Appendix C: Supplemental TMDL Loading Calculation Information for the Waikele Watershed

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The TMDL represents the maximum loading that can be assimilated by a waterbody while still achieving applicable water quality standards. The WQS are described in Section 3 of the TMDL report along with the TMDL numeric targets. TMDL development also involves a linkage analysis that connects TMDL targets with potential sources (see Section 6 of the TMDL report). The loading capacity (or maximum allowable load) was defined and each source category was provided with an allocation. The TMDL report includes load-based allocations for all potential sources. This appendix provides additional information to support the load- based calculations. Specifically, the distribution of simulated existing loads by owner and source type is provided, along with an example calculation for determining allocations. This information is intended to supplement the content described for the loading-based TMDLs presented in the main body of the TMDL report.

Establishment of the TMDL

A waterbody's loading capacity represents the maximum rate of loading of a pollutant that can be assimilated without violating WQC (40 CFR 130.2(f)). Establishing the relationship between instream water quality and source loading is an important component of TMDL development. It allows the determination of the relative contribution of sources to total pollutant loading and the evaluation of potential changes to water quality resulting from implementation of various management options. This relationship can be developed using a variety of techniques ranging from qualitative assumptions based on scientific principles to numerical computer modeling. The load-based TMDLs for the Waikele watershed were developed using flow estimated from an HSPF watershed model to assure compliance with the stream TMDL numeric targets (which are equivalent to the WQC).

To determine existing loads and TMDLs for the nutrient, turbidity, and sediment impaired waterbodies, the HSPF watershed loading model was used. The HSPF model was calibrated for a fourteen year period (water years 1998 to 2011) (Appendices A and B). These years covered a range of hydrologic conditions, including wet, dry, and average years. Because turbidity cannot be directly simulated using the watershed model (Section 6.1.1.3), sediment was simulated as a surrogate (Section 4.3.2.1). The model was calibrated to SSC, consistent with the majority of available data. The TMDL numeric targets for sediment are in TSS. TSS is generally lower than SSC due to the difference in the analytical methods (Glysson et al. 2000); therefore, use of SSC to estimate existing loads and TSS for loading capacity calculations was considered reasonable as it provides an implicit MOS (Section 7.1.4). Ultimately, achieving the sediment and nutrient TMDLs will contribute to meeting the turbidity WQS. Nutrient concentrations were simulated directly using the HSPF model.

The sediment and nutrients existing point and nonpoint source loads were estimated using HSPF for the fourteen year period. These represent the existing watershed loads in the TMDL and were summarized both annually and daily. In addition, the average daily simulated flow at the mouth of the watershed (model subbasin 10) was multiplied by the applicable dry or wet season numeric targets (Table 3) and a conversion factor to determine the daily allowable load (i.e., loading capacity) for each pollutant (note: the conversion factor was used to result in kilograms per day). Calculation of the loading capacity itself varied by numeric target type, as described below:

- **Geometric Mean Loading Capacity**: For dry and wet seasons, the geometric mean of both the allowable load and existing load were calculated from the HSPF model output. The geometric mean of the dry and wet season allowable loads represents the geometric mean loading capacities. The geometric mean of the simulated concentrations was also calculated for each season.
- **10% Exceedance Value Loading Capacity**: For dry and wet seasons, the daily modeled existing load was compared to the allowable load calculated using the 10% not-to-exceed WQC. All days exceeding the allowable load were further summarized. Specifically, for all exceedance days, average values were calculated for the allowable load, existing load, modeled flow, modeled concentration, and daily precipitation for the six different precipitation zones (Figure 10). The

average allowable load for the exceedance days was used to represent the 10% exceedance value loading capacity, which was only applicable for sediment during wet season.

- **2% Exceedance Value Loading Capacity**: Similar to the 10% exceedance value calculations, for dry and wet seasons, the daily modeled existing load was compared to the allowable load calculated using the 2% not-to-exceed WQC. For all days where the existing load was above the allowable load, average values were calculated for the allowable load, existing load, modeled flow, modeled concentration, and daily precipitation for the six different precipitation zones (Figure 10). The average allowable load for the exceedance days was used to represent the 2% exceedance value loading capacity. This value was not used in the TMDL document, but is provided to support management and implementation measures.

Necessary reductions in existing pollutant loads were calculated for the Waikele watershed to identify the reductions needed from existing loads to meet the loading capacities and corresponding numeric targets. These reductions are provided for guidance and reference only (compliance will be determined based on attainment of the allocations, not reductions). Reductions were calculated based on the modeled existing loads of sediment and nutrients relative to their respective loading capacity (based on the applicable sediment and nutrient numeric targets):

$$\text{Percent Reduction} = \frac{(\text{Modeled Existing Load} - \text{Loading Capacity})}{(\text{Modeled Existing Load})} \times 100$$

The allowable and existing loads were apportioned to the point and nonpoint sources as well as the margin of safety as described below.

Waste Load Allocations

The WLA is the portion of the loading capacity allocated to point source discharges to the waterbody. Point sources in the Waikele watershed include NPDES permits for construction and industrial stormwater and MS4s (Table 13). The WLAs assigned to construction and industrial stormwater permits is zero, as they are either required to implement BMPs as part of their permit conditions, or are included as part of an exisiting WLA. Load-based WLAs were calculated for each pollutant using the methodology described below:

- **Reserve Capacity for Future Permittees**: A separate WLA was also included as a reserve capacity for future permittees and land use changes anticipated in the watershed. This was calculated as 5 percent of the allowable load. This reserve capacity is expected to address additional development and other individual permittees not included in Table 13. There is at least one anticipated construction stormwater permittee in the watershed. This anticipated development is over 750 acres (over 2.5 percent of the watershed area). The 5 percent reserve capacity represents nearly double this anticipated contribution, thereby also allowing for additional future permittees.
- **MS4 Permits**: The WLAs are associated with MS4 permittees (CCH permit HIS000002; Hawaii DOT permit HIS000001; and U.S. Army Garrison Hawaii permit HIS000090). These permit areas were represented in the HSPF model; therefore, their WLAs are based on the loading simulated from each source. The proportion that each point source contributed to the pollutant-specific existing load was calculated from the model output. This proportion was applied to the remaining allowable load after subtracting out the future growth WLA, resulting in source-specific WLAs. Table C-1 presents the proportion of simulated existing loads by source for each pollutant, as well as the division of source-specific loading associated by point and nonpoint sources (only the proportion of point source loading was used in the WLA calculations). These proportions were determined during modeling configuration and analysis (Appendices A and B) and were also used to determine existing loads.

Table C-1. Distribution of simulated existing loads by owner and source type

Owner/Land Use Category	Proportion of Existing Load		Owner-Specific Distribution by Source Type*	
	Dry Season	Wet Season	Point Source (WLA)	Nonpoint Source (LA)
Total Nitrogen				
City & County of Honolulu	15.9%	20.1%	60.5%	39.5%
Military	3.8%	7.6%	43.1%	56.9%
State of Hawaii	7.0%	6.6%	25.8%	74.2%
Hawaii State Department of Education	0.8%	1.0%	0%	100%
Agriculture	54.3%	48.7%	0%	100%
Conservation	18.2%	15.9%	0%	100%
Total	**100.0%**	**100.0%**	**16.4%**	**83.6%**
Nitrite + Nitrate				
City & County of Honolulu	21.2%	21.7%	60.5%	39.5%
Military	5.7%	7.4%	43.1%	56.9%
State of Hawaii	8.4%	7.9%	23.0%	77.0%
Hawaii State Department of Education	1.0%	1.0%	0%	100%
Agriculture	60.7%	54.0%	0%	100%
Conservation	3.0%	8.0%	0%	100%
Total	**100.0%**	**100.0%**	**16.3%**	**83.7%**
Total Phosphorous				
City & County of Honolulu	15.5%	3.9%	60.5%	39.5%
Military	3.8%	2.0%	43.1%	56.9%
State of Hawaii	5.0%	9.0%	8.8%	91.2%
Hawaii State Department of Education	0.6%	0.1%	0%	100%
Agriculture	40.5%	82.3%	0%	100%
Conservation	34.6%	2.6%	0%	100%
Total	**100.0%**	**100.0%**	**15.7%**	**84.3%**
Sediment				
City & County of Honolulu	6.8%	2.8%	60.5%	39.5%
Military	2.4%	2.0%	43.1%	56.9%
State of Hawaii	4.4%	9.8%	4.1%	95.9%
Hawaii State Department of Education	0.3%	0.1%	0%	100%
Agriculture	48.2%	74.5%	0%	100%
Conservation	37.8%	10.8%	0%	100%
Total	**100.0%**	**100.0%**	**15.5%**	**84.5%**

* Proportions are based on the percent of total area compared to the MS4 area for each owner, with the exception of the State of Hawaii. The nonpoint source load (non-DOT areas) for the State of Hawaii was determined by tabulating the loads from model subbasins 14, 22, 24, 28, 29, and 43, which contain agricultural land uses that fall under state ownership. This proportion of the total State of Hawaii load was used to represent the LA.

Load Allocations

The LA is the portion of the loading capacity allocated to nonpoint source discharges to the waterbody. Nonpoint sources receiving load allocations in the Waikele watershed include agriculture, forested areas owned by the CCH and U.S. Army Garrison Hawaii, natural background (conservation land), the Department of Education, and agricultural and other lands owned by the State of Hawaii (but not subject to the DOT MS4 permit). These allocations were calculated using the proportion that each source

contributed to the simulated pollutant-specific existing load (Table C-1). The nonpoint source fraction of the existing load was applied for each source after subtracting the future growth WLA from the loading capacities.

Margin of Safety

A MOS must be included in a TMDL to account for any uncertainty or lack of knowledge regarding the pollutant loads and the response of the receiving water. The MOS can be implicit (incorporated into the TMDL analysis through conservative assumptions) or explicit (expressed in the TMDL as a portion of the loadings) or a combination of both. The TMDLs for the Waikele watershed included an implicit MOS.

TMDL Results and Allocations

The HSPF model was run for water years 1998-2011 for baseline (existing) conditions. The TMDLs were determined by calculating the dry and wet season allowable daily loads (see *Establishment of the TMDL* section above). Results are presented in kilograms per day (kgd). Allocations were subsequently calculated for individual sources using the methodologies described above for WLAs and LAs.

The dry and wet weather loading capacities and for total nitrogen, nitrite/nitrate, and sediment are presented in **Error! Reference source not found.**3 through **Error! Reference source not found.** for the geometric means and 10 percent exceedance value (for sediment only) TMDL numeric targets. As noted previously, the sediment TMDLs are a surrogate for turbidity. These tables also present the reductions necessary to meet the TMDLs (presented as both mass and percent) as well as the existing loads estimated for each modeled source. The calculations associated with the dry season total nitrogen TMDL and allocations are presented below in **Error! Reference source not found.** as an example.

Table C- 2. Example of TMDL allocation calculations

TMDL Component	Methodology	Dry Season Load (kgd)
Loading Capacity	Geometric mean of all daily dry weather allowable loads; daily allowable loads calculated as: simulated flow (in cfs) x dry weather WQC (0.180 mg/L) x 2.44657 (conversion factor to result in kilograms per day)	7.0
Wasteload Allocations		
City & County of Honolulu MS4	Proportional source contribution to existing load multiplied by the source-specific fraction of point source loading (Table C-1) applied to the available loading capacity: (7.0 x 15.9% x 60.5%) - Reserve WLA	0.4
U.S. Army Garrison Hawaii MS4	Proportional source contribution to existing load multiplied by the source-specific fraction of point source loading (Table C-1) applied to the available loading capacity: (7.0 x 3.8% x 43.1%) - Reserve WLA	0.1
State of Hawaii DOT MS4	Proportional source contribution to existing load multiplied by the source-specific fraction of point source loading (Table C-1) applied to the available loading capacity: (7.0 x 7.0% x 25.8%) - Reserve WLA	0.1
Construction Stormwater Permits	WLA = 0	0.0
Industrial Stormwater Permits	WLA = 0	0.0
Reserve WLA for Future Growth (5%)	5% of Loading Capacity: (7.0 x 0.05)	0.35
Load Allocations		
City & County of Honolulu	Proportional source contribution to existing load multiplied by the source-specific fraction of nonpoint source loading (Table C-1) applied to the available loading capacity:	0.7

TMDL Component	Methodology	Dry Season Load (kgd)
	(7.0 x 15.9% x 39.5%) – Reserve WLA	
U.S. Army Garrison Hawaii	Proportional source contribution to existing load multiplied by the source-specific fraction of nonpoint source loading (Table C-1) applied to the available loading capacity: (7.0 x 3.8% x 56.9%) – Reserve WLA	0.2
State of Hawaii	Proportional source contribution to existing load multiplied by the source-specific fraction of nonpoint source loading (Table C-1) applied to the loading capacity: (7.0 x 7.0% x 74.2%) _Reserve WLA	0.4
Hawaii State Department of Education MS4	Proportional source contribution to existing load multiplied by the source-specific fraction of point source loading (Table C-1) applied to the loading capacity: (7.0 x 0.8% x 100%)- Reserve WLA	0.05
Agriculture	Proportional source contribution to existing load multiplied by the source-specific fraction of nonpoint source loading (Table C-1) applied to the loading capacity: (7.0 x 54.3% x 100%) – Reserve WLA	3.6
Conservation Land	Proportional source contribution to existing load multiplied by the source-specific fraction of nonpoint source loading (Table C-1) applied to the loading capacity: (7.0 x 18.2% x 100%)	1.2
Existing Load	Geometric mean of all simulated daily dry weather existing loads	64.5
Load Reduction	(Existing Load - Loading Capacity)	57.5
Percent Reduction	(Existing Load - Loading Capacity)/(Existing Load) x 100	89%

* Remaining allocable load = loading capacity – MOS – construction stormwater WLA – industrial stormwater WLA – future growth WLA; 5.66 kilograms per day in this example

The TMDL document contains the TMDL tables calculated using the method described above, and the graphs that illustrate the annual dry and wet season allowable and existing geometric mean loads and concentrations (Figure C-1 through Figure C-33). As noted in the TMDL report, sediment geometric mean existing loads are below the allocable loads (Figure C-3), suggesting that stormflow conditions, which are better represented by the 10 and 2 percent exceedance values, may be contributing to the exceedances.

In addition to the sediment geometric mean analyses, a load duration curve was developed for the sediment 10 percent not-to-exceed numeric targets, providing a visual display of the allowable exceedance days as well as the flow and precipitation conditions associated with exceedances. The allowable load curve (black line) presented was calculated by multiplying the simulated flow with the appropriate numeric target and a conversion factor to result in daily loads. Allowable exceedance days are shown by green bars, representing the days on which exceedances of the WQC are not a violation of the standard (10 percent of the time, depending on the WQC).

Results of these analyses indicate that during lower flow periods, existing loads are frequently below the numeric targets. However, there are many days in the higher flow regimes that contribute significant sediment loads, resulting in exceedances of the 10 and 2 percent not to exceed TMDL numeric targets and associated loading capacities (Table C-6, Figure C-4).

Table C-3. Total nitrogen allocations and load reductions required to achieve geometric mean TMDLs

TMDL Component	Geometric Mean TMDL		Modeled Existing Load	
	Dry Season* Load (kgd)	Wet Season* Load (kgd)	Dry Season* Load (kgd)	Wet Season* Load (kgd)
Loading Capacity	7.01	16.24	N/A	N/A
Wasteload Allocations				
City County of Honolulu MS4	0.38	1.13	3.72	6.96
U.S. Army Garrison Hawaii MS4	0.09	0.42	0.87	2.60
State of Hawaii DOT MS4	0.07	0.16	0.69	0.96
Construction Stormwater General and Individual Permits	0	0	0	0
Industrial Stormwater General and Individual Permits	0	0	0	0
Reserve WLA for Future Growth (5%)	0.35	0.81	—	—
Load Allocations				
City County of Honolulu	0.68	1.98	6.54	12.23
U.S. Army Garrison Hawaii	0.16	0.75	1.56	4.66
State of Hawaii DOT (and other)	0.39	0.87	3.82	5.36
State of Hawaii DOE MS4	0.05	0.15	0.53	0.94
Agriculture	3.62	7.52	35.04	46.40
Conservation Land	1.21	2.45	11.73	15.09
Total Existing Load			64.48	95.22
Load Reduction			57.47	78.98
Percent Reduction			89%	83%

Note: Loads rounded to the nearest 0.1 kilogram or number (unless this would result in an allocation of zero); thus, totals may be different than the sum of their parts.
* Wet season is defined at November 1 through April 30 and dry season is May 1 through October 31.
Acronyms: kgd = kilograms per day, N/A = not applicable; "—" = not explicitly modeled

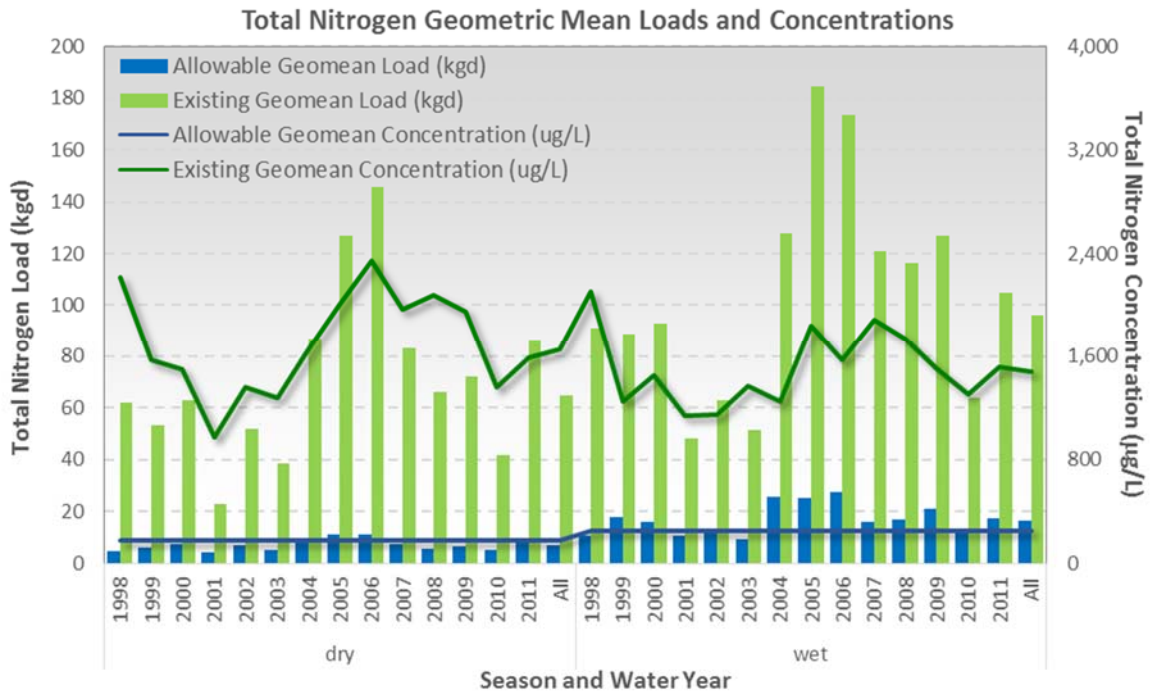

Figure C-1. Total nitrogen annual TMDL and existing condition geometric mean loads and concentrations

Table C-4. Nitrite + nitrate allocations and load reductions required to achieve geometric mean TMDLs

TMDL Component	Geometric Mean TMDL		Modeled Existing Load	
	Dry Season* Load (kgd)	Wet Season* Load (kgd)	Dry Season* Load (kgd)	Wet Season* Load (kgd)
Loading Capacity	1.17	4.55	N/A	N/A
Wasteload Allocations				
City County of Honolulu MS4	0.09	0.34	3.31	5.08
U.S. Army Garrison Hawaii MS4	0.02	0.12	0.88	1.72
State of Hawaii DOT MS4	0.01	0.05	0.55	0.78
Construction Stormwater General and Individual Permits	0	0	0	0
Industrial Stormwater General and Individual Permits	0	0	0	0
Reserve WLA for Future Growth (5%)	0.06	0.23	—	—
Load Allocations				
City County of Honolulu	0.15	0.60	5.82	8.92
U.S. Army Garrison Hawaii	0.04	0.21	1.58	3.07
State of Hawaii DOT (and other)	0.08	0.29	3.08	4.34
State of Hawaii DOE MS4	0.01	0.04	0.42	0.62
Agriculture	0.67	2.33	26.17	34.82
Conservation Land	0.03	0.35	1.28	5.16
Total Existing Load			43.09	64.52
Load Reduction			41.92	59.98
Percent Reduction			97%	93%

Note: Loads rounded to the nearest 0.1 kilogram or number (unless this would result in an allocation of zero); thus, totals may be different than the sum of their parts.
* Wet season is defined at November 1 through April 30 and dry season is May 1 through October 31.
Acronyms: kgd = kilograms per day, N/A = not applicable; "—" = not explicitly modeled

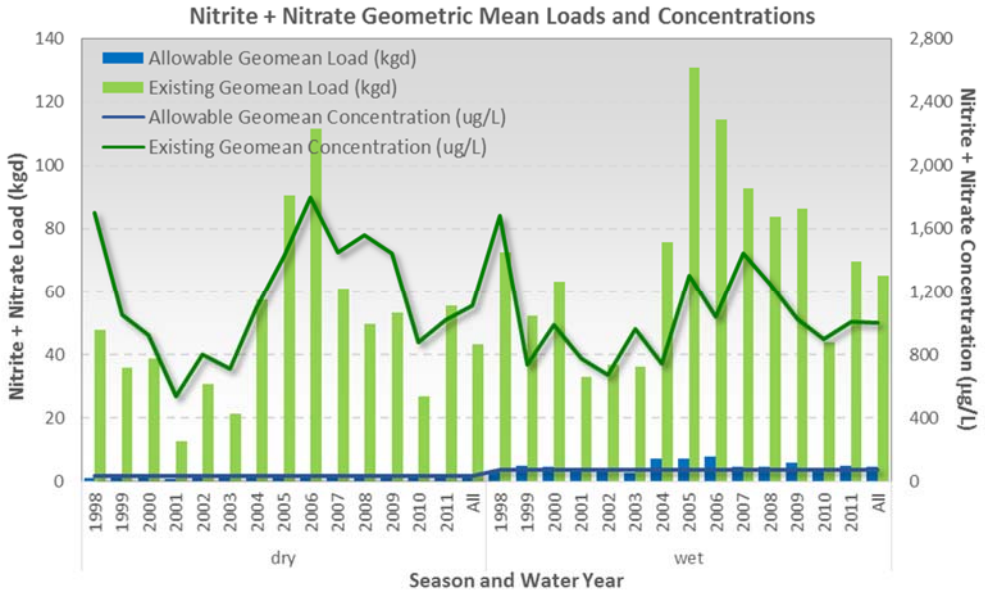

Figure C-2. Nitrite/nitrate annual TMDL and existing condition geometric mean loads and concentrations

Table C-5. Sediment allocations and load reductions required to achieve geometric mean TMDLs

TMDL Component	Geometric Mean TMDL		Modeled Existing Load	
	Dry Season Load (kgd)	Wet Season Load (kgd)	Dry Season Load (kgd)	Wet Season Load (kgd)
Loading Capacity	389.5	1,299.0	N/A	N/A
Wasteload Allocations				
City County of Honolulu MS4	9.2	12.7	1.7	2.2
U.S. Army Garrison Hawaii MS4	3.2	8.8	0.6	1.5
State of Hawaii DOT MS4	2.5	18.4	0.5	3.2
Construction Stormwater General and Individual Permits	0	0	0	0
Industrial Stormwater General and Individual Permits	0	0	0	0
Reserve WLA for Future Growth (5%)	19.5	65.0	—	—
Load Allocations				
City County of Honolulu	16.2	22.3	3.1	3.9
U.S. Army Garrison Hawaii	5.7	15.8	1.1	2.7
State of Hawaii DOT (and other)	14.0	102.7	2.6	17.8
State of Hawaii DOE MS4	1.06	1.3	0.2	0.2
Agriculture	178.4	919.1	33.7	159.6
Conservation Land	139.7	132.9	26.4	23.1
Total Existing Load			69.9	214.3
Load Reduction			N/A	N/A
Percent Reduction			N/A	N/A

Note: Loads rounded to the nearest 0.1 kilogram or number (unless this would result in an allocation of zero); thus, totals may be different than the sum of their parts.
* Wet season is defined at November 1 through April 30 and dry season is May 1 through October 31.
Acronyms: kgd = kilograms per day, N/A = not applicable; "—" = not explicitly modeled
Shaded values are for reference only

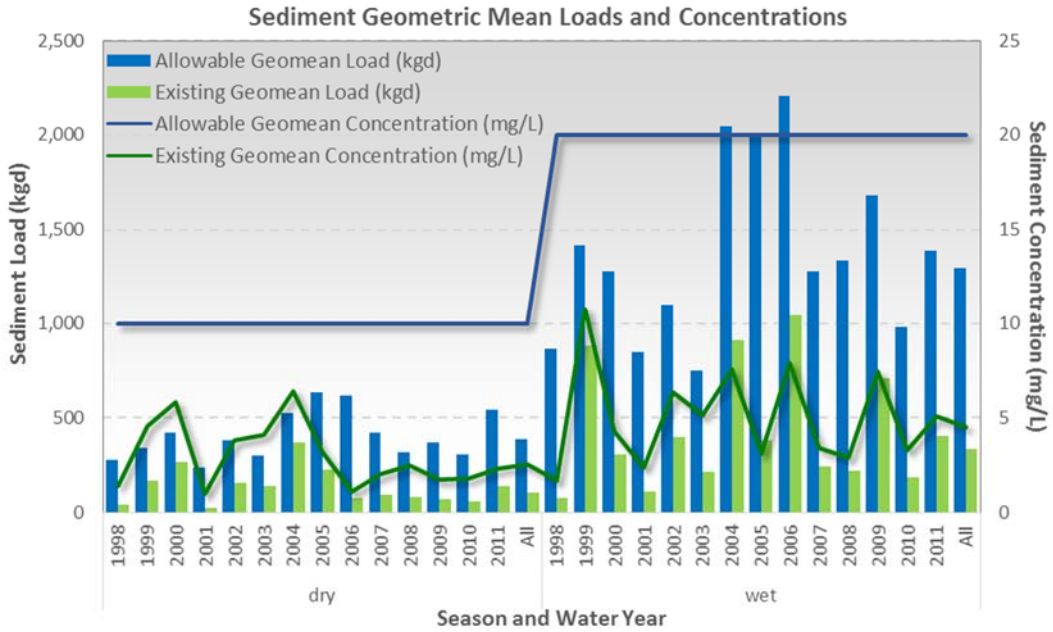

Figure C-3. Sediment annual TMDL and existing condition geometric mean loads and concentrations

Table C-6. Sediment allocations and load reductions required to achieve 10% exceedance value TMDLs

TMDL Component	Geometric Mean TMDL		Modeled Existing Load	
	Dry Season Load (kgd)	Wet Season Load (kgd)	Dry Season Load (kgd)	Wet Season Load (kgd)
Loading Capacity	4,991.0	18,997.2	N/A	N/A
Wasteload Allocations				
City County of Honolulu MS4	117.8	185.8	2,349.1	3,686.8
U.S. Army Garrison Hawaii MS4	41.1	129.0	819.8	2,559.1
State of Hawaii DOT MS4	32.1	269.8	640.2	5,353.4
Construction Stormwater General and Individual Permits	0	0	0	0
Industrial Stormwater General and Individual Permits	0	0	0	0
Reserve WLA for Future Growth (5%)	249.6	949.9	—	—
Load Allocations				
City County of Honolulu	207.0	326.4	4,127.6	6,478.1
U.S. Army Garrison Hawaii	73.5	230.6	1,466.2	4,576.9
State of Hawaii DOT (and other)	178.8	1,502.5	3,565.5	29,815.2
State of Hawaii DOE MS4	13.6	19.4	272.0	385.8
Agriculture	2,286.7	13,440.9	45,600.7	266,723.2
Conservation Land	1,790.7	1,942.9	35,709.7	38,555.7
Total Existing Load			94,550.8	358,134.2
Load Reduction			89,559.8	339,137.0
Percent Reduction			95%	95%

Note: Loads rounded to the nearest 0.1 kilogram or number (unless this would result in an allocation of zero); thus, totals may be different than the sum of their parts.
* Wet season is defined at November 1 through April 30 and dry season is May 1 through October 31.
Acronyms: kgd = kilograms per day, N/A = not applicable; "—" = not explicitly modeled
Shaded values are for reference only

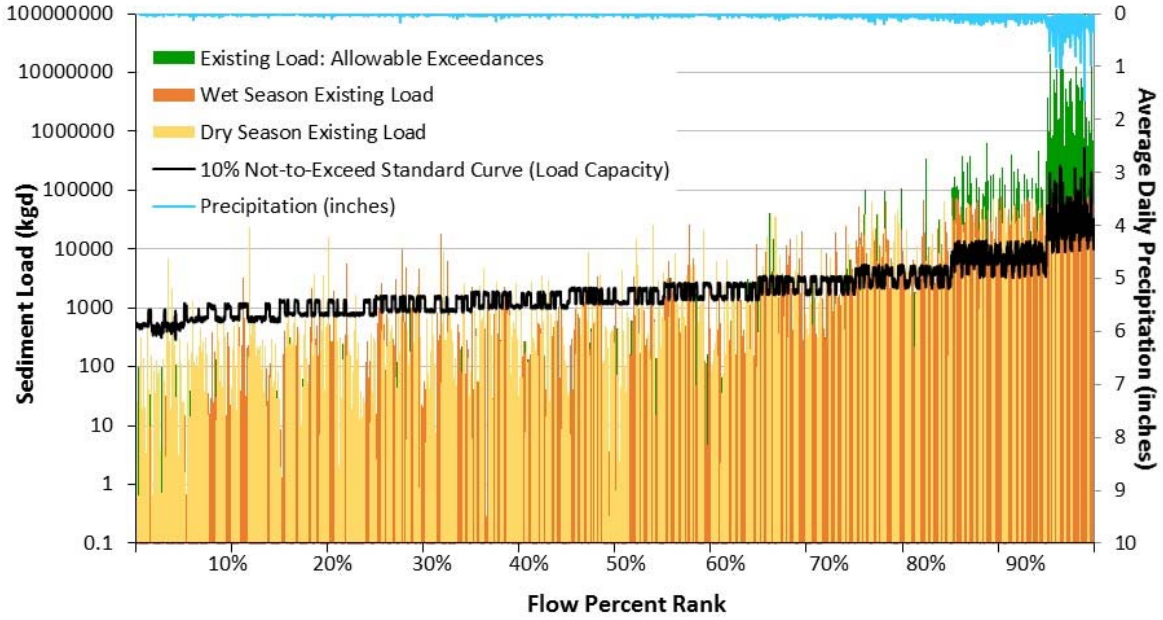

Figure C-4. Sediment load duration curve for 10 percent not-to-exceed WQC