Appendix C: Allocation Approach for Sediment and Nutrient TMDLs

For sediment and nutrients, the targets for the watershed TMDL are expressed as monthly average concentrations at specific compliance locations. The monthly average concentration targets can be met by many different combinations of daily concentrations and loads, and indeed do not constrain loads on individual days. Further, the concentrations at the compliance points are determined after losses in transit from the upstream source areas; thus, the at-source loads are equal to or greater than the loads present in-stream at the compliance points.

The TMDL scenario is predicted to meet the compliance targets, and thus contains a time series of source loads that are consistent with the waterbody loading capacity. The key to achieving use support is the set of management practices proposed in the TMDL scenario. Their impact is best summarized in terms of monthly and annual loading rates by source. However, as a result of the recent D.C. Circuit Court of Appeals decision in Friends of the Earth, Inc. v. EPA, et al., No. 05-0515 (2006), all future TMDLs and associated load allocations and wasteload allocations must be expressed in terms of a daily time increment. The TMDL must thus include daily load allocations. There is no requirement that a daily load expression result in a single, constant daily load limit that is applicable to all situations, although this is one potential formulation. Rather, the maximum daily load(s) that are permissible are those that meet the loading capacity of the waterbody – defined as "the greatest amount of load that a water can receive without violating water quality standards" (40 CFR 130.2). As the loading capacity varies based on ambient conditions, so too may the total maximum daily load that satisfies the loading capacity.

Nutrient and sediment loads in the Black River are strongly correlated to flow, as a significant amount of the loading is due to storm event washoff from nonpoint sources. As noted above, the TMDL is given by the scenario that achieves the monthly targets. The management objective of meeting the monthly concentration targets is consistent with this scenario, while loads on individual days will vary and may have little impact on achieving the targets. To specify a daily maximum load that achieves loading capacity, an appropriate strategy is to start with the predicted series of source loads in the TMDL scenario, then choose an upper confidence limit as the maximum load that is allowable on a daily basis. That is, the maximum daily loads that are consistent with the loading capacity are the set of loads that are consistent with the statistical distribution of daily loads in the allocation scenario. The daily load expression, while required by law, is thus a supplementary expression to the longer term loading capacity and allocations that form the essential part of achieving use support in the watershed.

The TMDL regulations at 140 CFR 130.2 define the TMDL as "the sum of the individual WLAs for point sources and LAs for nonpoint sources and natural background." WLAs (wasteload allocations) and LAs (load allocations) are defined as "portions of a receiving water's loading capacity", while loading capacity is defined as "the greatest amount of load that a water can receive without violating water quality standards." Total maximum daily loads for the Black River are defined as the sum of two general components: (1) a static or constant component consisting of the WLAs for wastewater treatment plants, and (2) a dynamic, flow-dependent component that contains the LAs for nonpoint sources, along with any WLAs for permitted MS4s. The resulting TMDLs will thus consist of constant terms plus an equation relating additional allowable loads to flow.

The dynamic or flow-dependent component is first derived as a total daily amount as a function of flow. This daily amount is then partitioned into a generalized LA for nonpoint sources and WLAs for individual MS4 permittees. The total daily amount for the dynamic component is defined as the upper 95th percent confidence limit on the regression of at-source loading (excluding the wastewater treatment plants and evaluated at the edge of stream) against flow. Daily loads that fall within these confidence limits are consistent with achieving the loading capacity; daily loads that exceed these confidence limits are considered to be not consistent with achieving the loading capacity, and thus exceed the total allowable maximum daily load. The assignment of a fraction of this load to MS4 permittees is then calculated as the allowable dynamic daily load times the fraction of upstream watershed area occupied by the MS4 times the ratio of the per-acre loading rate for the pollutant from urban areas to the averaging loading rate from all the dispersed sources in the watershed.

C-1. Subbasin 8

Existing and allowable loads were calculated for the West Branch Black River near the mouth (Subbasin 8). This sampling station drains 174.1 square miles and land use/land cover upstream of this station consists primarily of row crops (53%), deciduous forest (22%), pasture/hay (10%), and residential (9%) land uses. A total of 6,204 TP samples, nitrate, and TSS samples predicted using SWAT (Appendix B) were available for the analysis at Subbasin 8. Four WWTPs discharge upstream of Subbasin 8 and portions of two designated MS4s are within the upstream watershed.

C-1.1. Dynamic Load Components (Subbasin 8)

The dynamic load components are based on the relationship of source loading of pollutants to flow. These relationships were found to be approximately linear in log space. An upper 95th percentile confidence limit can then be developed from a regression of dynamic load on flow.

Figure C-1 shows the relationship of sediment source load to flow at Subbasin 8 after dropping the first year to allow for model spin-up. The relationship is approximately linear above 10 cfs. Therefore, the regression was calculated for flows of 10 cfs or greater.

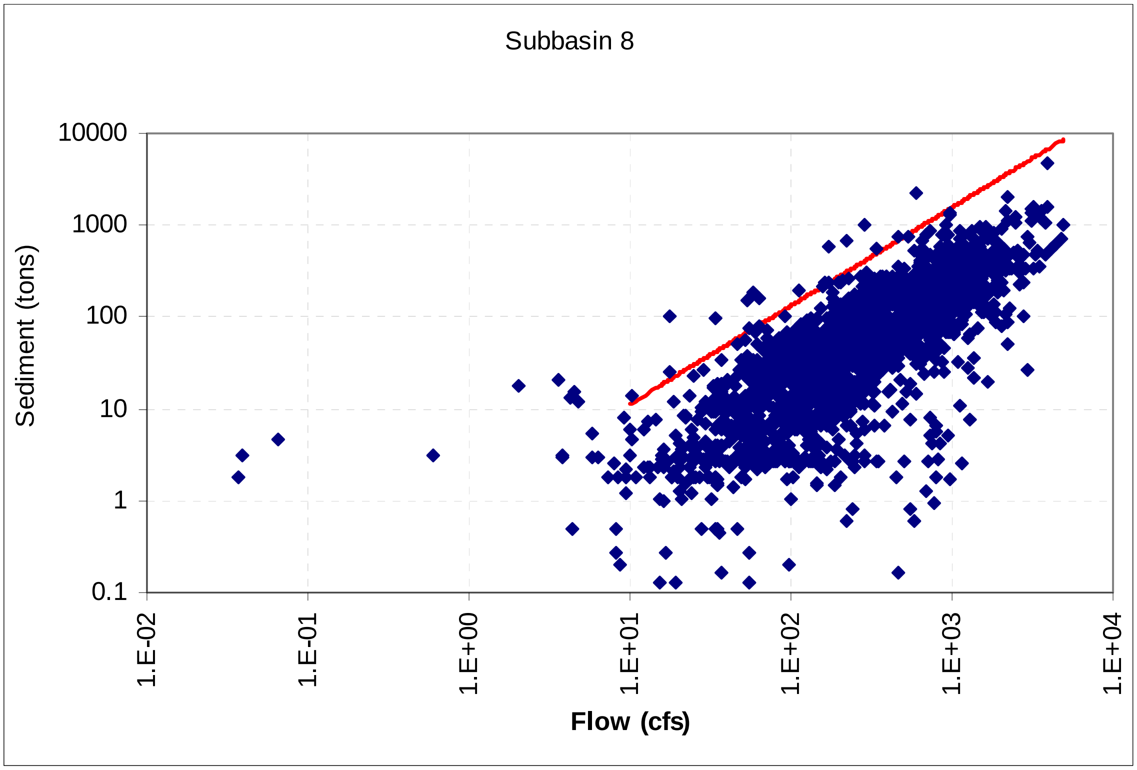

Figure C-1. Relationship of Dynamic Loads of Sediment to Flow at Subbasin 8 under TMDL Allocation Scenario

The regression of sediment load (Y, Metric tons/d) versus flow (Q, cfs) yields the following relationship:

$$\mathrm{Ln}(Y) = -2.2179 + 1.06919 \ln(Q).$$

A one-sided upper confidence limit (prediction limit) on the regression line (shown in red on Figure C-1) can then be calculated as

$$\mathrm{Ln}\,(Y) + t_{n-1,\,0.05}\, s_{y|Q0}\,,$$

where $t_{n-1,0.05}$ is Student's t statistic for sample size n at the 5% level and $s_{y|Q0}$ is the square root of the variance of the model residuals at a particular value of flow. This last term is given by

$$s^2_{y|Q0} = s^2_{y|Q}\left[\frac{1}{n} + \frac{(Q0-\bar{Q})^2}{\sum(Q_i-\bar{Q})^2} + 1\right],$$

where $s^2_{y|Q}$ is the variance of the sample model residuals or mean squared error of the reqression.

For the present case, *n* is large and the squared deviation of individual flows from the mean is small relative to the sum of such deviations, implying that the term in brackets is approximately equal to 1 and that $s^2_{y|Q}$ is well approximated by the constant value of $s^2_{y|Q}$, which is 1.2338 in this case. (Numerical analysis shows that the approximation is within 1 percent for the sample sizes and flows present here.) For the TSS regression at Subbasin 8, the equation for the upper prediction limit (*U*) then becomes

$\ln(U) = -0.03945 + 1.06919 \ln(Q)$.

Below a flow of 10 cfs, the regression relationship does not apply. For that flow range, a constant total load limit of 11.27 metric tons/d is applied (which is based on the value calculated by the equation at 10 cfs).

Part of this dynamic load limit is attributable to two MS4s: the City of Elyria, constituting 2.64% of the upstream drainage area, and the City of Oberlin, constituting 2.08% of the upstream drainage area. The loading rate of TSS from urban lands in the model is 1.236 times the basin average for Oberlin and 0.974 times the basin average for Elyria. It is assumed that MS4s do not contribute flow at very low flows instream (below 10 cfs at Subbasin 8).

For nitrate, the regression relationship and one-sided 95th percentile upper confidence limit are shown in Figure C-2. As with TSS, the regression is only applicable above a flow of 10 cfs, and below 10 cfs a constant daily limit of 44.51 kg is assigned. The equation for the upper confidence limit (kg/d) as a function of flow (cfs) is

$\ln(U) = 0.713184 + 1.33871 \ln(Q)$.

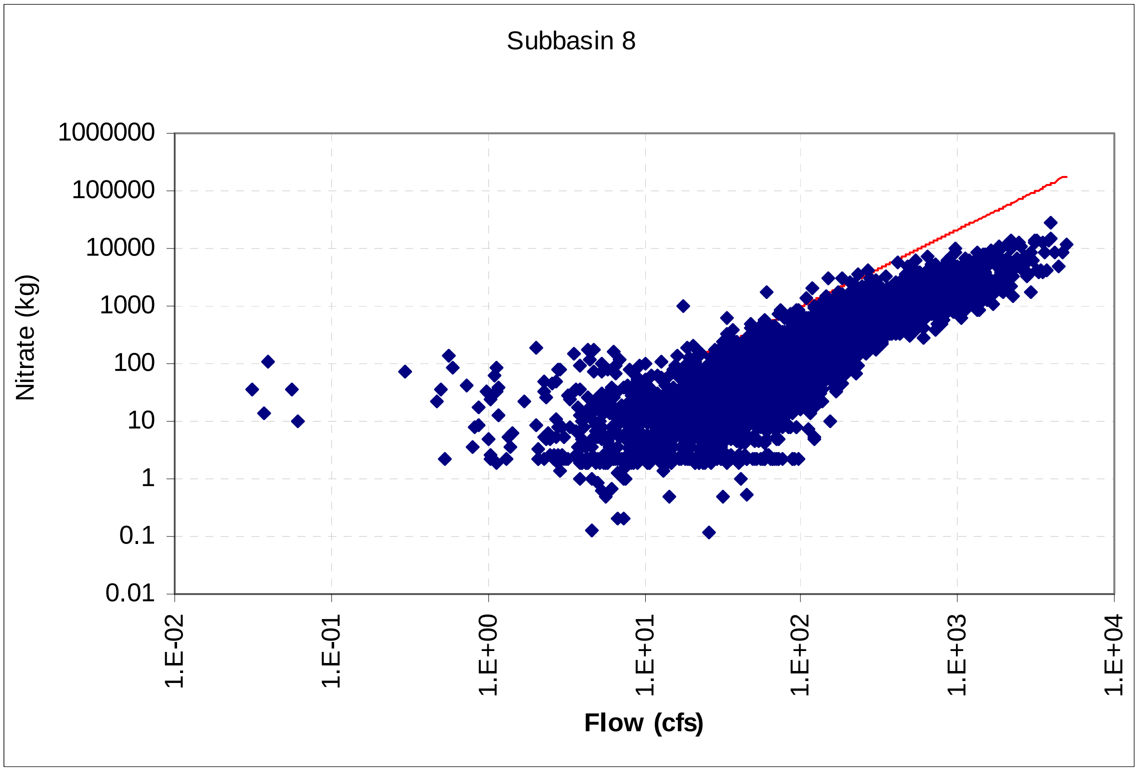

Figure C-2. Relationship of Dynamic Loads of Nitrate to Flow at Subbasin 8 under TMDL Allocation Scenario

For total phosphorus, the regression relationship and one-sided 95th percentile upper confidence limit are shown in Figure C-3. As with TSS, the regression is only applicable above a flow of 10 cfs, and below 10 cfs a constant daily limit of 6.50 kg is assigned. The equation for the upper confidence limit (kg/d) as a function of flow (cfs) is

$$\ln(U) = -1.01282 + 1.25296 \ln(Q).$$

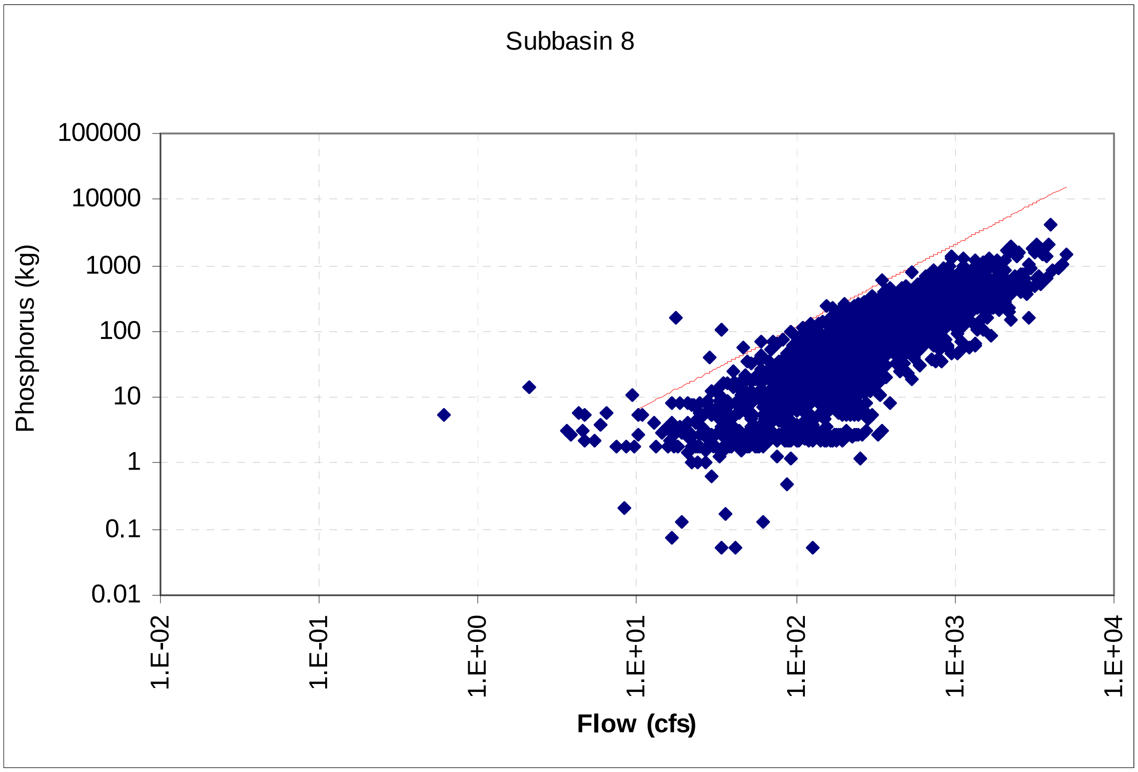

Figure C-3. Relationship of Dynamic Loads of Total Phosphorus to Flow at Subbasin 8 under TMDL Allocation Scenario

C-1.2. Wasteload Allocations (Subbasin 8)

Wasteload allocations for the MS4s are part of the dynamic load limit. Their fraction is expressed as the dynamic load limit times the fraction of area occupied by the MS4 times the loading rate ratio (Table C-1). The WLAs are for the portion of the MS4 upstream of the mouth of Subbasin 8 only.

Table C-1. WLA Calculations for MS4s Upstream of Subbasin 8

MS4	Constituent	Fraction of Area	Loading Ratio	Wasteload Allocation (per d)
City of Oberlin (part)	TSS (MT)	2.08%	1.236	0.02471 · exp(1.06919 ln(*Q*))
	Nitrate (kg)	2.08%	0.615	0.04251 · exp(1.33871 ln(Q))
	Total P (kg)	2.08%	1.002	0.00465 ·exp(1.25296 ln(Q))
City of Elyria	TSS (MT)	2.64%	0.974	0.02472 · exp(1.06919 ln(Q)

(part)	Nitrate (kg)	2.64%	1.590	0.08467 · exp(1.33871 ln(Q))
	Total P (kg)	2.64%	0.734	0.00704 ·exp(1.25296 ln(Q))

Loading from wastewater treatment plants is not included in the dynamic load analysis, because this load is not strongly correlated with flow. The impact of loads from the wastewater treatment plants is, however, affected by flow, because there tends to be more trapping and other losses of pollutants during low flow conditions when travel times are longer.

As with the nonpoint loads, a set of wastewater treatment plant loads that satisfy the TMDL are those that are used in the allocation scenario. These are input to the allocation scenario run as loads based on observed time series of flows, not permit limit loads – and are thus comparable to the long term average (LTA) used in permitting to satisfy a WLA after accounting for effluent variability (USEPA, 1991). The LTA is by definition less than the WLA.

Actual loads from WWTPs vary from day to day. The daily expression needed for the TMDL is equivalent to a permit Maximum Daily Limit (MDL). Following the recommendations in USEPA (1991, p. 101) the MDL is developed from the dynamic model output for the TMDL scenario run as follows:

- The effluent LTA and CV (coefficient of variation) are calculated from the effluent loads contained in the model scenario that shows compliance with water quality standards.
- The MDL is calculated from the LTA by multiplying by the factor exp ($z\sigma - 0.5\,\sigma^2$), where σ is equal to $\ln(CV^2+1)$ under lognormal distribution assumptions and z is 2.326 at the 99^{th} percentile probability basis.
- The daily expression for the TMDL is set equal to the MDL.

As with the dynamic load analysis, the first year of model output (1988) is eliminated from the analysis to allow for model spin-up.

There are four wastewater treatment plants within the upstream watershed of Subbasin 8. For TSS, the scenario runs indicate that no reduction is needed in loads from WWTPs. Therefore, the WLAs for TSS are equal to the current permit limits. WLA calculations are shown in Table C-2 through Table C-4.

Table C-2. TSS WLA Calculation for WWTPs Upstream of Subbasin 8

Facility	NPDES ID	Design Flow (MGD)	Permit Limit (mg/L)	WLA (kg/d)
Lagrange WWTP	OH0046221	0.363	18	24.73
Oberlin WWTP	OH0020427	1.5	18	102.21
Wellington WWTP	OH0026158	0.75	18	51.10
Findlay State Park Campground	OH00370044	0.025	18	1.70
Total WLA: WWTPs				179.74

Table C-3. Nitrate WLA Calculation for WWTPs Upstream of Subbasin 8

Facility	NPDES ID	Design Flow (MGD)	LTA (kg/d)	CV	WLA=MDL (kg/d)
Lagrange WWTP	OH0046221	0.363	2.20	0.281	2.62
Oberlin WWTP	OH0020427	1.5	33.06	0.305	40.49
Wellington WWTP	OH0026158	0.75	6.86	0.309	8.44
Findlay State Park Campground	OH00370044	0.025	0.19	1.895	2.03
				Total WLA: WWTPs	53.58

Table C-4. Total Phosphorus WLA Calculation for WWTPs Upstream of Subbasin 8

Facility	NPDES ID	Design Flow (MGD)	LTA (kg/d)	CV	WLA=MDL (kg/d)
Lagrange WWTP	OH0046221	0.363	0.32	0.304	0.39
Oberlin WWTP	OH0020427	1.5	1.96	0.301	2.39
Wellington WWTP	OH0026158	0.75	1.13	0.233	1.28
Findlay State Park Campground	OH00370044	0.025	0.02	1.896	0.25
				Total WLA: WWTPs	4.31

C-1.3. Load Allocations (Subbasin 8)

The load allocations to nonpoint sources are obtained by subtracting the MS4 wasteload allocations from the dynamic load limit daily expressions (Table C-5).

Table C-5. Load Allocations Upstream of Subbasin 8

Constituent	Flow Regime	Load Allocation (per day)
TSS (MT)	< 10 cfs	11.27
	≥ 10 cfs	$0.91188 \cdot \exp(1.06919 \ln(Q))$
Nitrate (kg)	< 10 cfs	44.51
	≥ 10 cfs	$1.91230 \cdot \exp(1.33871 \ln(Q))$
Total P (kg)	< 10 cfs	6.50
	≥ 10 cfs	$0.35150 \cdot \exp(1.25296 \ln(Q))$

C-2. Subbasin 9

Existing and allowable loads were calculated for the East Branch Black River near the mouth (Subbasin 9). This sampling station drains 125.89 square miles and land use/land cover upstream of this station consists primarily of row crops (48%), deciduous forest (28%), pasture/hay (9%), and residential (12%) land uses. Five WWTPs discharge upstream of Subbasin 8 and portions of three designated MS4s are within the upstream watershed.

C-2.1. Dynamic Load Components (Subbasin 9)

Figure C-4 shows the relationship of sediment source load to flow at Subbasin 9 after dropping the first year to allow for model spin-up. The relationship is approximately linear above 10 cfs. Therefore, the regression was calculated for flows of 10 cfs or greater.

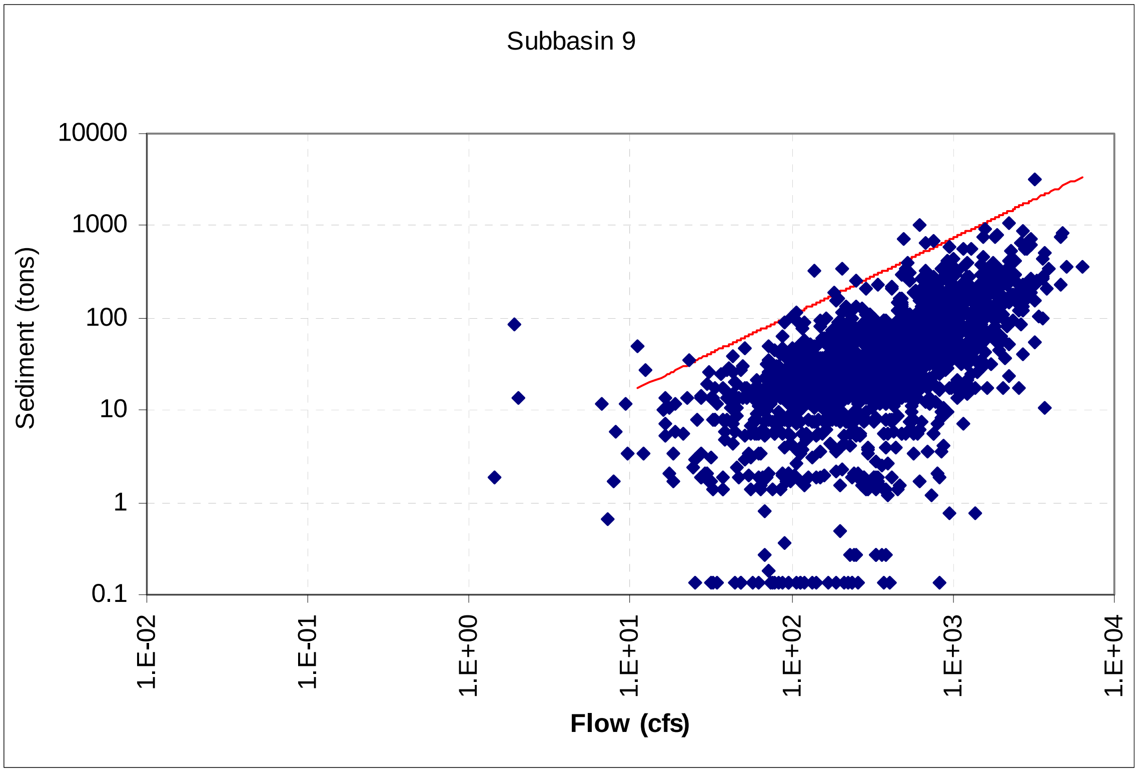

Figure C-4. Relationship of Dynamic Loads of Sediment to Flow at Subbasin 9 under TMDL Allocation Scenario

The equation for the upper prediction limit (U), calculated as for Subbasin 9, is

$$\ln(U) = 0.843364 + 0.832742 \ln(Q).$$

Below a flow of 10 cfs, the regression relationship does not apply. For that flow range, a constant total load limit of 15.81 metric tons/d is applied.

Part of this dynamic load limit is attributable to three MS4s: the City of Elyria, constituting 2.95% of the upstream drainage area, the City of Grafton, constituting 3.59% of the upstream area, and the City of North Ridgeville, constituting 1.06% of the upstream drainage area. The loading rate of TSS from urban lands in the model is 0.724 times the basin average for Elyria, 1.341 for Grafton, and 0.598 for North Ridgeville. It is assumed that MS4s do not contribute flow at very low flows instream (below 10 cfs at Subbasin 9).

For nitrate, the regression relationship and one-sided 95th percentile upper confidence limit are shown in Figure C-5. As with TSS, the regression is only applicable above a flow of 10 cfs, and below 10 cfs a constant daily limit of 66.76 kg is assigned. The equation for the upper confidence limit (kg/d) as a function of flow (cfs) is

$$\ln(U) = 1.80565 + 1.04036 \ln(Q).$$

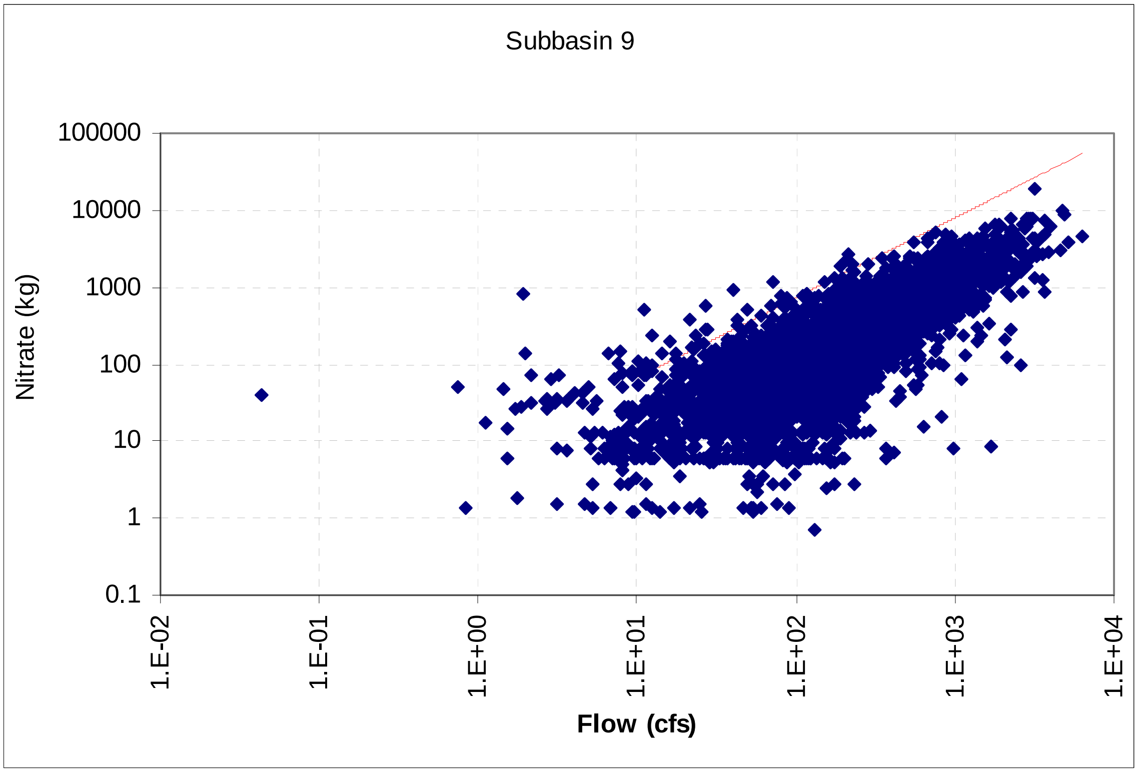

Figure C-5. Relationship of Dynamic Loads of Nitrate to Flow at Subbasin 9 under TMDL Allocation Scenario

For total phosphorus, the regression relationship and one-sided 95th percentile upper confidence limit are shown in Figure C-6. As with TSS, the regression is only applicable above a flow of 10 cfs, and below 10 cfs a constant daily limit of 11.29 kg is assigned. The equation for the upper confidence limit (kg/d) as a function of flow (cfs) is

$$\ln(U) = 0.179886 + 0.97455 \ln(Q).$$

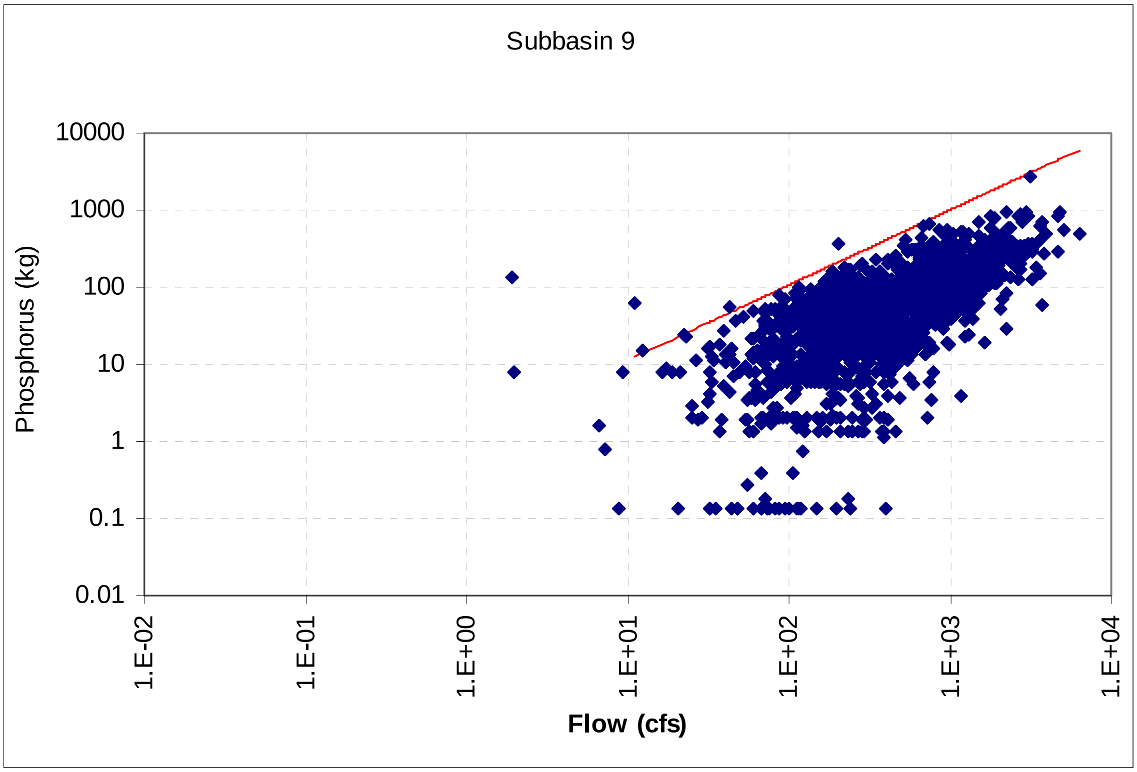

Figure C-6. Relationship of Dynamic Loads of Total Phosphorus to Flow at Subbasin 9 under TMDL Allocation Scenario

C-2.2. Wasteload Allocations (Subbasin 9)

Wasteload allocations for the MS4s are part of the dynamic load limit. Their fraction is expressed as the dynamic load limit times the fraction of area occupied by the MS4 times the loading rate ratio.

Table C-6. WLA Calculations for MS4s Upstream of Subbasin 9

MS4	Constituent	Fraction of Area	Loading Ratio	Wasteload Allocation (per d)
Elyria (part)	TSS (MT)	2.95%	0.724	0.04962 · exp(0.83274 ln(Q))
	Nitrate (kg)	2.95%	1.456	0.26130 · exp(1.04036 ln(Q))
	TP (kg)	2.95%	0.527	0.01860 · exp(0.97455 ln(*Q*))
North Ridgeville (part)	TSS (MT)	1.06%	0.598	0.01474 · exp(0.83274 ln(Q))
	Nitrate (kg)	1.06%	1.617	0.10426 · exp(1.04036 ln(Q))
	TP (kg)	1.06%	0.513	0.00651 · exp(0.97455 ln(*Q*))
Grafton	TSS (MT)	3.59%	1.341	0.11185 · exp(0.83274 ln(Q))
	Nitrate (kg)	3.59%	1.092	0.23849 · exp(1.04036 ln(Q))
	TP (kg)	3.59%	0.683	0.02937 · exp(0.97455 ln(*Q*))

Loading from wastewater treatment plants is not included in the dynamic load analysis, as described above. WLAs for the wastewater treatment plants are developed separately, as was done for Subbasin 8.

For TSS, the scenario runs indicate that no reduction is needed in loads from WWTPs. Therefore, the WLA for TSS is equal to the current permit limits. WLA calculations for the WWTPs are shown in Table C-7 through Table C-9.

Table C-7. TSS WLA Calculation for WWTPs Upstream of Subbasin 9

Facility	NPDES ID	Design Flow (MGD)	Permit Limit (mg/L)	WLA (kg/d)
Spencer WWTP	OH0022071	0.09	18	6.13
Lodi WWTP	OH0020991	0.8	18	54.51
Grafton WWTP	OH0025372	1.5	18	102.21
Eaton Estates WWTP	OH0026140	0.20	18	13.63
Brentwood Lake WWTP	OH0026158	0.12	18	8.18
			Total WLA: WWTPs	184.66

Table C-8. Nitrate WLA Calculation for WWTPs Upstream of Subbasin 9

Facility	NPDES ID	Design Flow (MGD)	LTA (kg/d)	CV	WLA=MDL (kg/d)
Spencer WWTP	OH0022071	0.09	2.18	0.295	2.64
Lodi WWTP	OH0020991	0.8	11.04	0.378	14.92
Grafton WWTP	OH0025372	1.5	11.12	0.316	13.81
Eaton Estates WWTP	OH0026140	0.20	2.12	0.202	2.33
Brentwood Lake WWTP	OH0026158	0.12	1.29	.261	1.50
				Total WLA: WWTPs	35.2

Table C-9. Total Phosphorus WLA Calculation for WWTPs Upstream of Subbasin 9

Facilit+y	NPDES ID	Design Flow (MGD)	LTA (kg/d)	CV	WLA=MDL (kg/d)
Spencer WWTP	OH0022071	0.09	0.32	0.304	0.39
Lodi WWTP	OH0020991	0.8	0.83	0.591	1.58
Grafton WWTP	OH0025372	1.5	1.60	0.381	2.18
Eaton Estates WWTP	OH0026140	0.20	0.26	0.203	0.29
Brentwood Lake WWTP	OH0026158	0.12	0.16	0.262	0.19
				Total WLA: WWTPs	4.63

C-2.3. Load Allocations (Subbasin 9)

The load allocations to nonpoint sources are obtained by subtracting the MS4 wasteload allocations from the expressions for the dynamic load limit (Table C-10).

Table C-10. Load Allocations Upstream of Subbasin 9

Constituent	Flow Regime	Load Allocation (per day)
TSS (MT)	< 10 cfs	15.81
	≥ 10 cfs	2.14796 · exp(0.83274 ln(Q))
Nitrate (kg)	< 10 cfs	66.76
	≥ 10 cfs	5.47983 · exp(1.04036 ln(Q))
Total P (kg)	< 10 cfs	11.29
	≥ 10 cfs	1.14260 · exp(0.97455 ln(*Q*))

C-3. Subbasin 24

Existing and allowable loads were calculated for the upper East Branch Black River, east of Spencer (Subbasin 24). This sampling station drains 95.85 square miles and land use/land cover upstream of this station consists primarily of row crops (53%), deciduous forest (34%), pasture/hay (9%), and residential (3%) land uses. One WWTP discharges upstream of Subbasin 24; there are no designated MS4s within the upstream watershed.

C-3.1. Dynamic Load Components (Subbasin 24)

Figure C-7 shows the relationship of sediment source load to flow at Subbasin 24 after dropping the first year to allow for model spin-up. The relationship is approximately linear above 10 cfs. Therefore, the regression was calculated for flows of 10 cfs or greater.

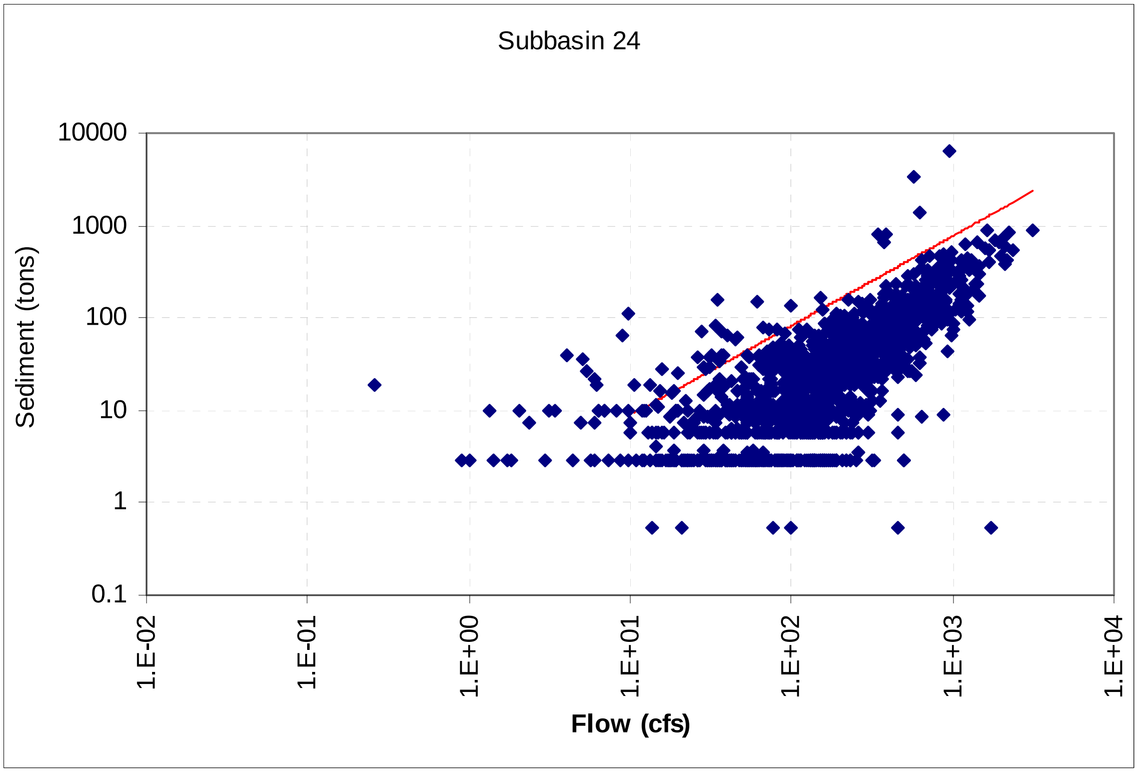

Figure C-7. Relationship of Dynamic Loads of Sediment to Flow at Subbasin 24 under TMDL Allocation Scenario

The equation for the upper prediction limit (U), calculated as for Subbasin 8, is

$$\ln(U) = -0.05745 + 0.97045 \ln(Q).$$

Below a flow of 10 cfs, the regression relationship does not apply. For that flow range, a constant total load limit of 8.82 metric tons/d is applied.

For nitrate, the regression relationship and one-sided 95th percentile upper confidence limit are shown in Table C-8. As with TSS, the regression is only applicable above a flow of 10 cfs, and below 10 cfs a constant daily limit of 46.78 kg is assigned. The equation for the upper confidence limit (kg/d) as a function of flow (cfs) is

$$\ln(U) = 1.00534 + 1.23341 \ln(Q).$$

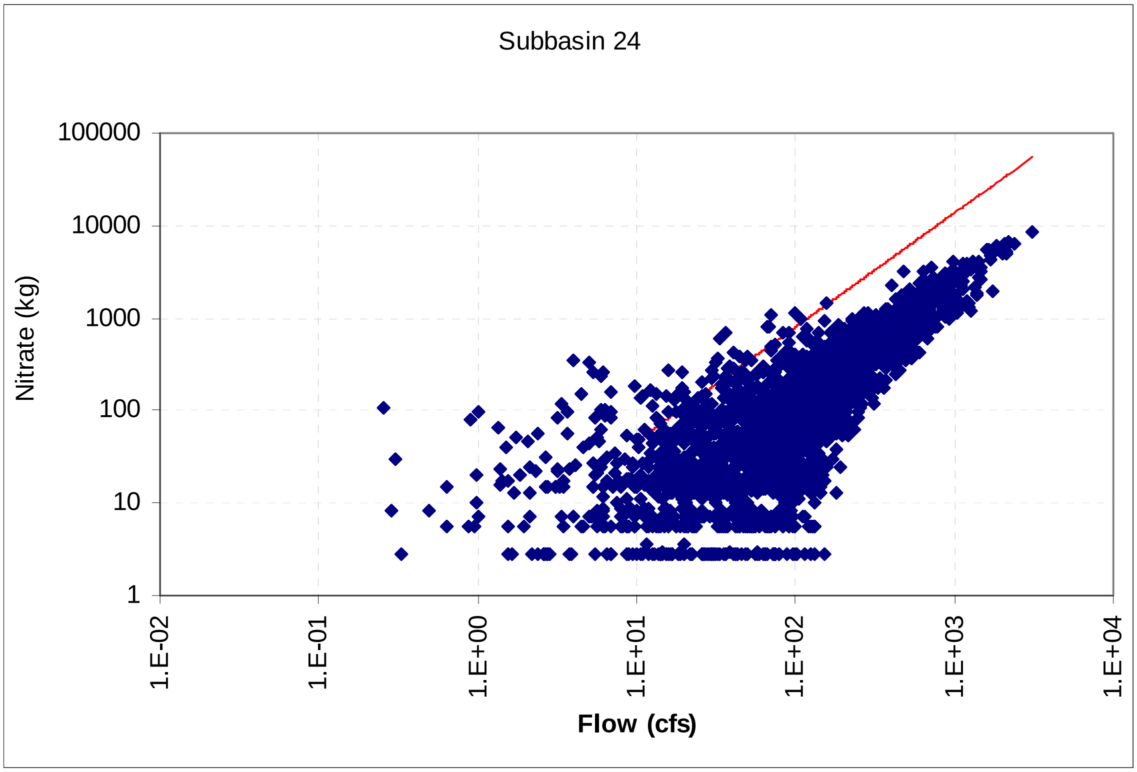

Figure C-8. Relationship of Dynamic Loads of Nitrate to Flow at Subbasin 24 under TMDL Allocation Scenario

For total phosphorus, the regression relationship and one-sided 95th percentile upper confidence limit are shown in Table C-9. As with TSS, the regression is only applicable above a flow of 10 cfs, and below 10 cfs a constant daily limit of 8.61 kg is assigned. The equation for the upper confidence limit (kg/d) as a function of flow (cfs) is

$$\ln(U) = -0.34532 + 1.08479 \ln(Q).$$

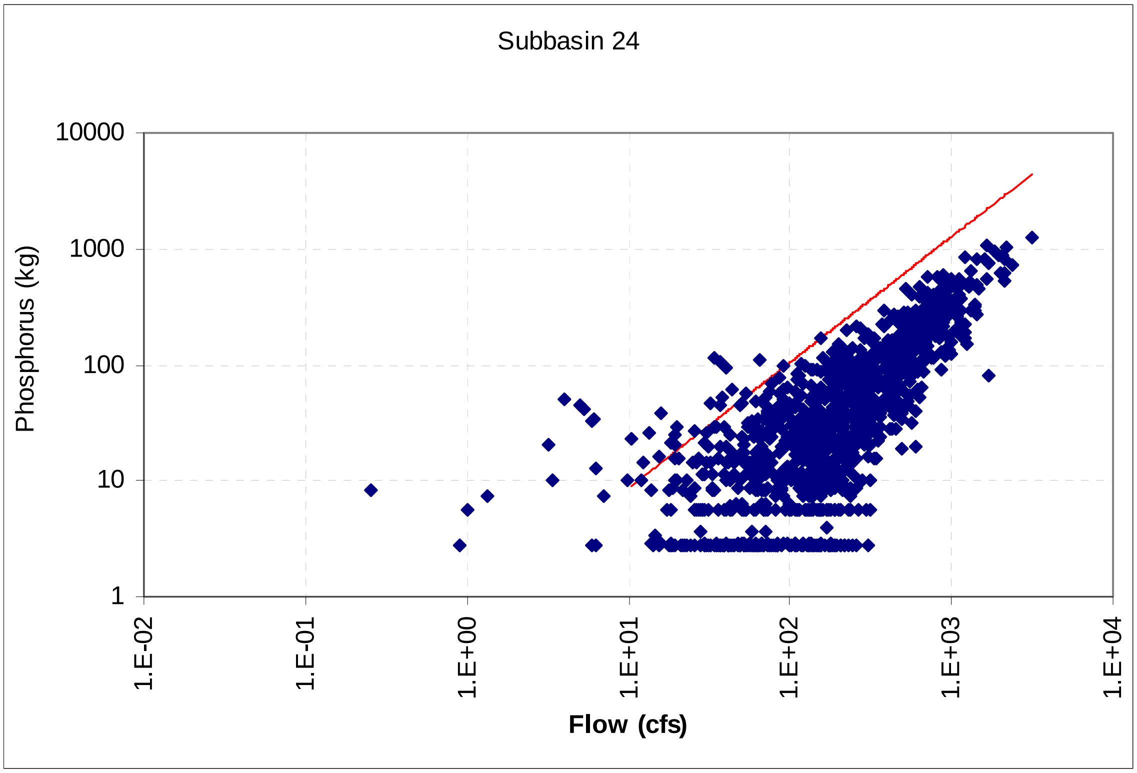

Figure C-9. Relationship of Dynamic Loads of Total Phosphorus to Flow at Subbasin 24 under TMDL Allocation Scenario

C-3.2. Wasteload Allocations (Subbasin 24)

As noted above, there are no wasteload allocations for MS4s in Subbasin 24.

The only WWTP upstream of Subasin 24 is Lodi, which is also upstream of Subbasin 9. Because the WLAs are developed independently of the dynamic load analysis, the WLAs calculated for Lodi in relation to Subbasin 9 are the same as those calculated in relation to Subbasin 24 (see Table C-7 through Table C-9).

C-3.3. Load Allocations (Subbasin 24)

Because there are no MS4s, the load allocations to nonpoint sources in Subbasin 24 are equal to the dynamic load limits (Table C-11).

Table C-11. Load Allocations Upstream of Subbasin 24

Constituent	Flow Regime	Load Allocation (per day)
TSS (MT)	< 10 cfs	8.82
	≥ 10 cfs	$0.94417 \cdot \exp(0.97045 \ln(Q))$
Nitrate (kg)	< 10 cfs	46.71
	≥ 10 cfs	$2.73284 \cdot \exp(1.23341 \ln(Q))$
Total P (kg)	< 10 cfs	8.61
	≥ 10 cfs	$0.707994 \cdot \exp(1.08479 \ln(Q))$