated urban land use was parameterized and modeled for copper and lead are included in the TMDL Modeling Report (**Appendix C**).

Urban runoff from larger, higher density urban areas may also be discharge under a NPDES permitted municipal separate storm sewer systems (MS4). MS4 programs are typically required to perform annual reporting and are subject to program inspection like municipal or industrial NPDES permitted facilities. Since these programs hold individual permits they will be expressed separately in the TMDL as a WLA.

#### 2.1.4 Landfills

Typical methods of disposal in Puerto Rico for non-recyclable materials are landfills. Many products that contain heavy metals, over the course of their life-cycle, may release contaminants which gain access to underground and surface waterbodies through leachate. Modern landfill design includes containment systems to prevent pollution from landfill materials, however; even with adequate containment systems, the life-time and performance of these systems over long time-frames is unknown. A typical landfill at capacity, for example, with millions of tons of waste, may contain thousands of kilograms of heavy metals, including copper, lead, and mercury (New York Academy of Sciences 2006). Six landfills are located near upstream waterbodies, within watersheds Río de Arecibo, Río Grande de Manatí, Río Bayamón to Río Hondo, and Río de la Plata. Within these watersheds, landfills could pose a risk of contamination to impaired waterbodies if not properly managed. Automobiles, specifically, contain both copper and lead in a variety of components including brake pads, tires, fluids, and various engine parts (TDC 2014, ULAR 2016). When these components corrode, as would happen with abandoned vehicles exposed to the elements over time, both copper and lead are released into the environment and can be transported either via sediment erosion or leachate via groundwater systems. No information was obtained that suggests any of the 6 landfills are sources of copper, lead, or mercury, and therefore no loading contribution was included in the modeling effort described in **Appendix C**, existing loads were assumed to be zero, and there were no allocations to landfills.

#### 2.1.5 Superfund

The Superfund program was developed in 1980 as the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) to provide implementation and funding for cleanup efforts of contaminated sites. Sites identified with a Superfund designation often exhibit soil and groundwater contamination which can leach offsite to adjacent parcels and receiving waters. Because groundwater often serves as the transport mechanism for contaminants, it can be difficult to predict and track their movement in the subsurface. Contaminants can include dense non-aqueous phase

liquids (DNAPL), organic substances, toxic substances and heavy metals. Other more traditional pollutants are often present at these sites, such as copper, lead, and mercury.

Four (4) Superfund sites were identified within watersheds modeled during this TMDL. Only two of the four assessment units containing Superfund sites are listed for copper or lead. None of the assessment units containing Superfund sites are listed for mercury, which suggests that the mercury listing in PRER10A5 is not being caused by an active Superfund site. **Table 2-2** presents a summary of the Superfund sites and the coincident assessment units.

Because no Superfund site was identified as a source of copper, lead, or mercury, no loading contribution was included in the modeling effort described in **Appendix C**, existing loads were assumed to be zero, and there were no allocations to Superfund sites.

**Table 2-2. Summary of identified Superfund sites within listed watersheds**

Site Description	Waterbody	Assessment Unit	Listed Pollutants
PAPELERA PUERTORRIQUE, INC	Río Grande de Arecibo	PRNR7A2	Copper, Lead
CIDRA GW CONTAMINATION	Río Arroyata	PRER10G	--
JUNCOS LANDFILL	Río Caguitas	PRER14I	--
HORMIGAS GW PLUME	Río Gurabo	PRER14G1	Copper

### 2.1.6 RCRA Facilities

Under the Resource Conservation and Recovery Act (RCRA), facilities that generate, transport, treat, store or dispose of hazardous waste must provide the USEPA with information concerning their waste activities. Hazardous waste handlers are required to provide basic site identification, permit or closure status, and any corrective action tracking. RCRA facilities in Puerto Rico are listed in EPA's EnviroFacts database, and on USEPA Region 2's website, which contains a list of 24 RCRA Cleanup Facilities. All Cleanup Facilities in Puerto Rico have groundwater contamination and human exposures "under control" except for one location where more information is needed. Per personal communication with PREQB, it is not believed that RCRA sites are significantly contributing to metal loading and are therefore not including in the TMDL allocation and analysis. A search of the EPAs RCRA clean facilities site (<https://www3.epa.gov/region02/rcra/caribind.htm>) did not identify any existing sources of copper, lead, or mercury, therefore no loading contribution was included in the modeling effort described in **Appendix C** and existing loads were assumed to be zero, and there were no allocations to RCRA sites.

### 2.1.7 Forest & Background

Sources of metals may also be found in sediments and rivers from natural areas and other background sources. Historically, there are also large areas of commercially exploitable deposits of metals throughout the central parts of Puerto Rico, especially in Río de Añasco, Río de Arecibo, and Río de Manatí watersheds (Gelabert 2004). Wastes from abandoned mines may have measurable impacts to nearby rivers and aquatic habitats owing to the erosion and re-deposition of waste material containing metals (USGS 2010). This type of sites would produce strong, localized signatures which were not observed in the monitoring data. Documentation of abandoned mining or mineral extraction sites was

not available to identify areas of influence. In October 2005, the USEPA conducted copper sampling of two WWTP effluents in Puerto Rico (Aguas Buenas and Caguas) in the receiving water stream, upstream and downstream of the discharge points. Copper concentrations downstream of the sites were 3.67 µg/L and 4.82 µg/L, with upstream values below the non-detect concentrations (PREQB 2007). Non-detect values in the monitoring data for the upstream sites, and low annual loading rates for natural land uses discussed in Appendix C suggest that natural and background sources are typically not contributing to waterbody impairment for copper, lead and mercury. Details on how natural and background sources of copper and lead were parameterized and modeled are included in the TMDL Modeling Report (**Appendix C**).

Atmospheric deposition has been cited as a source of mercury originating from emissions discharged by power plants and other industrial facilities (CSN 2015). While some literature suggests there may be localized pockets of mercury accumulation from wet-deposition in zones of higher precipitation, no definitive research was found to suggest that atmospheric deposition is a widespread source of mercury across Puerto Rico. Furthermore, a wider spatial pattern of exceedances would be expected if wet-deposition was a major factor in causing mercury exceedances. The trends analysis presented in **Section 1.5.3** shows no consistent pattern of exceedances across the island and in fact, only one exceedance of the mercury WQS was observed in the available data.

## 2.2 Point Sources

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The following sections provide information on point sources of copper, lead, and mercury.

### 2.2.1 Concentrated Animal Feeding Operation (CAFO)

Animal Feeding Operations (AFOs) are agricultural enterprises where animals are kept and raised in confined situations. These operations congregate animals, feed, manure and urine, dead animals, and production operations on a small land area. USDA data indicate that the vast majority of farms with livestock are small about 85 percent of these farms have fewer than 250 animal units (AUs), where an AU is equal to roughly one beef cow (therefore 1,000 AUs is equal to 1,000 beef cows or an equivalent number of other kinds of animals) (<https://www.epa.gov/sites/production/files/2015-10/documents/exexsum.pdf>) AFOs can pose a number of risks to water quality and public health, mainly because of the amount of animal manure and wastewater they generate. Concentrated animal feeding operations (CAFO) are certain higher risk AFOs that are addressed through an NPDES permit. A CAFO is defined by USEPA as a large, concentrated feeding operation, with more than 1,000 animal units (an animal equivalent of 1,000 pounds live weight), which equates to 1,000 heads of beef cattle, 700 dairy cows, 2,500 swine, 125,000 chickens, or 82,000 hens that are confined on site for more than 45 days during the year. As previously stated, copper and lead can be found in agricultural activities from fungicide, phosphorous-based fertilizers, and pesticides, especially in condensed areas. Copper has historically been found in high levels in manure, which can be concentrated in CAFOs (Hopkins and Ellsworth 2005). One active NPDES facility, To-Ricos, LTD (Las Piedras Feed Mill, NPDES permit ID: PRR053262) is located near Río Valenciano (PRER14G2). The permit discharge monitoring record (DMR) from EPA's Permit Compliance System for this facility includes copper but does not contain a discharge limit, and there is no record of effluent flows. Therefore, no existing load or TMDL WLA will be established for PRR053262. Other AFO's are incorporated in this TMDL through land-use modeling and assumptions for background concentrations of copper.

### 2.2.2 NPDES Permits

Municipal point sources, including wastewater treatment plants (WWTP) are permitted to discharge effluent to receiving waters under the NPDES program. Four listed assessment units including Río de

La Plata, Río Turabo, Río Grande de Añasco, and Río Culebrinas include municipal point sources possibly discharging pollutant(s) of concern to receiving waters. Industrial point sources are listed for all but one waterbody as possible source of copper, lead, and mercury. Lead has many different industrial applications, such as the production of lead-acid batteries, ammunitions, and other metal products (solder and pipes).

In recent years, industrial use of lead from paints and ceramic products has been significantly reduced, though there are still various legacy sources of these metals that exist. Copper may be produced at an industrial scale for batteries (as an electrolyte or ingredient in alkaline batteries), plumbing pipe, radiators, industrial catalysts and electrodes, coins, etc. Copper has also been used in marine antifouling coatings for boats and piers (Clean Estuary Partnership 2014). Mercury is utilized in the electrical industry (switches, thermostats), dentistry, and other industrial processes for antifungal agents, solvents, and preservatives. The industrial demand for mercury, and other metals however, has declined because of federal bans on metal additives in paints and pesticides. Watersheds with large-scale commercial and industrial operations present greater likelihood of contamination related to industrial point sources. Río Bayamón to Río Hondo, Río de Loíza, and Río Culebrinas contain higher percentages of developed land than other watersheds and are therefore at greater risk of contamination due to industry.

Detailed discharge monitoring records (DMR) were obtained for all facilities, where available, using the USEPA PCS-ICIS (Permit Compliance System and Integrated Compliance Information System databases) reporting system. Details on each NPDES permit in the watershed are included in the allocation discussion provided in **Section 3.2**.

### 2.2.3 Municipal Separated Sewer Systems (MS4)

Forty-two (42) municipalities operate regulated MS4s in assessment units included in this TMDL. These municipalities, associated permit IDs, and percent urban area are summarized in **Table 2-3** Table 3-4. The regulated area within each MS4 was determined using municipality and urban area boundaries mapped as part of the 2010 Decennial Census acquired from the US Census Bureau website. Since DMR data are not currently reported for these types of permits, pollutant loadings from these areas were simulated as part of the watershed model (**Section 3**).

Table 2-3. Summary of identified NPDES permitted MS4s by watershed

Assessment Unit	Permit ID	Municipality	Percent of Urban Area
Río de la Plata (PRER10A5)	PRR040047	Cayey	52.4%
	PRR040020	Cidra	25.8%
Río Bayamón (PRER12A1)	PRR040028	Aguas Buenas	13.8%
	PRR040002	Bayamón	22.8%
	PRR040001	Caguas	0.3%
	PRR040033	Catano	0.3%
	PRR040020	Cidra	13.3%
	PRR040058	Comerio	0.0%
	PRR040016	Guaynabo	30.6%
	PRR040036	San Juan	5.4%
	PRR040038	Toa Baja	0.0%

Assessment Unit	Permit ID	Municipality	Percent of Urban Area
Río Grande de Loíza (PRER14A1)	PRR040028	Aguas Buenas	3.5%
	PRR040001	Caguas	21.4%
	PRR040032	Canóvanas	0.5%
	PRR040018	Carolina	6.4%
	PRR040047	Cayey	0.0%
	PRR040020	Cidra	0.9%
	PRR040016	Guaynabo	0.1%
	PRR040017	Gurabo	11.3%
	PRR040014	Humacao	0.0%
	PRR040022	Juncos	8.6%
	PRR040049	Las Piedras	8.0%
	PRR040051	Loíza	0.0%
	PRR040044	Naguabo	0.6%
	PRR040078	Patillas	0.0%
	PRR040036	San Juan	1.2%
	PRR040037	San Lorenzo	12.9%
	PRR040003	Trujillo Alto	7.7%
	PRR040081	Yabucoa	0.0%
Río Grande de Arecibo (PRNR7A1)	PRR040029	Arecibo	7.2%
	PRR040073	Utua	6.3%
Río Grande de Manatí (PRNR8A3)	PRR040056	Barranquitas	34.5%
	PRR040059	Corozal	39.3%
	PRR040024	Naranjito	10.5%
	PRR040068	Orocovis	0.0%
Río Bauta PRNR8C2	PRR040056	Barranquitas	0.0%
	PRR040057	Ciales	2.1%
	PRR040079	Coamo	0.0%
	PRR040046	Morovis	0.0%
	PRR040068	Orocovis	5.9%
	PRR040074	Villalba	0.0%
Río Grande de Añasco (PRWR83A)	PRR040027	Aguada	0.0%
	PRR040040	Añasco	7.1%
	PRR040082	Lares	0.7%
	PRR040083	Las Marias	2.2%
	PRR040043	Mayaguez	5.7%
	PRR040025	Moca	0.0%
	PRR040076	Rincon	0.0%
	PRR040072	San Sebastian	1.7%

Assessment Unit	Permit ID	Municipality	Percent of Urban Area
Río Culebrinas (PRWR95A)	PRR040027	Aguada	15.0%
	PRR040015	Aguadilla	6.9%
	PRR040040	Añasco	0.0%
	PRR040063	Isabela	0.0%
	PRR040082	Lares	0.9%
	PRR040025	Moca	21.2%
	PRR040072	San Sebastian	31.6%

### 3 LOADING CAPACITY – LINKING WATER QUALITY AND POLLUTANT SOURCES

A TMDL establishes the allowable load of a pollutant or other quantifiable parameter based on the relationship between pollutant sources and instream water quality. This document provides the scientific basis for establishing water quality-based controls to reduce pollution from both point and nonpoint sources and to restore and maintain the quality of the state's water resources (USEPA 1991). An important first step in the development of a TMDL is the calculation of the loading capacity for impaired waters identified on the 303(d) list. The loading capacity is defined as the greatest amount of loading that a waterbody can receive without violating WQS. The loading capacity ultimately provides a reference point that informs the pollutant reduction efforts needed to comply with WQS. The loading capacity must consider the WQS for Puerto Rico receiving waters for each pollutant listed as presented in **Section 2**. The remainder of this section outlines the approach utilized to calculate the loading capacities for each pollutant included on the 303(d) list.

#### 3.1 Nonpoint Sources

Comprehensive, regional scale monitoring of nonpoint source runoff was, and is, not typically available for nonpoint sources with the spatial accuracy and temporal density as is available for point sources. Therefore, nonpoint source loads from the watershed were estimated using a continuous simulation watershed model of upland loading and transport of both sediment and metals to develop estimates of relative pollutant load by source. These estimates ultimately supported the development of both TMDL load allocations (LA) and land-based implementation strategies. The hydrologic and water quality model applied for this TMDL was the Loading Simulation Program in C++ (LSPC), a watershed modeling system that is built upon several Hydrologic Simulation Program–FORTRAN (HSPF) algorithms for simulating watershed hydrology, erosion, water quality processes, and in-stream fate and transport processes. Annual average estimates of current condition loads are presented by model subwatershed in **Table 3-1**. More detailed discussion of the watershed model development process is presented in **Appendix C**.

Table 3-1. Simulated average annual total copper load (pounds / year)

Assessment Unit	Agriculture	Pasture	Urban (unregulated)	Forest and Background	Total NPS
<b>Río de la Plata Watershed</b>					
PRER10A5	0.00	46.91	101.52	307.29	455.72
<b>Río Bayamón to Río Hondo Watershed</b>					
PRER12A1	2.80	95.06	87.11	143.97	328.95
PRER12B1	0.00	0.00	264.79	8.67	273.46
<b>Río Grande de Loíza Watershed</b>					
PRER14A1	13.05	820.31	373.36	842.19	2,048.91
PRER14G1	13.05	603.84	557.97	214.74	1,389.59
PRER14G2	3.27	119.17	240.66	80.33	443.42
PRER14J	0.00	30.99	262.51	140.38	433.87
<b>Río Grande de Arecibo Watershed</b>					
PRNR7A1	84.13	96.93	413.62	866.26	1,460.93

Assessment Unit	Agriculture	Pasture	Urban (unregulated)	Forest and Background	Total NPS
PRNR7A2	0.00	2.41	144.95	347.86	495.22
<b>Río Grande de Manatí Watershed</b>					
PRNR8A3	0.00	0.00	5.36	87.70	93.06
PRNR8C2	0.00	0.00	20.17	161.29	181.46
<b>Río Grande de Añasco Watershed</b>					
PRWR83A	112.97	38.74	324.19	930.07	1,405.98
<b>Río Culebrinas Watershed</b>					
PRWR95A	40.55	152.12	229.30	572.68	994.65
Total	269.82	2,006.47	3,025.50	4,703.44	10,005.23

Table 3-2. Simulated average annual total lead load (pounds / year)

Assessment Unit	Agriculture	Pasture	Urban (unregulated)	Forest and Background	Total NPS
<b>Río de la Plata Watershed</b>					
PRER10A5	0.00	13.88	11.76	76.74	102.38
<b>Río Bayamón to Río Hondo Watershed</b>					
PRER12B1	0.00	0.66	36.04	1.34	38.04
<b>Río Grande de Loíza Watershed</b>					
PRER14G2	0.96	34.93	29.33	16.65	81.87
<b>Río Grande de Arecibo Watershed</b>					
PRNR7A2	0.00	0.69	16.93	66.81	84.43
Total	0.96	50.16	94.06	161.54	306.72

### 3.2 NPDES Permits

Based on the inventory presented in **Section 2.2.2**, seventy-six (76) active NPDES permits were identified as discharging to, or upstream of, listed assessment units with records available to include in the analysis. DMRs were obtained from USEPA's PCS-ICIS reporting system for each identified municipal point source which contained monthly records of flow and pollutant concentration by permit. **Table 3-3** presents a summary of the average annual flow and pollutant loads (2008-2016) for each identified municipal discharger derived from the available DMR data. The reported permit limit value was used when no DMR data was available. For the purposes of assessing TMDL allocations, the current permit limits will be used.

Table 3-3. Inventory of identified active NPDES permits by watershed and assessment unit

Watershed	Assessment Unit	Location <sup>1</sup>	Type <sup>2</sup>	NPDES ID	Facility Name	Flow (MGD) <sup>3</sup>	Cu (ug/L) <sup>3</sup>	Pb (ug/L) <sup>3</sup>	Hg (ug/L) <sup>3</sup>
Río Culebrinas	PRWR95A	L	M	PR0026557	PRASA - CULEBRINAS WTP	0.753	23.93	8.09	0.017
	PRWR95A	L	M	PR0024015	PRASA - RAMEY FILTER PLT	0.044	75.66	12.25	0.010
	PRWR95A	L	M	PR0022926	PRASA PERCHAS WTP	0.011	54.46	1.45	0.010
	PRWR95A	L	M	PR0023981	SAN SEBASTIÁN FILTRATION PLANT	0.506	49.79	4.83	0.010
	PRWR95A	L	M	PR0020851	SAN SEBASTIAN STP	0.571	8.35	1.32	0.077
	PRWR95A	L	M	PRR053037	SAN SEBASTIAN WWTP	0.027	16.74	2.32	0.010
	PRWR95K	U	M	PR0024317	HOYAMALA WARD SECONDARY SCHOOL	0.006	13.70	2.99	0.010
Río de Bayamón	PREL12A2	U	M	PR0022543	CIDRA FILTRATION PLANT	0.555	20.73	3.15	0.005
	PRER12A2	U	M	PR0022896	PRASA WTP AGUAS BUENAS	0.139	28.56	2.32	0.000
Río de la Plata	PRER10A5	L	I	PRR053112	CC PALLET'S INC	0.027	0.00	2.32	0.010
	PRER10A5	L	I	PRR053114	COCA COLA PUERTO RICO BOTTLERS	0.027	0.03	2.32	0.010
	PRER10A5	L	M	PR0026077	PRASA - CAYEY WTP	0.526	13.30	1.44	0.018
	PRER10A5	L	M	PR0023779	PRASA - JARDINES EL TORITO WWTP	0.424	1.84	0.22	0.000
	PRER10A5	L	M	PR0022519	PRASA WTP CAYEY FILTER PLANT	0.093	23.47	2.94	0.010
	PREL210A5	U	M	PR0022586	PRASA GUAMANI WTP	0.004	4.00	1.10	0.010
Río Grande de Añasco	PRWR83A	L	M	PR0026701	ESPIÑO LARES 4.0 MGD FILTRATION PLANT	0.192	17.97	2.31	0.006
	PRWR83A	L	M	PR0022942	PRASA ANASCO WTP	0.362	85.30	8.99	0.010
	PRWL83H	U	M	PR0024333	CASA CASTANER INC	0.004	7.73	2.62	0.010
	PRWR83G	U	M	PR0026883	PRASA - BUCARABONES WTP	0.025	9.45	1.41	0.039
	PRWR83H	U	M	PR0026191	PRASA - GUILARTE WTP	0.035	5.30	1.86	0.010
	PRWR83I	U	M	PR0025194	PRASA GUAYO (INDIERA ALTA) WTP	0.068	6.11	0.79	0.006
	PRWR83E	U	M	PR0020583	PRASA LAS MARIAS	0.147	16.50	1.03	1.031
	PRWR83I	U	M	PR0025411	PRASA RIO PRIETO YAUCO FILTER	0.060	16.52	1.60	0.056

Watershed	Assessment Unit	Location <sup>1</sup>	Type <sup>2</sup>	NPDES ID	Facility Name	Flow (MGD) <sup>3</sup>	Cu (ug/L) <sup>3</sup>	Pb (ug/L) <sup>3</sup>	Hg (ug/L) <sup>3</sup>
	PRWL83H	U	M	PR0026450	PRASA WTP LARES	0.337	33.21	5.98	0.020
	PRWR83F	U	M	PR0022951	PRASA WTP LAS MARIAS	0.021	27.97	2.41	0.010
	PRWR83G	U	M	PR0022934	PRASA WTP MONTE DEL ESTADO	0.018	15.94	1.52	0.041
	PRWR83H	U	M	PR0026948	PRASA YAHUECAS WTP	0.098	7.43	1.22	0.009
Río Grande de Arecibo	PRNR7A2	L	M	PR0026255	PRASA - SABANA GRANDE WARD WTP	0.026	23.71	4.11	0.091
	PRNR7A2	L	M	PR0026603	PRASA UTUADO NEW WWTP	1.026	9.00	1.02	0.029
	PRNR7A2	L	M	PR0026271	PRASA WTP RONCADOR	0.114	21.18	0.34	0.006
	PRNR7A2	L	M	PR0024155	PRASA WTP UTUADO	0.220	89.18	2.60	0.010
	PRNR7A1	L	I	PR0026123	THAMES-DICK SUPERAQUEDUCT	19.059	16.74	2.32	0.010
	PRNR7A2	L	M	PR0020915	UTUADO WASTEWATER TREATMENT PLANT	0.856	8.35	1.32	0.004
	PRNR7A3	U	M	PR0020214	ADJUNTAS WASTEWATER TREATMENT PLANT	0.563	9.56	2.32	0.010
	PRNR7B1	U	M	PR0024210	ARECIBO URBANO (PRASA)	0.312	49.58	3.51	0.010
	PRNR7C1	U	I	PRR053208	BAXTER HEALTHCARE OF PUERTO RICO, INC.	0.027	9.00	0.05	0.010
	PRNR7B1	U	M	PR0024821	CAMPAMENTO CROZIER-RES FOREST	0.005	11.00	3.10	0.010
	PRNR7A3	U	M	PR0025739	PRASA - ADJUNTAS NUEVA WTP	0.012	6.14	2.32	0.010
	PRNR7C1	U	M	PR0026867	PRASA CANALIZO WTP	0.110	5.21	0.51	0.006
	PRNR7C1	U	M	PR0024121	PRASA JAYUYA URBANO	0.580	18.40	2.61	0.018
	PRNR7C2	U	M	PR0025208	PRASA MAMEYES ABAJO WTP	0.058	26.29	1.60	0.010
	PRNR7C2	U	M	PR0025224	PRASA MAMEYES ARRIBA WTP	0.036	28.52	1.78	0.006
	PRNL1-7A1	U	M	PR0025534	PRASA RIO ARRIBA WTP	0.033	43.29	2.04	0.005
	PRNR7B2	U	M	PR0022713	PRASA TANAMA WTP	0.003	21.32	3.16	0.097
	PRNR7A3	U	M	PR0022691	PRASA WTP ADJUNTAS	0.014	38.19	3.61	0.043
	PRNR7C2	U	M	PR0023132	SECOND UNIT MAMEYES SCHOOL	0.007	10.08	2.32	0.010

Watershed	Assessment Unit	Location <sup>1</sup>	Type <sup>2</sup>	NPDES ID	Facility Name	Flow (MGD) <sup>3</sup>	Cu (ug/L) <sup>3</sup>	Pb (ug/L) <sup>3</sup>	Hg (ug/L) <sup>3</sup>
	PRNL1-7A1	U	M	PRR053033	UTUADO WWTP	0.027	16.74	2.32	0.010
Río Grande de Loíza	PRER14G1	L	I	PR0026695	AMGEN MANUFACTURING LIMITED	0.800	19.00	8.00	0.010
	PRER14G1	L	I	PRR053017	AMGEN MANUFACTURING, INC	0.027	0.04	2.32	0.010
	PRER14J	L	M	PR0022888	CAGUAS (PRASA)	0.139	20.53	2.57	0.016
	PRER14A1	L	I	PRR053172	CANTERA CARRAIZO INC	0.027	16.74	2.32	0.010
	PRER14G2	L	M	PR0025119	CEIBA SUR-JUNCOS FILTRATION PLANT	0.081	45.18	3.94	0.002
	PRER14G2	L	I	PRR053115	CENTURY PACKING CORP	0.027	0.01	2.32	0.010
	PRER14A1	L	I	PRR053069	EATON CORPORATION	0.027	16.74	2.32	0.010
	PRER14A2	L	I	PRR053269	IFCO GURABO	0.027	15.60	0.10	0.010
	PRER14A1	L	I	PRR053073	LILLY DEL CARIBE INC. PR01	0.027	0.03	2.32	0.010
	PRER14A1	L	I	PRR053074	LILLY DEL CARIBE INC. PR05	0.027	0.02	2.32	0.010
	PRER14G1	L	I	PRR053192	MEDTRONIC PUERTO RICO OPERATION COMPANY	0.027	16.74	2.32	0.010
	PRER14G1	L	M	PR0026743	PRASA GURABO WTP	0.178	280.41	3.82	0.010
	PRER14A2	L	M	PR0025470	PRASA JAGUAL WTP	0.031	49.97	2.02	0.009
	PRER14J	L	M	PR0025101	PRASA PARCELAS BORINQUEN WWTP	0.280	7.01	0.53	0.000
	PRER14J	L	M	PR0026018	PRASA SAN SALVADOR WTP	0.032	62.73	6.47	0.047
	PRER14K	L	M	PR0022870	PRASA WTP SAN LORENZO	0.191	16.20	1.19	0.011
	PRER14A1	L	I	PRR053016	PROFESSIONAL READY MIX, INC.	0.027	16.74	2.32	0.010
	PRER14G2	L	M	PR0024309	SECOND UNIT RIVERA MOLINA SCH	0.014	23.03	2.62	0.014
	PRER14A2	L	I	PRR053134	STAR READY MIX INC.	0.027	16.74	2.32	0.010
	PRER14G1	L	I	PRR053132	WAREHOUSEHOLDING & MANAGEMENT CORP.	0.027	0.01	2.32	0.010
	PRER14H	U	I	PRR053270	IFCO CAGUAS INC.	0.027	15.60	0.10	0.010
	PREQ14E	U	M	PR0025577	LA GLORIA WARD SCHOOL	0.005	16.72	2.32	0.010
PREQ14D	U	M	PR0026719	PLANTA FILTRACION TRUJILLO BAJO	0.072	5.54	2.32	0.005	

Watershed	Assessment Unit	Location <sup>1</sup>	Type <sup>2</sup>	NPDES ID	Facility Name	Flow (MGD) <sup>3</sup>	Cu (ug/L) <sup>3</sup>	Pb (ug/L) <sup>3</sup>	Hg (ug/L) <sup>3</sup>
	PRER14H	U	I	PRR053128	SCHNITZER PUERTO RICO, INC. - CAGUAS	<i>0.027</i>	22.10	0.15	<i>0.010</i>
	PRER14L	U	M	PR0024287	SECONDARY SCHOOL ESPINO WARD	0.116	21.76	2.32	0.011
Río Grande de Manatí	PRNR8A3	L	M	PR0022497	PRASA BARANQUITAS WTP	0.036	42.56	3.01	0.019
	PRNR8A3	L	M	PR0022501	PRASA BARRANCAS WTP	0.222	16.74	1.71	<i>0.010</i>
	PRNR8A3	L	M	PR0024422	PRASA NEGROS	0.345	62.70	3.90	0.049
	PRNR8A3	L	M	PR0023124	S.U. LAJITAS WARD SCHOOL	0.015	9.67	3.17	0.012

1. L = Within a listed assessment unit; U = Upstream of a listed assessment unit

2. M = Municipal; I = Industrial

3. Values in *italics* indicated missing data. The median of all available facilities was used as an estimate.

### 3.3 Municipal Separated Sewer Systems (MS4)

Forty-two (42) municipalities operate regulated MS4s with a portion of the assessment units included in this TMDL as summarized in **Table 3-4**. A geographical information system (GIS) coverage of urban areas from the 2000 Census was used to separate the urban areas into MS4 and non-MS4 urban areas based on the percentage of each MS4 area when compared to the total urban area within the assessment unit.

The TMDLs in **Section 4** will assign each permittee an individual WLA. Since pollutant contributions from urban areas were estimated using the LSPC watershed model (**Section 3.1**), the WLAs assigned to each MS4 permittee were assigned proportional to the total urban load within the given assessment unit.

Table 3-4. Summary of identified NPDES permitted MS4s by watershed

Assessment Unit	Permit ID	Municipality	Percent of Urban Area	Total Copper (pounds / year)	Total Lead (pounds / year)
Río de la Plata (PRER10A5)	PRR040047	Cayey	52.4%	532.7707	99.2213
	PRR040020	Cidra	25.8%	261.9436	48.7834
Río Bayamón (PRER12A1)	PRR040028	Aguas Buenas	13.8%	165.4965	
	PRR040002	Bayamón	22.8%	273.7815	
	PRR040001	Caguas	0.3%	3.3410	
	PRR040033	Catano	0.3%	3.0509	
	PRR040020	Cidra	13.3%	159.0386	
	PRR040058	Comerio	0.0%	0.4508	
	PRR040016	Guaynabo	30.6%	367.2186	
	PRR040036	San Juan	5.4%	64.4291	
	PRR040038	Toa Baja	0.0%	0.3996	
Río Grande de Loíza (PRER14A1)	PRR040028	Aguas Buenas	3.5%	178.0310	
	PRR040001	Caguas	21.4%	1075.1855	
	PRR040032	Canóvanas	0.5%	22.6533	
	PRR040018	Carolina	6.4%	322.8184	
	PRR040047	Cayey	0.0%	0.3986	
	PRR040020	Cidra	0.9%	47.3479	
	PRR040016	Guaynabo	0.1%	4.8632	
	PRR040017	Gurabo	11.3%	566.2452	
	PRR040014	Humacao	0.0%	1.0623	
	PRR040022	Juncos	8.6%	434.7700	
	PRR040049	Las Piedras	8.0%	402.9962	
	PRR040051	Loíza	0.0%	0.0001	
	PRR040044	Naguabo	0.6%	29.2577	
	PRR040078	Patillas	0.0%	0.0080	
PRR040036	San Juan	1.2%	61.4510		

Assessment Unit	Permit ID	Municipality	Percent of Urban Area	Total Copper (pounds / year)	Total Lead (pounds / year)
	PRR040037	San Lorenzo	12.9%	648.5067	
	PRR040003	Trujillo Alto	7.7%	385.6214	
	PRR040081	Yabucoa	0.0%	0.1246	
Río Grande de Arecibo (PRNR7A1)	PRR040029	Arecibo	7.2%	60.8795	
	PRR040073	Utua	6.3%	52.9428	
Río Grande de Manatí (PRNR8A3)	PRR040056	Barranquitas	34.5%	35.0047	
	PRR040059	Corozal	39.3%	39.9518	
	PRR040024	Naranjito	10.5%	10.6541	
	PRR040068	Orocovis	0.0%	0.0000	
Río Bauta PRNR8C2	PRR040056	Barranquitas	0.0%	0.0003	
	PRR040057	Ciales	2.1%	1.9611	
	PRR040079	Coamo	0.0%	0.0070	
	PRR040046	Morovis	0.0%	0.0025	
	PRR040068	Orocovis	5.9%	5.6652	
	PRR040074	Villalba	0.0%	0.0029	
Río Grande de Añasco (PRWR83A)	PRR040027	Aguada	0.0%	0.0352	0.0065
	PRR040040	Añasco	7.1%	49.3087	9.0742
	PRR040082	Lares	0.7%	4.5222	0.8322
	PRR040083	Las Marias	2.2%	15.4975	2.8520
	PRR040043	Mayaguez	5.7%	39.6543	7.2976
	PRR040025	Moca	0.0%	0.0925	0.0170
	PRR040076	Rincon	0.0%	0.0058	0.0011
	PRR040072	San Sebastian	1.7%	12.1131	2.2292
Río Culebrinas (PRWR95A)	PRR040027	Aguada	15.0%	292.0789	53.8866
	PRR040015	Aguadilla	6.9%	134.2920	24.7760
	PRR040040	Añasco	0.0%	0.3145	0.0580
	PRR040063	Isabela	0.0%	0.4471	0.0825
	PRR040082	Lares	0.9%	18.0961	3.3386
	PRR040025	Moca	21.2%	413.2326	76.2387
	PRR040072	San Sebastian	31.6%	616.4649	113.7337

Grey shading indicates that the given pollutant is not listed for that waterbody

## 4 TMDL CALCULATIONS & ALLOCATIONS

A TMDL for a given waterbody and pollutant includes three fundamental components: (1) a wasteload allocation (WLA) for each point source contributing to the waterbody, (2) a load allocation (LA) for the sum of all nonpoint sources (including ambient sources) contributing to the waterbody, and (3) a margin of safety (MOS) that accounts for uncertainty in the waterbody's response to the application of the point source and nonpoint source loads. The basic TMDL equation, whether developed directly through a pollutant or through surrogate indicators, is commonly expressed using these three fundamental components as:

$$TMDL = WLA + LA + MOS$$

TMDLs are also often described as the total mass of a pollutant that a waterbody can assimilate and still maintain its designated uses as expressed via a TMDL target, and frequently related directly to a numeric WQS. In determining the three components of a TMDL, the total allowable pollutant loadings from each source category (or individual source where applicable) contributing to the waterbody must be less than or equal to the TMDL target. In accordance with 40 CFR 130.2(1), TMDLs may be expressed in terms of allowable mass loadings or in terms water quality concentrations that may not be exceeded. The following sections describe the calculated TMDLs for Puerto Rico.

Numeric targets identify the specific water column, sediment, and/or tissue goals or endpoints for the TMDL that equate to attainment of the narrative and/or numeric WQS. Impairments included on the 303(d) list for the Puerto Rico waterbodies include several different pollutants, all associated with water column criteria. Since all waterbodies fall within the *SD* classification, a single set of pollutant-specific WQS will be used throughout this document for all TMDLs. All TMDL efforts will focus on load reductions that lead to attainment of these WQS and the TMDL IP efforts will identify and prioritize efforts that lead to restoration of water quality to WQS.

The TMDLs presented in the following sections are based on copper and lead watershed-scale loadings. To further demonstrate and link the modeled concentrations and loadings to numeric WQS, concentration duration curves (CDC) were developed for several representative assessment units (**Figure 4-1** and **Figure 4-2**).

Based on the analysis of available mercury data that indicated a single exceedance and the lack of any evidence pointing to specific sources, no existing load, loading capacity, or load allocations were developed for mercury. Please refer to **Section 1.5.3** for a summary of available mercury data and **Section 4.2** for a description of the rationale for not developing load estimate in the watershed where the single exceedance was observed.



Figure 4-1. Demonstration of Copper WQS Attainment for Río Grande de Loíza (PRER14A1)

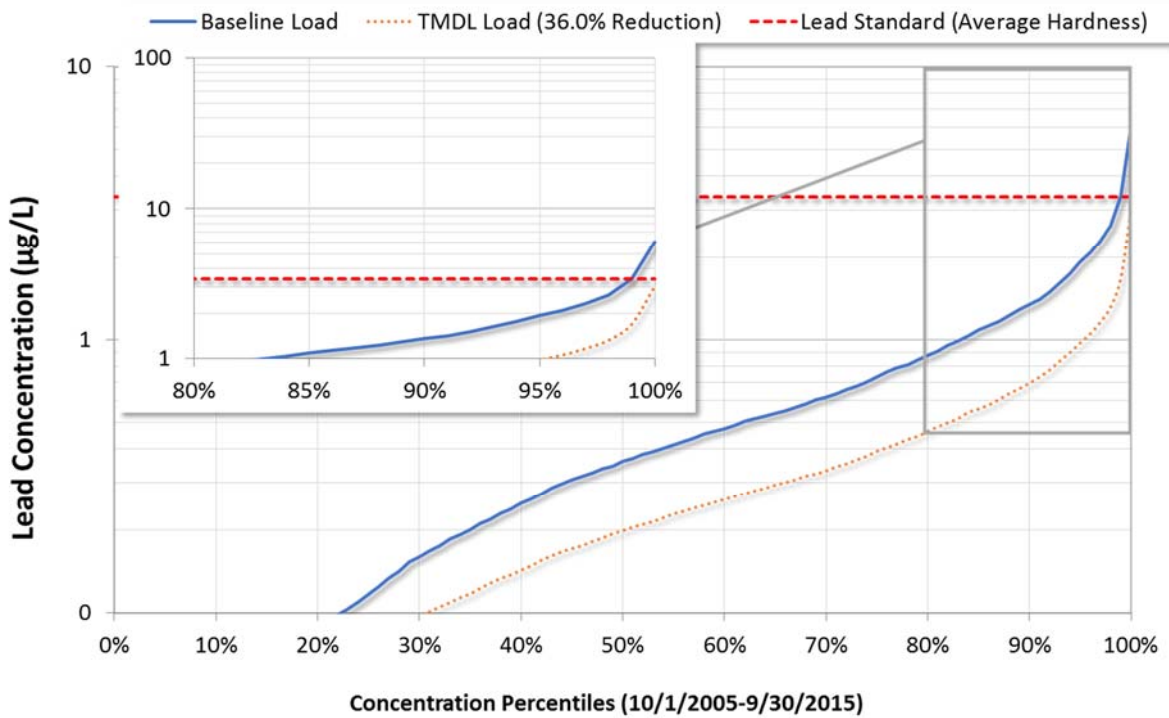


Figure 4-2. Demonstration of Lead WQS Attainment for Río Valenciano (PRER14G2)

## 4.1 Margin of Safety

The margin of safety (MOS) is the portion of a TMDL that accounts for any uncertainty in the relationship between pollutant loading and water quality. This factor is included in the TMDL allocation to account for uncertainties inherent in the analysis because of limitation in the available data, scale of the analysis, and assumptions made during model development. USEPA guidance suggests two approaches to implement an MOS, either (1) implicitly incorporate the MOS by using conservative assumptions to develop allocations; or (2) explicitly designate a portion of the loading capacity as the MOS and use the remainder for allocations (EPA 1999). The TMDLs presented in the following sections incorporate an explicit 5% MOS, which was applied to the WQS, in conjunction with conservative assumptions in the watershed model which included:

- Instream losses in the LSPC model were set conservatively for both copper and lead to minimize the impacts of transport loss. Instream loss of particulate metals would likely occur through sorption to and settling with sediment. Instream sediment transport process were not simulated in detail.
- The time-period used for loading capacity analysis (WY 2006 through WY 2015) included a range of flow regimes and weather conditions, including rainfall from several hurricanes. The TMDL calculation therefore includes achieving the maximum exceedance during this timeframe.

## 4.2 Río de La Plata (PRER10A5)

Total copper and total lead TMDLs and allocations for the Río de La Plata (PRER10A5) assessment unit are presented in **Table 4-1**, and **Table 4-2**, respectively. TMDLs were calculated using loading predictions and reductions applied in the LSPC model (**Section 3.1** and **Appendix C**). The TMDLs and allocations are expressed as daily loads, calculated as the mean of annual loads from the watershed model divided by 365.25 (the average number of days in a year).

Analysis of total mercury sampling data for the Río de La Plata (PRER10A5) assessment unit presented in **Section 1.5.3** demonstrated that only a single mercury sample taken in the previous 10 years contained an exceedance when compared against the WQS of 0.5 µg /L. The remaining 8 samples showed mercury levels well below the WQS, and in some cases below the detection limit. Additional analysis presented in **Table 1-8** of the listed assessment units included in this TMDL show that the median and 75<sup>th</sup> percentile of mercury samples fall well below the WQS for all assessment units. Similarly, the 90<sup>th</sup> percentile mercury samples also fall below the WQS in all by one assessment unit. Furthermore, no municipal or industrial permit DMR data show any exceedance occurring coincident with the measured exceedance in Río de la Plata (PRER10A5). Based on review of this available monitoring data, **no allocation is being developed for mercury**.

Table 4-1. Río de La Plata (PRER10A5) Copper TMDL = WLA + LA+MOS

Load Type	Source	Copper (pounds / day)		
		Current Load	TMDL	Percent Reduction
Total Load		2.3268	1.1209	51.8%
MOS		0.0000	0.0560	0.0%
LA	Agriculture	0.0000	0.0000	0.0%
	Pasture	0.1284	0.0128	90.0%

Load Type	Source	Copper (pounds / day)		
		Current Load	TMDL	Percent Reduction
	Forest & Background	0.8413	0.8413	0.0%
	Landfills	0.0000	0.0000	0.0%
	RCRA Sites	0.0000	0.0000	0.0%
	Superfund Sites	0.0000	0.0000	0.0%
	Urban (Unregulated)	0.2779	0.0278	90.0%
WLA	MS4 Cayey (PRR040047)	0.6676	0.0668	90.0%
	MS4 Cidra (PRR040020)	0.3282	0.0328	90.0%
	CC PALLET'S INC (PRR053112)	0.0000	0.0000	0.0%
	COCA COLA PUERTO RICO BOTTLERS (PRR053114)	0.0000	0.0000	0.0%
	PRASA - CAYEY WTP (PR0026077)	0.0584	0.0584	0.0%
	PRASA - JARDINES EL TORITO WWTP (PR0023779)	0.0065	0.0065	0.0%
	PRASA GUAMANI WTP (PR0022586)	0.0001	0.0001	0.0%
	PRASA WTP CAYEY FILTER PLANT (PR0022519)	0.0183	0.0183	0.0%

Table 4-2. Río de La Plata (PRER10A5) Lead TMDL = WLA + LA+MOS

Load Type	Source	Lead (pounds / day)		
		Current Load	TMDL	Percent Reduction
Total Load		0.4062	0.3299	18.8%
MOS		0.0000	0.0165	0.0%
LA	Agriculture	0.0000	0.0000	0.0%
	Pasture	0.0380	0.0190	50.0%
	Forest & Background	0.2101	0.2101	0.0%
	Landfills	0.0000	0.0000	0.0%
	RCRA Sites	0.0000	0.0000	0.0%
	Superfund Sites	0.0000	0.0000	0.0%
	Urban (Unregulated)	0.0322	0.0161	50.0%
WLA	MS4 Cayey (PRR040047)	0.0773	0.0387	50.0%
	MS4 Cidra (PRR040020)	0.0380	0.0190	50.0%
	CC PALLET'S INC (PRR053112)	0.0005	0.0005	0.0%
	COCA COLA PUERTO RICO BOTTLERS (PRR053114)	0.0005	0.0005	0.0%
	PRASA - CAYEY WTP (PR0026077)	0.0063	0.0063	0.0%
	PRASA - JARDINES EL TORITO WWTP (PR0023779)	0.0008	0.0008	0.0%

Load Type	Source	Lead (pounds / day)		
		Current Load	TMDL	Percent Reduction
	PRASA GUAMANI WTP (PR0022586)	0.0000	0.0000	0.0%
	PRASA WTP CAYEY FILTER PLANT (PR0022519)	0.0023	0.0023	0.0%

### 4.3 Río Grande de Manatí (PRNR8A3)

The total copper TMDL and allocation for the Río Grande de Manatí (PRNR8A3) assessment unit is presented in **Table 4-3**. The TMDL was calculated using loading predictions and reductions applied in the LSPC model (**Section 3.1** and **Appendix C**). The TMDL and allocation is expressed as a daily load, calculated as the mean of annual loads in the TMDL Scenario model output divided by 365.25 (the average number of days in a year).

Table 4-3. Río Grande de Manatí (PRNR8A3) Copper TMDL = WLA + LA+MOS

Load Type	Source	Copper (pounds / day)		
		Current Load	TMDL	Percent Reduction
Total Load		0.5590	0.5147	7.9%
MOS		0.0000	0.0257	0.0%
LA	Agriculture	0.0000	0.0000	0.0%
	Pasture	0.0000	0.0000	0.0%
	Forest & Background	0.2401	0.2401	0.0%
	Landfills	0.0000	0.0000	0.0%
	RCRA Sites	0.0000	0.0000	0.0%
	Superfund Sites	0.0000	0.0000	0.0%
	Urban (Unregulated)	0.0147	0.0037	75.0%
WLA	MS4 Barranquitas (PRR040056)	0.0321	0.0080	75.0%
	MS4 Corozal (PRR040059)	0.0367	0.0092	75.0%
	MS4 Naranjito (PRR040024)	0.0098	0.0024	75.0%
	MS4 Orocovis (PRR040068)	0.0000	0.0000	75.0%
	PRASA BARRANQUITAS WTP (PR0022497)	0.0127	0.0127	0.0%
	PRASA BARRANCAS WTP (PR0022501)	0.0310	0.0310	0.0%
	PRASA NEGROS (PR0024422)	0.1807	0.1807	0.0%
	S.U. LAJITAS WARD SCHOOL (PR0023124)	0.0012	0.0012	0.0%

#### 4.4 Río Bauta (PRNR8C2)

The total copper TMDL and allocation for the Río Bauta (PRNR8C2) assessment unit is presented in **Table 4-4**. TMDLs were calculated using loading predictions and reductions applied in the LSPC model (**Section 3.1** and **Appendix C**). The TMDL and allocation is expressed as a daily load, calculated as the mean of annual loads in the TMDL Scenario model output divided by 365.25 (the average number of days in a year).

Table 4-4. Río Bauta (PRNR8C2) Copper TMDL = WLA + LA+MOS

Load Type	Source	Copper (pounds / day)		
		Current Load	TMDL	Percent Reduction
Total Load		0.5016	0.4806	4.2%
MOS		0.0000	0.0240	0.0%
LA	Agriculture	0.0000	0.0000	0.0%
	Pasture	0.0000	0.0000	0.0%
	Forest & Background	0.4416	0.4416	0.0%
	Landfills	0.0000	0.0000	0.0%
	RCRA Sites	0.0000	0.0000	0.0%
	Superfund Sites	0.0000	0.0000	0.0%
	Urban (Unregulated)	0.0552	0.0138	75.0%
WLA	MS4 Barranquitas (PRR040056)	0.0000	0.0000	75.0%
	MS4 Ciales (PRR040057)	0.0012	0.0003	75.0%
	MS4 Coamo (PRR040079)	0.0000	0.0000	75.0%
	MS4 Morovis (PRR040046)	0.0000	0.0000	75.0%
	MS4 Orocovis (PRR040068)	0.0036	0.0009	75.0%
	MS4 Villalba (PRR040074)	0.0000	0.0000	75.0%

#### 4.5 Río Grande de Arecibo (PRNR7A1)

The total copper TMDL and allocation for the Río Grande de Arecibo (PRNR7A1) assessment unit is in

Table 4-5. This TMDL was calculated using loading predictions and reductions applied in the LSPC model (**Section 3.1** and **Appendix C**). The TMDL and allocation is expressed as a daily load, calculated as the mean of annual loads in the TMDL Scenario model output divided by 365.25 (the average number of days in a year).

Table 4-5. Río Grande de Arecibo (PRNR7A1) Copper TMDL = WLA + LA+MOS

Load Type	Source	Copper (pounds / day)		
		Current Load	TMDL	Percent Reduction
Total Load		4.4667	3.5264	21.1%
MOS		0.0000	0.1763	0.0%
LA	Agriculture	0.2303	0.0461	80.0%
	Pasture	0.2654	0.0531	80.0%
	Forest & Background	2.3717	2.3717	0.0%
	Landfills	0.0000	0.0000	0.0%
	RCRA Sites	0.0000	0.0000	0.0%
	Superfund Sites	0.0000	0.0000	0.0%
	Urban (Unregulated)	1.1324	0.5096	55.0%
WLA	MS4 Arecibo (PRR040029)	0.0945	0.0425	55.0%
	MS4 Utuado (PRR040073)	0.0822	0.0370	55.0%
	ARECIBO URBANO (PRASA) (PR0024210)	0.1293	0.1293	0.0%
	BAXTER HEALTHCARE OF PUERTO RICO, INC. (PRR053208)	0.0020	0.0020	0.0%
	CAMPAMENTO CROZIER-RES FOREST (PR0024821)	0.0004	0.0004	0.0%
	PRASA CANALIZO WTP (PR0026867)	0.0048	0.0048	0.0%
	PRASA JAYUYA URBANO (PR0024121)	0.0891	0.0891	0.0%
	PRASA MAMEYES ABAJO WTP (PR0025208)	0.0127	0.0127	0.0%
	PRASA MAMEYES ARRIBA WTP (PR0025224)	0.0085	0.0085	0.0%
	PRASA RIO ARRIBA WTP (PR0025534)	0.0118	0.0118	0.0%
	PRASA TANAMA WTP (PR0022713)	0.0005	0.0005	0.0%
	SECOND UNIT MAMEYES SCHOOL (PR0023132)	0.0006	0.0006	0.0%
	THAMES-DICK SUPERAQUEDUCT (PR0026123)	0.0266	0.0266	0.0%
UTUADO WWTP (PRR053033)	0.0038	0.0038	0.0%	

#### 4.6 Río Grande de Arecibo (PRNR7A2)

The total copper and total lead TMDLs and allocations for the Río Grande de Arecibo (PRNR7A2) assessment unit are presented in

Table 4-6 and Table 4-7, respectively. These TMDLs were calculated using loading predictions and reductions applied in the LSPC model (**Section 3.1** and **Appendix C**). The TMDLs and allocations are expressed as daily loads, calculated as the mean of annual loads from the watershed model divided by 365.25 (the average number of days in a year).

Table 4-6. Río Grande de Arecibo (PRNR7A2) Copper TMDL = WLA + LA+MOS

Load Type	Source	Copper (pounds / day)		
		Current Load	TMDL	Percent Reduction
Total Load		1.7310	1.5868	8.3%
MOS		0.0000	0.0793	0.0%
LA	Agriculture	0.0000	0.0000	0.0%
	Pasture	0.0066	0.0013	80.0%
	Forest & Background	0.9524	0.9524	0.0%
	Landfills	0.0000	0.0000	0.0%
	RCRA Sites	0.0000	0.0000	0.0%
	Superfund Sites	0.0000	0.0000	0.0%
	Urban (Unregulated)	0.3969	0.1786	55.0%
WLA	ADJUNTAS WASTEWATER TREATMENT PLANT (PR0020214)	0.0449	0.0449	0.0%
	PRASA - ADJUNTAS NUEVA WTP (PR0025739)	0.0006	0.0006	0.0%
	PRASA - SABANA GRANDE WARD WTP (PR0026255)	0.0051	0.0051	0.0%
	PRASA UTUADO NEW WWTP (PR0026603)	0.0771	0.0771	0.0%
	PRASA WTP ADJUNTAS (PR0022691)	0.0044	0.0044	0.0%
	PRASA WTP RONCADOR (PR0026271)	0.0201	0.0201	0.0%
	PRASA WTP UTUADO (PR0024155)	0.1634	0.1634	0.0%
	UTUADO WASTEWATER TREATMENT PLANT (PR0020915)	0.0596	0.0596	0.0%

Table 4-7. Río Grande de Arecibo (PRNR7A2) Lead TMDL = WLA + LA+MOS

Load Type	Source	Lead (pounds / day)		
		Current Load	TMDL	Percent Reduction
Total Load		0.2668	0.2656	0.4%
MOS		0.0000	0.0133	0.0%
LA	Agriculture	0.0000	0.0000	0.0%
	Pasture	0.0019	0.0013	30.0%
	Forest & Background	0.1829	0.1829	0.0%
	Landfills	0.0000	0.0000	0.0%
	RCRA Sites	0.0000	0.0000	0.0%
	Superfund Sites	0.0000	0.0000	0.0%
	Urban (Unregulated)	0.0464	0.0324	30.0%
WLA	ADJUNTAS WASTEWATER TREATMENT PLANT (PR0020214)	0.0109	0.0109	0.0%

Load Type	Source	Lead (pounds / day)		
		Current Load	TMDL	Percent Reduction
	PRASA - ADJUNTAS NUEVA WTP (PR0025739)	0.0002	0.0002	0.0%
	PRASA - SABANA GRANDE WARD WTP (PR0026255)	0.0009	0.0009	0.0%
	PRASA UTUADO NEW WWTP (PR0026603)	0.0087	0.0087	0.0%
	PRASA WTP ADJUNTAS (PR0022691)	0.0004	0.0004	0.0%
	PRASA WTP RONCADOR (PR0026271)	0.0003	0.0003	0.0%
	PRASA WTP UTUADO (PR0024155)	0.0048	0.0048	0.0%
	UTUADO WASTEWATER TREATMENT PLANT (PR0020915)	0.0094	0.0094	0.0%

#### 4.7 Río Bayamón (PRER12A1)

The total copper TMDL and allocations for the Río Bayamón (PRER12A1) assessment unit is presented in **Table 4-8**. This TMDL was calculated using loading predictions and reductions applied in the LSPC model (**Section 3.1** and **Appendix C**). The TMDL and allocation is expressed as a daily load, calculated as the mean of annual loads in the TMDL Scenario model output divided by 365.25 (the average number of days in a year).

Table 4-8. Río Bayamón (PRER12A1) Copper TMDL = WLA + LA+MOS

Load Type	Source	Copper (pounds / day)		
		Current Load	TMDL	Percent Reduction
Total Load		2.5488	0.9088	64.3%
MOS		0.0000	0.0454	0.0%
LA	Agriculture	0.0077	0.0015	80.0%
	Pasture	0.2603	0.0521	80.0%
	Forest & Background	0.3942	0.3942	0.0%
	Landfills	0.0000	0.0000	0.0%
	RCRA Sites	0.0000	0.0000	0.0%
	Superfund Sites	0.0000	0.0000	0.0%
	Urban (Unregulated)	0.2385	0.0389	83.7%
WLA	MS4 Aguas Buenas (PRR040028)	0.2424	0.0395	83.7%
	MS4 Bayamon (PRR040002)	0.4010	0.0653	83.7%
	MS4 Caguas (PRR040001)	0.0049	0.0008	83.7%
	MS4 Catano (PRR040033)	0.0045	0.0007	83.7%
	MS4 Cidra (PRR040020)	0.2329	0.0380	83.7%
	MS4 Comerio (PRR040058)	0.0007	0.0001	83.7%
	MS4 Guaynabo (PRR040016)	0.5378	0.0877	83.7%

Load Type	Source	Copper (pounds / day)		
		Current Load	TMDL	Percent Reduction
	MS4 San Juan (PRR040036)	0.0944	0.0154	83.7%
	MS4 Toa Baja (PRR040038)	0.0006	0.0001	83.7%
	CIDRA FILTRATION PLANT (PR0022543)	0.0959	0.0959	0.0%
	PRASA WTP AGUAS BUENAS (PR0022896)	0.0332	0.0332	0.0%

#### 4.8 Río Guaynabo (PRER12B1)

The total copper and total lead TMDLs and allocations for the Río Guaynabo (PRER12B1) assessment unit is presented in **Table 4-9** and **Table 4-10**, respectively. These TMDLs were calculated using loading predictions and reductions applied in the LSPC model (**Section 3.1** and **Appendix C**). The TMDLs and allocations are expressed as daily loads, calculated as the mean of annual loads from the watershed model divided by 365.25 (the average number of days in a year).

Table 4-9. Río Guaynabo (PRER12B1) Copper TMDL = WLA + LA+MOS

Load Type	Source	Copper (pounds / day)		
		Current Load	TMDL	Percent Reduction
Total Load		0.7487	0.1776	76.3%
MOS		0.0000	0.0089	0.0%
LA	Agriculture	0.0000	0.0000	0.0%
	Pasture	0.0000	0.0000	0.0%
	Forest & Background	0.0237	0.0237	0.0%
	Landfills	0.0000	0.0000	0.0%
	RCRA Sites	0.0000	0.0000	0.0%
	Superfund Sites	0.0000	0.0000	0.0%
	Urban (Unregulated)	0.7250	0.1450	80.0%

Table 4-10. Río Guaynabo (PRER12B1) Lead TMDL = WLA + LA+MOS

Load Type	Source	Lead (pounds / day)		
		Current Load	TMDL	Percent Reduction
Total Load		0.1023	0.0506	50.6%
MOS		0.0000	0.0025	0.0%
LA	Agriculture	0.0000	0.0000	0.0%
	Pasture	0.0000	0.0000	0.0%
	Forest & Background	0.0037	0.0037	0.0%

Load Type	Source	Lead (pounds / day)		
		Current Load	TMDL	Percent Reduction
	Landfills	0.0000	0.0000	0.0%
	RCRA Sites	0.0000	0.0000	0.0%
	Superfund Sites	0.0000	0.0000	0.0%
	Urban (Unregulated)	0.0987	0.0444	55.0%

#### 4.9 Río Grande de Loíza (PRER14A1)

The total copper TMDL and allocations for the Río Grande de Loíza (PRER14A1) assessment unit is presented in **Table 4-11**. This TMDL was calculated using loading predictions and reductions applied in the LSPC model (**Section 3.1** and **Appendix C**). The TMDL and allocation is expressed as a daily load, calculated as the mean of annual loads in the TMDL Scenario model output divided by 365.25 (the average number of days in a year).

Table 4-11. Río Grande de Loíza (PRER14A1) Copper TMDL = WLA + LA+MOS

Load Type	Source	Copper (pounds / day)		
		Current Load	TMDL	Percent Reduction
	Total Load	10.7452	3.3455	68.9%
	MOS	0.0000	0.1673	0.0%
LA	Agriculture	0.0357	0.0031	91.3%
	Pasture	2.2459	0.1717	92.4%
	Forest & Background	2.3058	2.3058	0.0%
	Landfills	0.0000	0.0000	0.0%
	RCRA Sites	0.0000	0.0000	0.0%
	Superfund Sites	0.0000	0.0000	0.0%
	Urban (Unregulated)	1.0222	0.1022	90.0%
WLA	MS4 Aguas Buenas (PRR040028)	0.2148	0.0215	90.0%
	MS4 Caguas (PRR040001)	1.2972	0.1297	90.0%
	MS4 Canovanas (PRR040032)	0.0273	0.0027	90.0%
	MS4 Carolina (PRR040018)	0.3895	0.0389	90.0%
	MS4 Cayey (PRR040047)	0.0005	0.0000	90.0%
	MS4 Cidra (PRR040020)	0.0571	0.0057	90.0%
	MS4 Guaynabo (PRR040016)	0.0059	0.0006	90.0%
	MS4 Gurabo (PRR040017)	0.6832	0.0683	90.0%
	MS4 Humacao (PRR040014)	0.0013	0.0001	90.0%
	MS4 Juncos (PRR040022)	0.5245	0.0525	90.0%

Load Type	Source	Copper (pounds / day)		
		Current Load	TMDL	Percent Reduction
	MS4 Las Piedras (PRR040049)	0.4862	0.0486	90.0%
	MS4 Loiza (PRR040051)	0.0000	0.0000	90.0%
	MS4 Naguabo (PRR040044)	0.0353	0.0035	90.0%
	MS4 Patillas (PRR040078)	0.0000	0.0000	90.0%
	MS4 San Juan (PRR040036)	0.0741	0.0074	90.0%
	MS4 San Lorenzo (PRR040037)	0.7824	0.0782	90.0%
	MS4 Trujillo Alto (PRR040003)	0.4652	0.0465	90.0%
	MS4 Yabucoa (PRR040081)	0.0002	0.0000	90.0%
	CANTERA CARRAIZO INC (PRR053172)	0.0038	0.0038	0.0%
	EATON CORPORATION (PRR053069)	0.0038	0.0038	0.0%
	IFCO CAGUAS INC. (PRR053270)	0.0035	0.0035	0.0%
	IFCO GURABO (PRR053269)	0.0035	0.0035	0.0%
	LA GLORIA WARD SCHOOL (PR0025577)	0.0008	0.0008	0.0%
	LILLY DEL CARIBE INC. PR01 (PRR053073)	0.0000	0.0000	0.0%
	LILLY DEL CARIBE INC. PR05 (PRR053074)	0.0000	0.0000	0.0%
	PLANTA FILTRACION TRUJILLO BAJO (PR0026719)	0.0033	0.0033	0.0%
	PRASA JAGUAL WTP (PR0025470)	0.0128	0.0128	0.0%
	PRASA WTP SAN LORENZO (PR0022870)	0.0259	0.0259	0.0%
	PROFESSIONAL READY MIX, INC. (PRR053016)	0.0038	0.0038	0.0%
	SCHNITZER PUERTO RICO, INC. - CAGUAS (PRR053128)	0.0050	0.0050	0.0%
	SECONDARY SCHOOL ESPINO WARD (PR0024287)	0.0210	0.0210	0.0%
	STAR READY MIX INC. (PRR053134)	0.0038	0.0038	0.0%

#### 4.10 Río Gurabo (PRER14G1)

The total copper TMDL and allocation for the Río Gurabo (PRER14G1) assessment unit is presented in

Table 4-12. This TMDL was calculated using loading predictions and reductions applied in the LSPC model (**Section 3.1** and **Appendix C**). The TMDL and allocation is expressed as a daily load, calculated as the mean of annual loads in the TMDL Scenario model output divided by 365.25 (the average number of days in a year).

Table 4-12. Río Gurabo (PRER14G1) Copper TMDL = WLA + LA+MOS

Load Type	Source	Copper (pounds / day)		
		Current Load	TMDL	Percent Reduction
Total Load		4.3514	1.4770	66.1%
MOS		0.0000	0.0739	0.0%
LA	Agriculture	0.0357	0.0031	91.3%
	Pasture	1.6532	0.1125	93.2%
	Forest & Background	0.5879	0.5879	0.0%
	Landfills	0.0000	0.0000	0.0%
	RCRA Sites	0.0000	0.0000	0.0%
	Superfund Sites	0.0000	0.0000	0.0%
	Urban (Unregulated)	1.5276	0.1528	90.0%
WLA	AMGEN MANUFACTURING LIMITED (PR0026695)	0.1268	0.1268	0.0%
	AMGEN MANUFACTURING, INC (PRR053017)	0.0000	0.0000	0.0%
	MEDTRONIC PUERTO RICO OPERATION COMPANY (PRR053192)	0.0038	0.0038	0.0%
	PRASA GURABO WTP (PR0026743)	0.4163	0.4163	0.0%
	WAREHOUSE HOLDING & MANAGEMENT CORP. (PRR053132)	0.0000	0.0000	0.0%

#### 4.11 Río Valenciano (PRER14G2)

The total copper and total lead TMDLs and allocations for the Río Valenciano (PRER14G2) assessment unit are presented in **Table 4-13** and **Table 4-14**, respectively. These TMDLs were calculated using loading predictions and reductions applied in the LSPC model (**Section 3.1** and **Appendix C**). The TMDLs and allocations are expressed as daily loads, calculated as the mean of annual loads from the watershed model divided by 365.25 (the average number of days in a year).

Table 4-13. Río Valenciano (PRER14G2) Copper TMDL = WLA + LA+MOS

Load Type	Source	Copper (pounds / day)		
		Current Load	TMDL	Percent Reduction
Total Load		1.2475	0.3691	70.4%
MOS		0.0000	0.0185	0.0%
LA	Agriculture	0.0089	0.0004	95.0%
	Pasture	0.3263	0.0309	90.5%
	Forest & Background	0.2199	0.2199	0.0%
	Landfills	0.0000	0.0000	0.0%
	RCRA Sites	0.0000	0.0000	0.0%

Load Type	Source	Copper (pounds / day)		
		Current Load	TMDL	Percent Reduction
	Superfund Sites	0.0000	0.0000	0.0%
	Urban (Unregulated)	0.6589	0.0659	90.0%
WLA	CEIBA SUR-JUNCOS FILTRATION PLANT (PR0025119)	0.0307	0.0307	0.0%
	CENTURY PACKING CORP (PRR053115)	0.0000	0.0000	0.0%
	SECOND UNIT RIVERA MOLINA SCH (PR0024309)	0.0028	0.0028	0.0%

Table 4-14. Río Valenciano (PRER14G2) Lead TMDL = WLA + LA+MOS

Load Type	Source	Lead (pounds / day)		
		Current Load	TMDL	Percent Reduction
Total Load		0.2277	0.1457	36.0%
MOS		0.0000	0.0073	0.0%
LA	Agriculture	0.0026	0.0013	50.0%
	Pasture	0.0956	0.0478	50.0%
	Forest & Background	0.0456	0.0456	0.0%
	Landfills	0.0000	0.0000	0.0%
	RCRA Sites	0.0000	0.0000	0.0%
	Superfund Sites	0.0000	0.0000	0.0%
	Urban (Unregulated)	0.0803	0.0401	50.0%
WLA	CEIBA SUR-JUNCOS FILTRATION PLANT (PR0025119)	0.0027	0.0027	0.0%
	CENTURY PACKING CORP (PRR053115)	0.0005	0.0005	0.0%
	SECOND UNIT RIVERA MOLINA SCH (PR0024309)	0.0003	0.0003	0.0%

#### 4.12 Río Turabo (PRER14J)

The total copper TMDL and allocation for the Río Turabo (PRER14J) assessment unit is presented in

Table 4-15. This TMDL was calculated using loading predictions and reductions applied in the LSPC model (**Section 3.1** and **Appendix C**). The TMDL and allocation is expressed as a daily load, calculated as the mean of annual loads in the TMDL Scenario model output divided by 365.25 (the average number of days in a year).

Table 4-15. Río Turabo (PRER14J) Copper TMDL = WLA + LA+MOS

Load Type	Source	Copper (pounds / day)		
		Current Load	TMDL	Percent Reduction
Total Load		1.2449	0.5492	55.9%
MOS		0.0000	0.0275	0.0%
LA	Agriculture	0.0000	0.0000	0.0%
	Pasture	0.0848	0.0085	90.0%
	Forest & Background	0.3843	0.3843	0.0%
	Landfills	0.0000	0.0000	0.0%
	RCRA Sites	0.0000	0.0000	0.0%
	Superfund Sites	0.0000	0.0000	0.0%
	Urban (Unregulated)	0.7187	0.0719	90.0%
WLA	CAGUAS (PRASA) (PR0022888)	0.0239	0.0239	0.0%
	PRASA PARCELAS BORINQUEN WWTP (PR0025101)	0.0164	0.0164	0.0%
	PRASA SAN SALVADOR WTP (PR0026018)	0.0168	0.0168	0.0%

#### 4.13 Río Grande de Añasco (PRWR83A)

The total copper TMDL and allocation for the Río Grande de Añasco (PRWR83A) assessment unit is presented in **Table 4-16**. This TMDL was calculated using loading predictions and reductions applied in the LSPC watershed model (**Section 3.1** and **Appendix C**). The TMDL and allocation is expressed as a daily load, calculated as the mean of annual loads in the TMDL Scenario model output divided by 365.25 (the average number of days in a year).

Table 4-16. Río Grande de Añasco (PRWR83A) Copper TMDL = WLA + LA+MOS

Load Type	Source	Copper (pounds / day)		
		Current Load	TMDL	Percent Reduction
Total Load		4.4664	3.5680	20.1%
MOS		0.0000	0.1784	0.0%
LA	Agriculture	0.3093	0.1083	65.0%
	Pasture	0.1061	0.0371	65.0%
	Forest & Background	2.5464	2.5464	0.0%
	Landfills	0.0000	0.0000	0.0%
	RCRA Sites	0.0000	0.0000	0.0%
	Superfund Sites	0.0000	0.0000	0.0%
	Urban (Unregulated)	0.8876	0.2219	75.0%
WLA	MS4 Aguada (PRR040027)	0.0001	0.0000	75.0%

Load Type	Source	Copper (pounds / day)		
		Current Load	TMDL	Percent Reduction
	MS4 Anasco (PRR040040)	0.0766	0.0191	75.0%
	MS4 Lares (PRR040082)	0.0070	0.0018	75.0%
	MS4 Las Marias (PRR040083)	0.0241	0.0060	75.0%
	MS4 Mayaguez (PRR040043)	0.0616	0.0154	75.0%
	MS4 Moca (PRR040025)	0.0001	0.0000	75.0%
	MS4 Rincon (PRR040076)	0.0000	0.0000	75.0%
	MS4 San Sebastian (PRR040072)	0.0188	0.0047	75.0%
	CASA CASTANER INC (PR0024333)	0.0003	0.0003	0.0%
	ESPINO LARES 4.0 MGD FILTRATION PLANT (PR0026701)	0.0287	0.0287	0.0%
	PRASA - BUCARABONES WTP (PR0026883)	0.0020	0.0020	0.0%
	PRASA - GUILARTE WTP (PR0026191)	0.0015	0.0015	0.0%
	PRASA ANASCO WTP (PR0022942)	0.2575	0.2575	0.0%
	PRASA GUAYO (INDIERA ALTA) WTP (PR0025194)	0.0035	0.0035	0.0%
	PRASA LAS MARIAS (PR0020583)	0.0202	0.0202	0.0%
	PRASA RIO PRIETO YAUCO FILTER (PR0025411)	0.0083	0.0083	0.0%
	PRASA WTP LARES (PR0026450)	0.0934	0.0934	0.0%
	PRASA WTP LAS MARIAS (PR0022951)	0.0050	0.0050	0.0%
	PRASA WTP MONTE DEL ESTADO (PR0022934)	0.0024	0.0024	0.0%
	PRASA YAHUECAS WTP (PR0026948)	0.0061	0.0061	0.0%

#### 4.14 Río Culebrinas (PRWR95A)

The total copper TMDL and allocation for the Río Culebrinas (PRWR95A) assessment unit is presented in **Table 4-17**. This TMDL was calculated using loading predictions and reductions applied in the LSPC watershed model (**Section 3.1** and **Appendix C**). The TMDL and allocation is expressed as a daily load, calculated as the mean of annual loads in the TMDL Scenario model output divided by 365.25 (the average number of days in a year).

Table 4-17. Río Culebrinas (PRWR95A) Copper TMDL = WLA + LA+MOS

Load Type	Source	Copper (pounds / day)		
		Current Load	TMDL	Percent Reduction
	Total Load	5.1146	2.9851	41.6%
	MOS	0.0000	0.1493	0.0%
LA	Agriculture	0.1110	0.0389	65.0%
	Pasture	0.4165	0.1458	65.0%

Load Type	Source	Copper (pounds / day)		
		Current Load	TMDL	Percent Reduction
	Forest & Background	1.5679	1.5679	0.0%
	Landfills	0.0000	0.0000	0.0%
	RCRA Sites	0.0000	0.0000	0.0%
	Superfund Sites	0.0000	0.0000	0.0%
	Urban (Unregulated)	0.6278	0.1569	75.0%
WLA	MS4 Aguada (PRR040027)	0.3868	0.0967	75.0%
	MS4 Aguadilla (PRR040015)	0.1779	0.0445	75.0%
	MS4 Anasco (PRR040040)	0.0004	0.0001	75.0%
	MS4 Isabela (PRR040063)	0.0006	0.0001	75.0%
	MS4 Lares (PRR040082)	0.0240	0.0060	75.0%
	MS4 Moca (PRR040025)	0.5473	0.1368	75.0%
	MS4 San Sebastian (PRR040072)	0.8164	0.2041	75.0%
	HOYAMALA WARD SECONDARY SCHOOL (PR0024317)	0.0007	0.0007	0.0%
	PRASA - CULEBRINAS WTP (PR0026557)	0.1503	0.1503	0.0%
	PRASA - RAMEY FILTER PLT (PR0024015)	0.0278	0.0278	0.0%
	PRASA PERCHAS WTP (PR0022926)	0.0052	0.0052	0.0%
	SAN SEBASTIÁN FILTRATION PLANT (PR0023981)	0.2104	0.2104	0.0%
	SAN SEBASTIAN STP (PR0020851)	0.0398	0.0398	0.0%
	SAN SEBASTIAN WWTP (PRR053037)	0.0038	0.0038	0.0%

## 5 VARIABILITY & UNCERTAINTY

This section presents an analysis of variable conditions that could impact the allocations presented in **Section 4**. Seasonal variation describes conditions that change on the day, month or annual timeframe. The influence of these factors is implicitly incorporated through the watershed modeling presented in **Appendix C**, which was used as the basis for estimating nonpoint source loads. The model incorporates long-term observed data from the historic record which includes observed *variability* in key input parameters. Variability and uncertainty in Puerto Rico describes long-term, systemic shifts in rainfall, temperature, and other climate conditions that would not be reflected in the historic record. Accounting for these trends would require projection of future condition(s) with *uncertainty* as to the direction and magnitude of these trends.

### 5.1 Seasonal Variation

Puerto Rico experiences frequent precipitation events with some rainfall occurring about once every 1-2 days, and rainfall events  $\geq 0.1$  inches typically occurring at least once a week. Most rainfall occurs between August and November coinciding with hurricane season, which runs from June to November, with most frequent occurrences in August and October. Showers, which can be locally heavy, can be expected any time of the year. Most showers have a short duration. Runoff events are infrequent, sudden, and dramatic and are characterized by high flows. **Table 5-1** summarizes these, and other long-term monthly rainfall statistics, for the San Juan International Airport.

Table 5-1. Monthly rainfall statistics at the San Juan International Airport (011641)

WBAN 011641 (October 1, 1980 through September 30, 2016)											
Period	Mean	High		Low		1-Day Maximum		Average No. Rain Days			
		(in.)	Year	(in.)	Year	(in.)	Date	$\geq 0.01$	$\geq 0.10$	$\geq 0.50$	$\geq 1.00$
Jan	3.71	11.1	2010	0.7	1983	3.7	1/7/1998	18	9	2	0
Feb	2.54	6.7	1982	0.2	1983	2.1	2/17/1989	15	6	1	0
Mar	2.15	9.3	2012	0.1	2005	3.1	3/25/2012	13	5	1	0
Apr	4.78	15.0	2005	0.1	1997	7.1	4/15/1988	14	7	2	1
May	6.46	14.6	2013	1.5	2007	4.5	5/13/1986	17	9	4	2
Jun	4.65	13.6	2011	0.2	2012	3.2	6/12/2013	15	8	3	1
Jul	5.55	14.2	2013	1.6	2015	9.2	7/18/2013	19	10	3	1
Aug	6.23	18.6	2011	1.8	1994	5.8	8/22/2011	20	10	4	1
Sep	5.86	15.2	1996	1.7	1987	8.8	9/18/1989	18	10	3	1
Oct	5.39	11.9	2005	1.8	1992	4.0	10/10/2005	18	11	3	1
Nov	6.56	12.2	2009	1.9	1980	3.7	11/4/1992	20	12	4	1
Dec	5.25	16.8	1981	1.0	1997	7.0	12/12/1981	20	11	3	1
<b>Annual</b>	<b>59.1</b>							<b>207</b>	<b>107</b>	<b>33</b>	<b>13</b>

The TMDLs presented in **Section 4** for each of the thirteen Puerto Rico waterbodies were developed based on long-term climate conditions representing the period from 10/1/1990 through 9/30/2016. Seasonal variation has been captured using these long-term representative conditions which inherently capture a range of wet years, dry years, hurricanes, and other seasonal patterns. The use of this long-term data set in simulating watershed processes and selecting a critical condition appropriately captures the seasonal variation observed over the past two decades.

## 5.2 Consideration of Extreme Events

In addition to seasonal variation, it is also important to consider how extreme climatic events could impact the loading of pollutants, the allocations to sources, and implementation planning. Extreme events have impacted Puerto Rico through rising atmospheric temperatures, rising sea level, and more intense tropical storms and hurricanes (USEPA 2016). Hayhoe (2013) conducted a downscaling of global climate models for precipitation and temperature and found that Puerto Rico is expected to warm faster than the global average, rainfall is projected to decrease, particularly in the wet season, with more frequent dry days. The frequency of ‘moderate extreme’ precipitation (e.g., more than 1 inch of rain) is projected to decrease, while more extreme precipitation (e.g., more than 3 inches of rain in a day) is expected to become more common.

**Figure 5-1** presents a 50-year analysis of annual rainfall at the San Juan International Airport showing the 25<sup>th</sup>, 50<sup>th</sup> and 75<sup>th</sup> percentile, 10-year moving averages. The range between the 25<sup>th</sup>, 50<sup>th</sup> and 75<sup>th</sup> percentile moving averages show both increasing and decreasing trends across time, with a somewhat elevated magnitude during the most recent decade. While not conclusive regarding long-term climate change, this analysis depicts a range of potential annual conditions, both wetter and dryer, under which implemented management actions will need to perform.

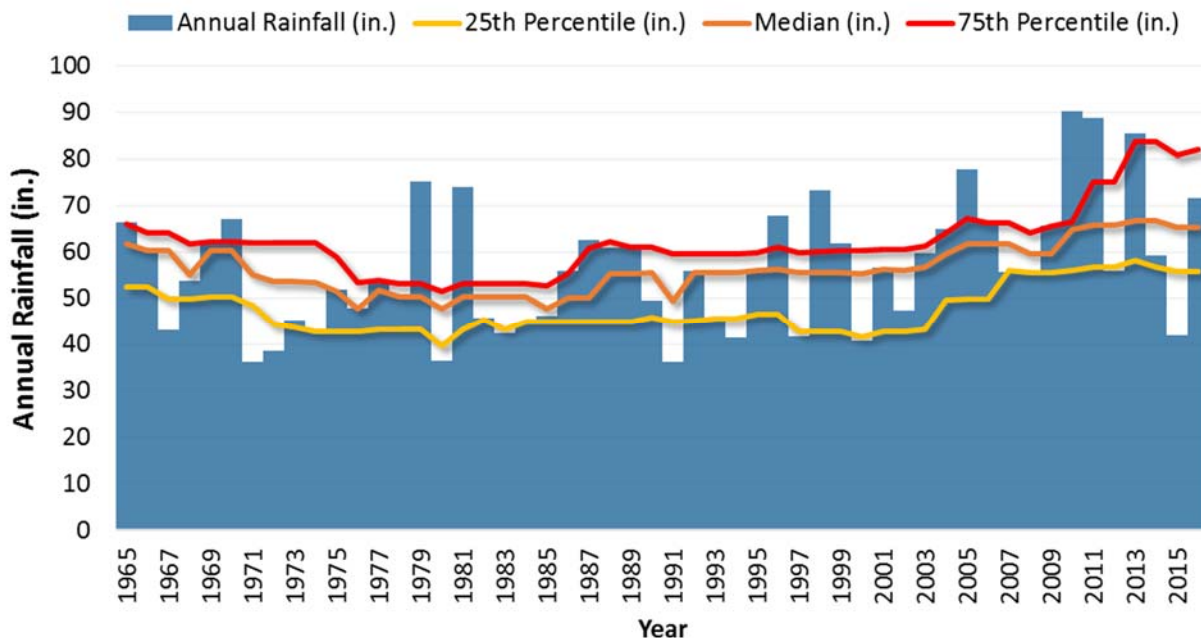


Figure 5-1. Summary of long-term precipitation at the San Juan International Airport.

When conducting this TMDL analysis, no modeling was conducted with future climate projections to determine the impact of possible changes to precipitation and temperature on loadings of copper,

lead, or mercury. However, looking at the variability of historical trends in copper exceedance provides some insight about the resilience of the system under a range of climatological conditions such as rainfall. Copper data sampled between 1981 and 2015 at all gauges were evaluated to assess how percent exceedance varied with average annual rainfall. The goal of that analysis was to identify the nature of observed exceedances occurring for average and extreme years in the historical record. First, the copper data were tallied by water year. Second, the years were binned into 10 groups by average annual rainfall magnitude. Finally, percent exceedance was calculated for each group using samples from years within each of those 10 groups, as presented in **Figure 5-2**. A coarse interpretation of the results suggests that years with near-average rainfall tend to have more exceedances than extremely wet or extremely dry years. There is some intra-year variability that is not fully addressed in this assessment. For example, large rainfall events occurring during an average rainfall year are probably more likely to cause an exceedance. Exceedance frequency will also vary with antecedent instream conditions. Therefore, if drier than average rainfall years prevail in the future (as suggested by Hayhoe, 2013), assessment of historical conditions suggest that higher-than-average exceedance potential occurs. An increase in intense events under drier conditions will also tend to increase exceedance potential.

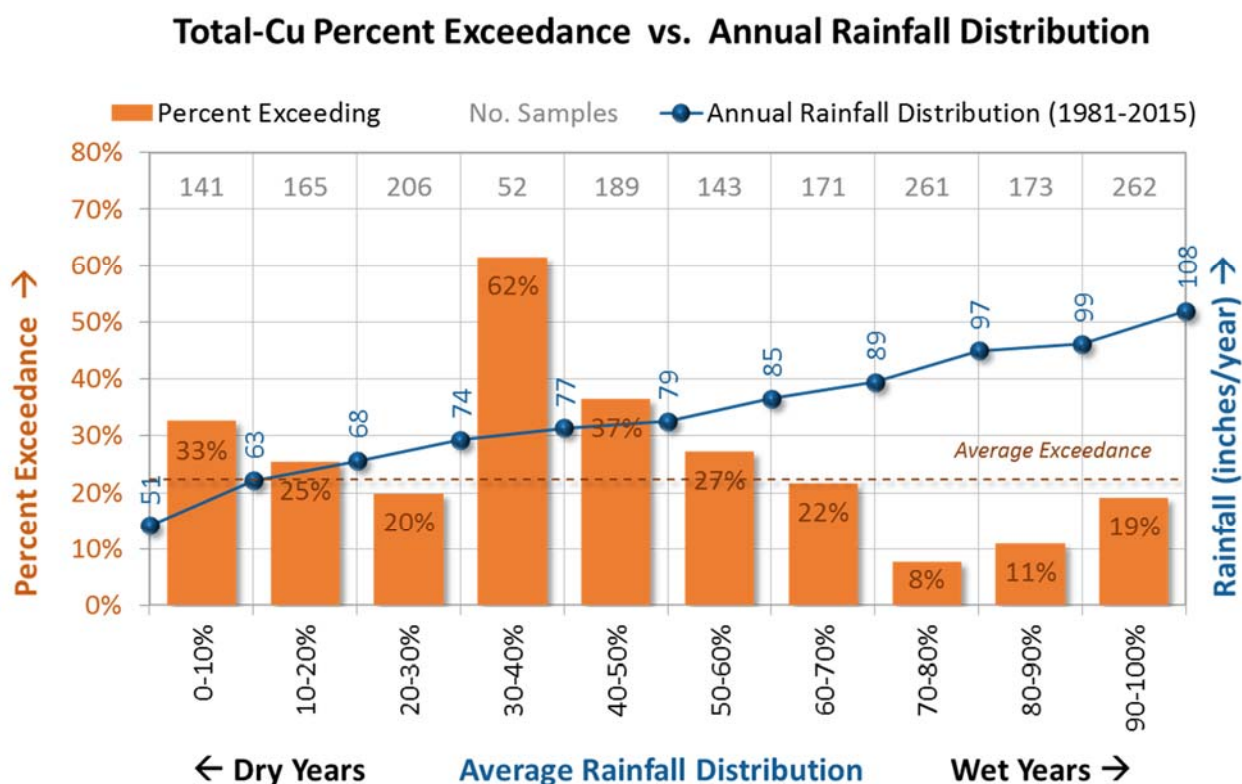


Figure 5-2. Percent exceedance vs. annual rainfall distribution for all copper samples in at all stations between 1981 and 2015.

The implementation strategy discussed in **Section 8** includes measures that will minimize possible heavy metal exceedances due to extreme events in Puerto Rico with the intent of resiliency over a range of climatic and other conditions. Implementation actions include: a focus on stormwater practices that infiltrate water and minimize runoff of sediment and metals (especially with high intensity rainfall events), new agricultural practices to stabilize soils, thereby reducing sedimentation and erosion, and stream corridor policies that return waterbodies to their more natural and stable conditions.

## 6 REASONABLE ASSURANCE

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When a TMDL is developed for waters that are impaired by point sources alone, the issuance of NPDES permits provides the reasonable assurance that the WLA identified in the TMDL will be achieved. The limits provided in the NPDES permits are set at a level protective of water quality. Detailed monitoring requirements assure compliance with the limits and enforcement actions can be taken when out of compliance. When a TMDL is developed that allocates pollutant loads to both point and nonpoint sources, the TMDL should demonstrate reasonable assurance that the LAs will be achieved and the WQS will be attained. The rationale for the reasonable assurance is to ensure that the WLAs and LAs established in the TMDL are not based on unreasonable or unrealistic assumptions regarding the amount of nonpoint source pollutant reductions that will occur. This is necessary because the WLAs for point sources are determined, in part, based on the expected contributions made by nonpoint sources to the total pollutant reductions necessary to achieve WQS. If the reductions embodied in LAs are not fully achieved because of a failure to fully implement needed nonpoint source pollution controls or if the reduction potential of the proposed best management practices (BMPs) was overestimated, the collective reductions from all sources will not result in attainment of WQS. In waters impaired by nonpoint sources alone and where no WLA's are assigned, there is no requirement to demonstrate reasonable assurance as a condition of USEPA approval of the TMDL.

For this TMDL, the allocations were established for both permitted discharges and nonpoint sources. However, the nonpoint source LAs make up most of the pollutant contributions and, therefore, proposed nonpoint source control measures will be critical to meeting WQS.

There is reasonable assurance that the goals of these TMDLs can be met with continued watershed planning efforts like those referenced in this TMDL document (see **Section 8** the Implementation Plan). Watershed planning efforts focus on control of sediments and adherence to Regulation for the Control of Erosion and Prevention of Sedimentation (RCEPS process, including writing of comprehensive permit requirements to reduce sediment loading, routine inspection at multiple planning and pre-construction phases, and willingness to inspect and enforce requirements of the permit.

As a component of this TMDL effort, a program inventory was created to provide information on the types of programs that could be leveraged to provide technical, programmatic, or educational support for watershed protection efforts, including availability of funding. As an example, Section 319 of the Clean Water Act (CWA) can provide funding for the installation of BMPs that prevent or reduce frequent nonpoint source pollution in Puerto Rico. The 319 program is focused on implementation and it has been the source of numerous watershed improvements in Puerto Rico.

## 7 MONITORING PLAN TO TRACK TMDL EFFECTIVENESS

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After recommended management actions have been implemented, TMDL effectiveness monitoring and assessment are conducted to track the effectiveness of TMDL implementation, and to evaluate whether alternative management approaches are needed. This monitoring plan is an essential component of TMDL implementation that serves as a source of feedback for refining and optimizing these management approaches. PREQB ambient water quality monitoring program operates under an agreement with US Geological Survey to sample surface water throughout Puerto Rico. Most states rely on their current ambient monitoring network to evaluate TMDL effectiveness, but this is not always ideal because ambient water quality networks are not typically designed to provide targeted data. Instead, they are often focused on condition assessment and characterizing conditions at a watershed scale. A TMDL effectiveness monitoring plan should build on current water quality monitoring efforts, and include selecting a study design, choosing water quality parameters to monitor, and estimating sample size requirements.

There are various considerations for study designs for TMDL effectiveness monitoring. Trend monitoring involves long-term sampling data, analyzed for trends over time, from samples that are collected from the same location at regular intervals. Before/After samples are collected before and after TMDL implementation from the same location to test whether changes in water quality have occurred. Another study design involves using Upstream/Downstream samples that are collected on the same day from upstream and downstream of an implementation action to test whether water quality changes have occurred. Finally, a paired watershed study design involves samples collected on the same day from the target watershed in addition to a nearby watershed where no metal management actions have been taken to test whether water quality changes have occurred.

Many variables, including variations in precipitation and seasonal pollutant mass fluxes, impact water quality within Puerto Rico with regard to metals concentrations. For these reasons, it can be useful to assess TMDL effectiveness if those parameters are statistically associated with metal concentrations. A common covariate for pollutants in surface waters, especially rivers, is streamflow. From a review of the data available for the assessment units listed as impaired, it is recommended that the post-TMDL monitoring program reassesses the available data, including sample locations and timing. In addition, a well-defined monitoring plan should be developed that focuses on specific pollution sources and their impacts (land uses, discharge points, areas of concentrated boat activity). In addition, adding sample locations that help to gather ambient water quality should be considered, as well as flow/current conditions outside of the direct influence of land-based sources as a means of better understanding natural sources. Once determined, the sample locations should be used for all sampling events and should not be moved or modified without a compelling reason. Understanding the trends in water quality requires this consistency over time.

Consideration should also be given to water quality monitoring during "first flush" events in key watersheds. Monitoring would include strategic timing to sample priority waterbodies during the first storm event(s) following a prolonged dry period. Sampling during these times will provide the magnitude of stored pollutants (e.g. septic effluent, created eroded materials, etc.) during the dry period. This sampling will also illuminate the magnitude of stored land-based pollutant loads and prioritize watersheds for water quality mitigation activities. In addition, it is important to have sample size requirements to demonstrate statistically significant changes in each watershed.

Given the typical impairments observed, the following is recommended as a minimum sampling parameter suite. Sampling data should include metadata that documents conditions during sampling, including weather conditions (i.e., flagging as wet vs. dry weather samples) and presence of possible

pollution sources (for example, outfalls), etc. This information provides supporting information that can help interpret data, particularly when the data are out of the ordinary for a specific location.

- Hardness (as CaCO<sub>3</sub>)
- Total Suspended Solids
- Total Suspended Sediment
- Turbidity
- Water Temperature
- pH

Hardness (as CaCO<sub>3</sub>) is important for calculating the WQS applicable with each sample. Other parameters, such as sediment or turbidity, can be helpful in identifying sources of metals contributions from the landscape and determining which form (particulate or dissolved) they originate from. Finally, other factors such as pH and water temperature help govern the bioavailability of trace metals which impacts their toxicity transport mechanism (CSN 2015).

## 8 IMPLEMENTATION PLAN

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The TMDLs presented in this document call for a significant reduction in heavy metal loading to listed Puerto Rico waterbodies. It is recommended that an adaptive water quality management strategy include structural and nonstructural pollution control, monitoring plans, and stakeholder involvement. This section outlines key recommendations for TMDL implementation.

### 8.1 Stormwater Management

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Stormwater runoff from impervious surfaces such as roads, parking lots, and buildings, contributes to heavy metal impairments in most Puerto Rico waterbodies. Management recommendations to reduce particulate metals loading from stormwater runoff are:

1. NPDES permits issued for MS4 programs should be consistent with the TMDLs presented in this report
2. An assessment of MS4 programs of municipalities in impaired watersheds should be completed to determine local stormwater management strategies. For example, roads could be paved or construction could be halted or altered based on runoff and sedimentation to local waterbodies.
3. Any new development or redevelopment should incorporate green infrastructure designs that reduce stormwater runoff and pollutant loads and mimic natural hydrology. For example, installations of bioswales, pervious pavement, and detention ponds can replace traditional infrastructure.
4. Public outreach should involve educating homeowners of the benefits of green infrastructure and water reuse to improve stormwater pollution in residential and commercial areas near impaired waterbodies.
5. Surveys of unpaved roads, uncompleted construction projects, and other areas with high erosion potential that require stabilization.

### 8.2 Agriculture & CAFO

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Heavy metal loading from agriculture and CAFOs result from erosion of sediment, fertilizers, and animal waste. Education should occur on a variety of levels and target decision makers (elected officials, heads of agencies, and political appointees), farm owners and farm workers, and the general public. The importance of protecting natural resources and the impact of nonpoint source pollution need to be communicated effectively, focusing on linkages between healthy natural resources, clean drinking water and a strong economy.

General management recommendations to reduce heavy metal loading are listed below:

1. Proper fertilizer application, manure collection, and storage/waste disposal.
2. Review of pesticide and fungicide applications
3. Erosion control of agricultural lands to reduce sediment transport of particulate metals
4. Surveys and reviews of existing management practices and erosion control plans.
5. Outreach and education involving appropriate agricultural practices and encouragement of structural BMP usage for reducing heavy metal loading to impaired waterbodies. Examples of structural BMPs include sediment control basins, constructed wetlands, and stabilization practices.

Public education and outreach activities & materials can take on a variety of forms, depending on the target audience:

- Decision makers need general information on the impacts of nonpoint source pollution, how nonpoint source pollution affects the environment, ways of controlling nonpoint source pollution, and how the adverse impacts of nonpoint source pollution affect the economy, the health and aesthetics of the region.
- Farmers need detailed information on how to select and implement proper nonstructural and structural BMPs, operate and maintain structural BMPs, recognize the limitations of the land and obtain the maximum sustainable yield within those limitations, manage land properly, and develop and implement control plans.
- The general public needs to understand the linkages between their actions, nonpoint source pollution, and degradation of the natural environment.
- Education programs should be tailored to the specific needs of the community, the needs of the farmers, and the education level of the target audiences.

An effective strategy for public education and outreach regarding agricultural nonpoint source pollution should include:

- Development of a commission or similar mechanism for coordinating educational policy for the region;
- Integrate efforts with Puerto Rico Agricultural Extension Service (PRAES) to coordinate and offer conference and meeting concerning pesticides ground water contamination.
- Collaborate with the USDA Natural Resources Conservation Service (NRCS) in the implementation of the NRCS's National Water Quality Initiative
- Strengthen the actions corresponding to the management of pesticides present in monitored areas in coordination with Puerto Rico Department of Agriculture (PRDA).
- Follow up other state and federal agencies as well as other partners to encourage them to direct efforts to address the highest priority watersheds identified as part of the list of priorities developed for the Nonpoint Source (NPS) Management Program document of PREQB
- Community education programs;
- Field demonstrations and follow-up site visits;
- School and community workshops;
- Outreach and extension programs, including courses for farm workers;
- Use of media (TV, radio, videos, etc.);
- Development of outreach materials such as fact sheets, guidance documents, and courses for decision makers, farmers, and the general public;
- Education of the political leaders who develop and implement public policy in the Watershed; and
- Appointment of one responsible or lead coordinating agency.

### **8.3 Municipal & Industrial Permitted Discharges**

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Compliance of heavy metal loadings with permitted limits municipal and industrial discharges, landfills, and other point sources is imperative for attainment of WQs. Management recommendations to reduce heavy metals loads from point sources are:

1. WLAs for NPDES permitted facilities should be outlined in permits as maximum allowable loading for copper, lead, and mercury. Control measures should be put in place where applicable and financially feasible. Actions that can be taken include reduction of aging facilities, tertiary treatment, or other heavy metal removal projects.
2. NPDES permitted facilities should be required to monitor discharges and report concentrations of heavy metals consistently.
3. Ongoing efforts to inventory, map, and update permit records over time should continue. Details on each point source should include dates of installation, permit information, water quality data, governing agencies, landscape surrounding the area, and any other applicable details about the structures.
4. Follow-up to the facilities present in the assessment units in the high priority level, according to the PREQB Nonpoint Priority List.
5. Promote on the Department of Agriculture the use of the Nonpoint Priority List as a working tool to reduce heavy metal loads according to the priority levels.
6. Continue the implementation of the Regulation for the Control of Erosion and Prevention of Sedimentation (RCEPS) as part of the PREQB's 319 (h) Nonpoint Sources Management Plan and to support the Puerto Rico Coastal Nonpoint Source Program (Section 6217).
7. Continue the implementation of the *Reglamento para el Control de los Desperdicios fecales de Animales de Empresas Pecuarias* (the confined animal waste control regulation) adopted by PREQB on FY-09. Review and process 100 permits applications in accordance with the provisions of the confined animal waste control regulation received on a timely manner, during the fiscal year. These include permit applications received from facilities in high priority assessment units in Puerto Rico

## 9 ADMINISTRATIVE RECORD

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An electronic copy of the administrative record was compiled to support these TMDLs.

## 10 REFERENCES

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