Appendix P
Model Configuration, Calibration and Validation

Basin: New England Coastal

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Watershed Background

The New England Coastal basin was selected as one of the 15 non-pilot application watersheds for the 20 Watershed study. Watershed modeling for the non-pilot areas is accomplished using the SWAT model only, and model calibration and validation results are presented in abbreviated form.

Water Body Characteristics

The New England Coastal basins study unit encompasses parts of western and central Maine, eastern New Hampshire, eastern Massachusetts, most of Rhode Island, and a small part of eastern Connecticut. Important drainage basins include the Kennebec (5,890 mi^2), Androscoggin (3,520 mi^2), Saco (1,700 mi^2), and Merrimack (5,010 mi^2) River Basins in Maine, New Hampshire, and northern Massachusetts, and the Charles (321 mi^2), Taunton (530 mi^2), and Blackstone (335 mi^2) River Basins in Massachusetts and Rhode Island. Mean annual streamflow in these rivers ranges from 302 cubic feet per second (cfs) in the Charles River at Waltham, Massachusetts to 9,080 cfs in the Kennebec River at North Sidney, Maine. Most of these rivers originate in mountainous forested areas and their headwaters are often fast-flowing, cobble and boulder bottom streams. The study unit also contains a large number of natural lakes, many of which are enlarged and controlled by dams.

An estimated 7.8 million people lived in the study unit in 1990. At that time, land use was an estimated 75 percent forested; 11 percent residential, commercial, and industrial; 6 percent agricultural; 5 percent water bodies, and 3 percent other uses. The New England Coastal basins study unit contains a mixture of rugged mountains, narrow to broad valleys, and flat plains. Elevations in the study unit range from sea level along the coast to greater than 6,000 ft in the White Mountains of New Hampshire.

The 20 Watershed models focus on the central and north-central portions of the watershed, encompassing 10 HUC8s and 10,225 mi^2 (Figure 1).

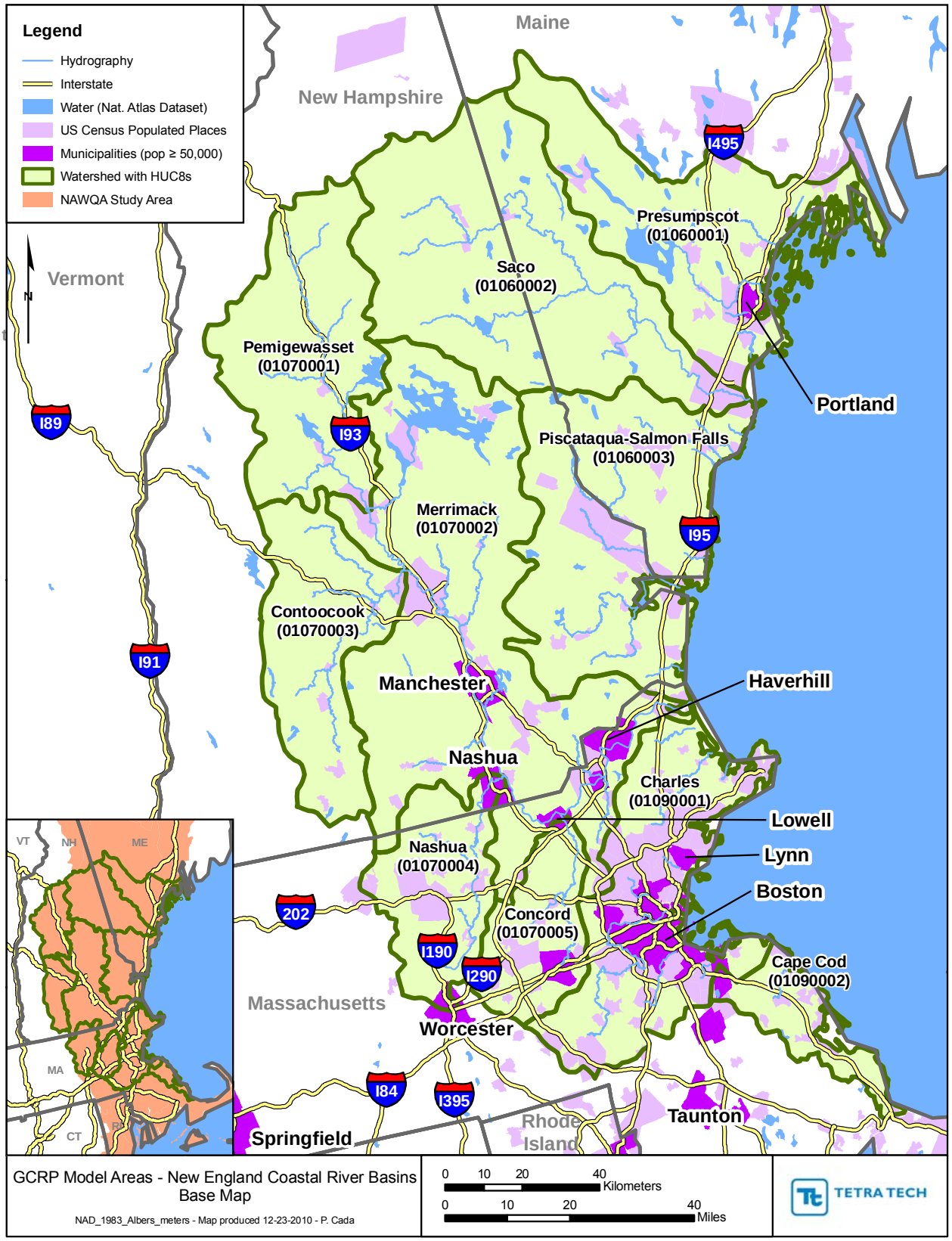

Figure 1. Location of the New England Coastal basin.

Soil Characteristics

Soils in the watershed, as described in STATSGO soil surveys, fall primarily into hydrologic soil groups (HSGs) B (moderately high infiltration capacity) and C (moderate infiltration capacity). SWAT uses information drawn directly from the soils data layer to populate the model.

Land Use Representation

Land use/cover in the watershed is based on the 2001 National Land Cover Database (NLCD) coverage (Figure 2). NLCD land cover classes were aggregated according to the scheme shown in Table 1 for representation in the 20 Watershed model. SWAT uses the built-in hydrologic response unit (HRU) overlay mechanism in the ArcSWAT interface. SWAT HRUs are formed from an intersection of land use and STATSGO major soils. The distribution of land use in the watershed is summarized in Table 2.

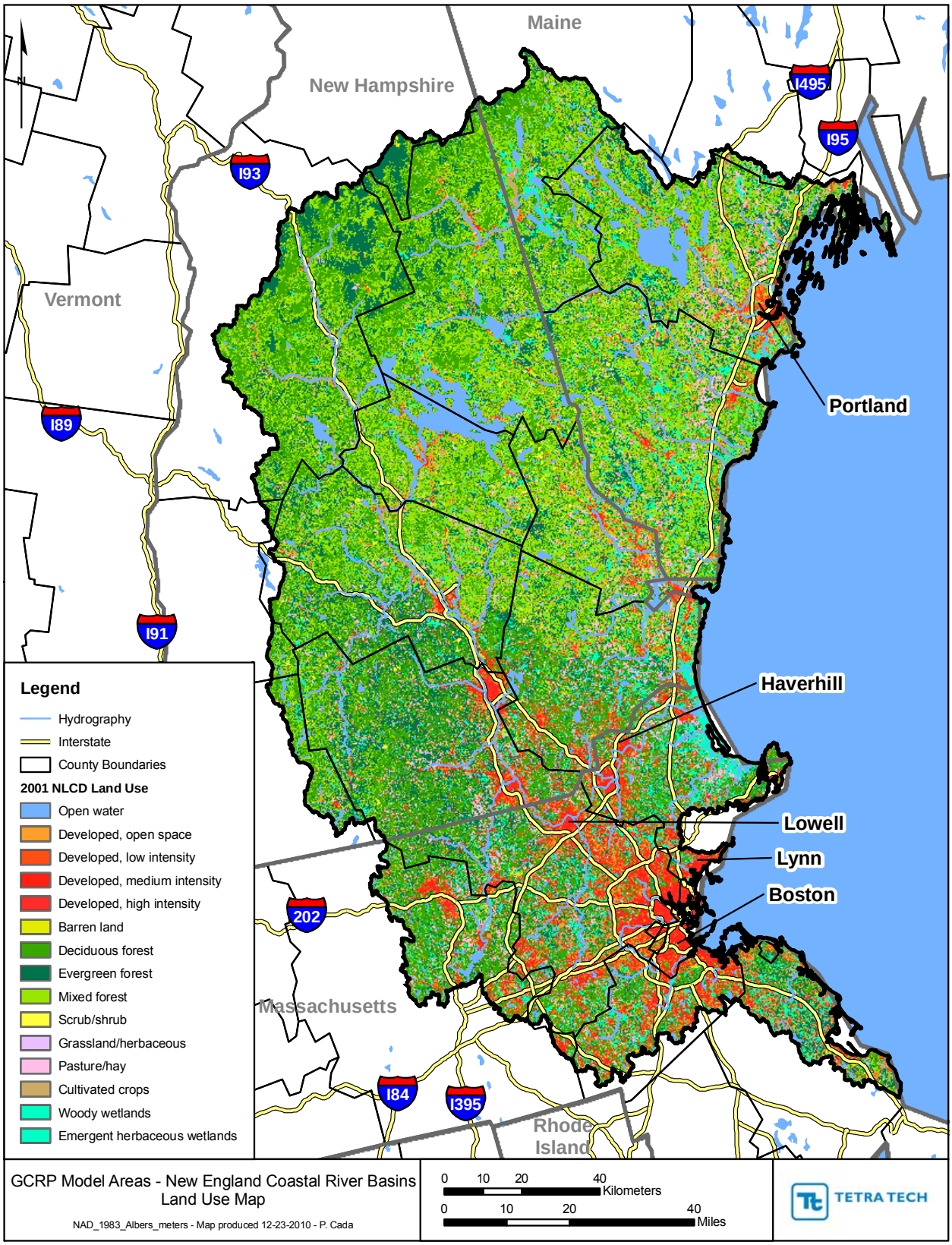

Figure 2. Land use in the New England Coastal basin.

Table 1. Aggregation of NLCD land cover classes

NLCD Class	Comments	SWAT class
11 Water	Water surface area usually accounted for as reach area	WATR
12 Perennial ice/snow		WATR
21 Developed open space		URLD
22 Dev. Low Intensity		URMD
23 Dev. Med. Intensity		URHD
24 Dev. High Intensity		UIDU
31 Barren Land		SWRN
41 Forest	Deciduous	FRSD
42 Forest	Evergreen	FRSE
43 Forest	Mixed	FRST
51-52 Shrubland		RNGB
71-74 Herbaceous Upland		RNGE
81 Pasture/Hay		HAY
82 Cultivated		AGRR
91-97 Wetland	Emergent & woody wetlands	WETF, WETL, WETN
98-99 Wetland	Aquatic bed wetlands (not emergent)	WATR

Table 2. Land use distribution for the New England Coastal basin (2001 NLCD) (mi^2)

HUC 8 watershed	Open water	Developed[a]				Barren land	Forest	Shrubland	Pasture/Hay	Cultivated	Wetland	Total
		Open space	Low density	Medium density	High density							
Presumpscot **01060001**	83.26	74.25	42.86	14.66	7.23	3.73	609.16	27.18	64.23	14.18	74.71	**1,015.46**
Saco **01060002**	50.12	62.75	23.84	5.62	1.54	5.22	1,334.54	52.89	37.79	22.09	105.14	**1,701.54**
Piscataqua-Salmon Falls **01060003**	31.20	102.96	64.17	24.42	8.42	9.72	836.11	49.22	91.23	15.76	150.20	**1,383.41**
Pemigewasset **01070001**	24.92	20.94	9.31	2.81	0.41	1.86	872.63	14.97	9.37	11.35	15.37	**983.95**
Merrimack **01070002**	142.74	144.36	145.01	106.63	24.60	11.15	1,409.87	42.81	124.09	26.07	138.29	**2,315.63**
Contoocook **01070003**	18.68	29.06	11.14	3.10	0.41	1.38	601.47	11.45	29.05	5.15	40.50	**751.40**
Nashua **01070004**	17.57	29.67	33.29	25.19	7.44	1.79	306.44	7.56	38.38	5.37	42.32	**515.02**
Concord **01070005**	12.49	43.57	48.96	42.68	8.72	1.14	158.85	4.20	25.16	3.69	46.13	**395.58**
Charles **01090001**	26.10	98.65	130.76	154.72	57.05	5.11	293.26	8.20	37.65	3.48	126.80	**941.80**
Cape Cod **01090002**	8.46	27.90	27.84	14.32	2.73	3.60	87.27	2.67	5.17	5.33	36.21	**221.50**
Total	**415.54**	**634.11**	**537.19**	**394.16**	**118.58**	**44.71**	**6,509.60**	**221.15**	**462.12**	**112.47**	**775.67**	**10,225.30**

[a]The percent imperviousness applied to each of the developed land uses is as follows: open space (8.22%), low density (32.81%), medium density (60.90%), and high density (87.25%).

Point Sources

There are numerous point source discharges in the watershed. Only the major dischargers, generally defined as those with a design flow greater than 1 MGD are included in the simulation (Table 3). The major dischargers are represented at long-term average flows, without accounting for changes over time or seasonal variations.

Table 3. Major point source discharges in the New England Coastal basin

NPDES ID	Name	Design flow (MGD)	Observed flow (MGD) (1991-2006 average)
ME0101117	SACO WASTEWATER TREATMENT FACI	4.2	2.0
ME0100048	BIDDEFORD CITY OF	2.6	4.9
NH0100668	ROCHESTER WWTF	5.0	2.8
NH0100277	SOMERSWORTH WPCF	2.4	1.5
NH0100871	EXETER WWTF	3.0	2.7
MA0101745	AMESBURY WWTP	1.9	1.8
MA0101427	NEWBURYPORT WW P	3.4	2.6
MA0101621	HAVERHILL WPAF	18.0	10.7
MA0100447	GREATER LAWRENCE SD	52.0	34.2
MA0100633	LOWELL REGIONAL WW UTILITY	32.0	30.1
MA0100668	CONCORD WWTF	1.2	1.4
MA0101711	BILLERICA WWTP	5.5	2.9
NH0100056	DERRY WWTP	4.0	1.8
NH0100170	NASHUA WWTF	16.0	12.1
NH0100161	MERRIMACK WWTF	5.0	70.0
MA0100013	AYER WWTP	1.8	1.2
MA0004561	HOLLINGSWORTH & VOSE CO		2.4
MA0100986	EAST FITCHBURG WWTF	12.3	8.0
MA0100404	MWRA - CLINTON STP	3.0	2.6
MA0100579	MILFORD WWTF	4.3	3.6
NH0100471	MILFORD WWTF	2.2	1.4
NH0100447	MANCHESTER WWTF	34.0	43.3
NH0100901	CONCORD-HALL STREET WWTF	10.1	4.2
NH0100960	WINNIPESAUKEE RIVER BASIN	11.5	5.9
NH0100005	ASHLAND WWTF	1.6	1.0
NH0100706	LINCOLN WWTP	1.5	7.9
NH0000230	MONADNOCK PAPER MILLS, INC.	1.3	1.2
MA0100498	MARLBOROUGH EASTERLY WWTP	5.5	3.4

MA0101001	MAYNARD WWTF	1.5	1.0
MA0101788	HUDSON WWTF	2.7	2.9
MA0100480	MARLBOROUGH WESTERLY WWTP	2.9	3.6
MA0100412	WESTBOROUGH WWTP	7.7	5.2
ME0002321	S D WARREN COMPANY		17.4
MA0100978	MEDFIELD WWTP	1.5	1.3
MA0102598	CHARLES RIVER PCD	4.5	3.5
ME0100633	SOUTH PORTLAND CITY OF	9.3	5.0
ME0100617	SANFORD SEWER DISTRICT	4.4	2.8
NH0100625	HAMPTON WWTP	4.7	2.2
NH0100234	PORTSMOUTH-PIERCE ISLAND WWTP	4.8	47.9
MA0102695	SCITUATE_WWTP	1.6	1.3
MA0100587	PLYMOUTH WWTP	1.8	1.7
ME0100102	BRUNSWICK SEWER DISTRICT	3.9	2.7

Most of these point sources have reasonably complete monitoring for total suspended solids (TSS). Assumptions were made for total nitrogen and total phosphorus depending upon the type of facility. The point sources were initially represented in the model with the median of reported values for total phosphorus, TSS and total nitrogen.

Meteorological Data

The required meteorological time series for the 20 Watershed SWAT simulations are precipitation and air temperature. The 20 Watershed simulations do not include water temperature and uses a degree-day method for snowmelt. SWAT estimates Penmann-Monteith potential evapotranspiration using a statistical weather generator for inputs other than temperature and precipitation. These meteorological time series are drawn from the BASINS4 Meteorological Database (USEPA 2008), which provides a consistent, quality-assured set of nationwide data with gaps filled and records disaggregated. Scenario application requires simulation over 30 years, so the available stations are those with a common 30-year period of record (or one that can be filled from an approximately co-located station) that covers the year 2003. A total of 52 precipitation stations were identified for use in the New England Coastal watershed model with a common period of record of 10/1/1972-9/30/2003 (Table 4). Temperature records are sparser; where these are absent temperature is taken from nearby stations with an elevation correction.

Table 4. Precipitation stations for the New England Coastal watershed model

COOP ID	Name	Latitude	Longitude	Temperature	Elevation (m)
274732	LINCOLN	44.0500	-71.6667	x	267
273530	GRAFTON	43.5667	-71.9500	x	253
170934	BRUNSWICK	43.9000	-69.9333	x	21
199316	WEST MEDWAY	42.1333	-71.4333	x	64
278972	WEARE	43.0847	-71.7382	x	219
270998	BRISTOL	43.6001	-71.7167	x	143
273182	FRANKLIN FALLS DAM	43.4668	-71.6500	x	131

COOP ID	Name	Latitude	Longitude	Temperature	Elevation (m)
275780	NEW DURHAM 3 NNW	43.4833	-71.1833	x	195
278885	WARREN	43.9098	-71.8877	x	216
275013	MACDOWELL DAM	42.9000	-71.9832		293
276550	OTTER BROOK LAKE	42.9501	-72.2332	x	207
274218	FORT SCOTT	43.1830	-71.7500		41
275150	MARLOW	43.1168	-72.2000	x	357
174566	LEWISTON	44.1001	-70.2167		55
190408	BARRE FALLS DAM	42.4334	-72.0332		277
194105	LAWRENCE	42.7001	-71.1667		18
176905	PORTLAND WSFO AP	43.6423	-70.3044		14
190736	BLUE HILL	42.2123	-71.1146		192
190770	BOSTON WSFO AP	42.3606	-71.0105	x	6
272174	DURHAM	43.1500	-70.9500	x	24
271683	CONCORD WSO AIRPORT	43.1954	-71.5010	x	105
192451	EAST WAREHAM	41.7656	-70.6693	x	6
190190	ASHBURNHAM	42.6168	-71.8833	x	335
190860	BROCKTON	42.0500	-71.0000	x	24
192997	FRANKLIN	42.0834	-71.4167	x	73
193505	HAVERHILL	42.7592	-71.0608	x	5
193876	IPSWICH	42.6667	-70.8666	x	24
194313	LOWELL	42.6500	-71.3666		34
194744	MIDDLETON	42.6001	-71.0167	x	27
194760	MILFORD	42.1667	-71.5167		85
195285	NEWBURYPORT 3 WNW	42.8334	-70.9333	x	5
196486	PLYMOUTH-KINGSTON	41.9833	-70.7000		14
199923	WORCESTER WSO AP	42.2673	-71.8760		301
273024	FITZWILLIAM 2 W	42.7833	-72.1833	x	354
274480	LAKEPORT 2	43.5500	-71.4667		152
275211	MASSABESIC LAKE	42.9833	-71.4000		76
275639	MOUNT WASHINGTON	44.2668	-71.2999	x	1909
275712	NASHUA 2 NNW	42.7833	-71.4832	x	40
276818	PINKHAM NOTCH	44.2668	-71.2500		612
276945	PLYMOUTH	43.7833	-71.6500		201
177479	SANFORD 2 NNW	43.4668	-70.7832	x	85

COOP ID	Name	Latitude	Longitude	Temperature	Elevation (m)
179314	WEST BUXTON 2 NNW	43.7001	-70.6166	x	46
170844	BRIDGTON 3 NW	44.0834	-70.7332	x	171
190535	BEDFORD	42.4833	-71.2832	x	49
275629	MOUNT SUNAPEE	43.3334	-72.0832	x	387
196783	READING	42.5168	-71.1333	x	27
193624	HINGHAM	42.2333	-70.9167	x	9
272800	EPPING	43.0333	-71.0832	x	49
270681	BENTON 5 SW	44.0333	-71.9333	x	366
172238	EAST HIRAM	43.8833	-70.7500	x	161
198757	WALPOLE 2	42.1667	-71.2500	x	50

Watershed Segmentation

The New England Coastal basin was divided into 90 subwatersheds for the purposes of modeling (Figure 3). Saco River at USGS 01066000 was chosen for initial calibration. The model encompasses the complete watershed and does not require specification of any upstream boundary conditions for application.

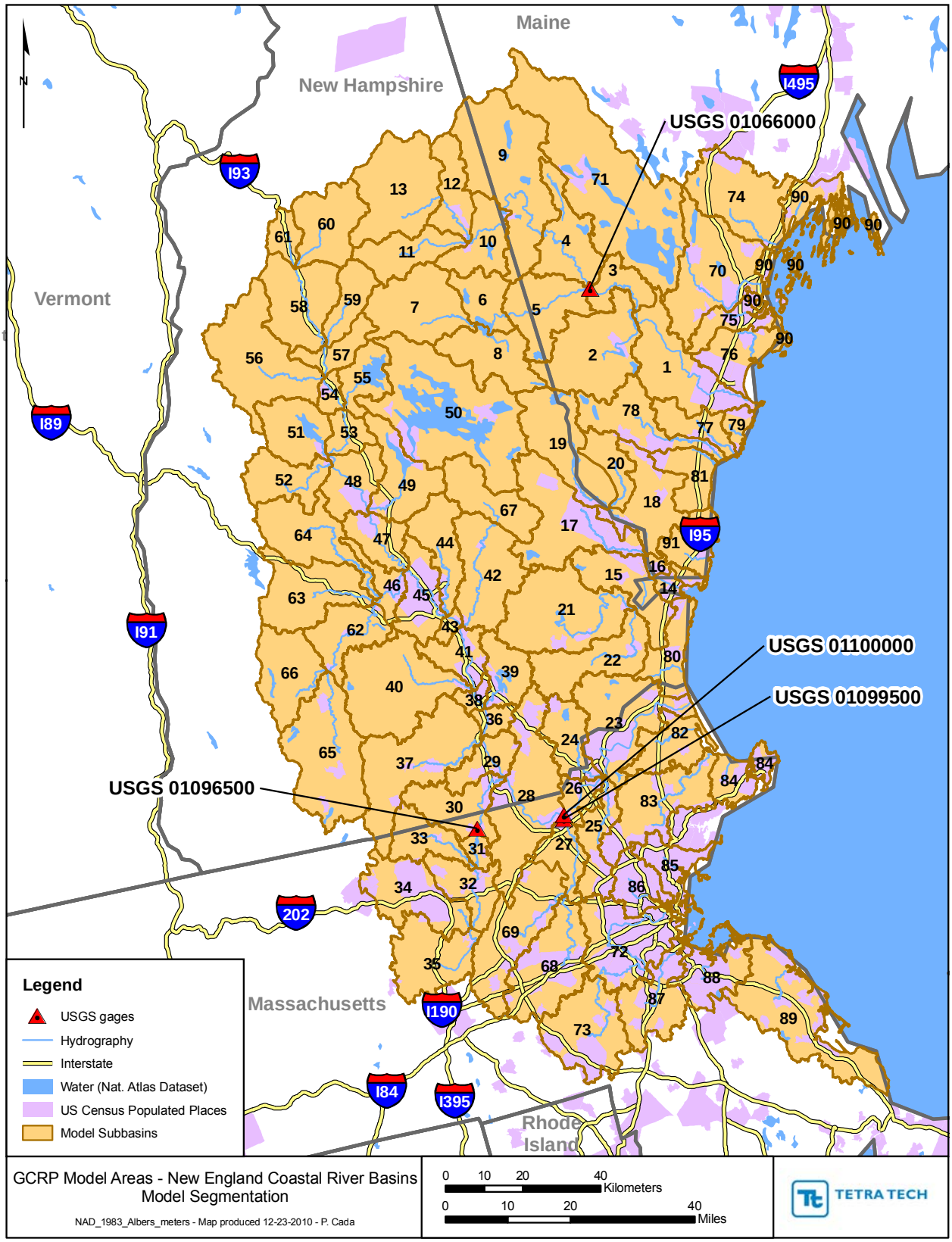

Figure 3. Model segmentation and USGS stations utilized for the New England Coastal basin.

Calibration Data and Locations

The specific site chosen for initial calibration was the Saco River at Cornish, Maine a flow and water quality monitoring location that approximately coincides with the mouth of an 8-digit HUC at its outflow to the Saco River. The Saco River watershed was selected because there is a good set of flow and water quality data available and the watershed lacks major point sources and impoundments. Additional calibration and validation was pursued at multiple locations (Table 5). Parameters derived on the Saco River were not fully transferable to other portions of the New England Coastal basin, and additional calibration was conducted at multiple gage locations.

Table 5. Calibration and validation locations in the New England Coastal basin

Station name	USGS ID	Drainage area (mi^2)	Hydrology calibration	Water quality calibration
Saco River at Cornish, Maine	01066000	1293	x	x
Nashua River at Eat Pepperel, MA	01096500	435	x	
Concord River at River Meadow Brook at Lowell, MA	01099500	400	x	
Merrimack River below Concord River at Lowell, MA	01100000	4635	x	x

The model hydrology calibration period was set to Water Years 1993-2003 (within the 32-year period of record for modeling). Hydrologic validation was then performed on Water Years 1983-1993. Water quality calibration used calendar years 1993-2003, while validation used 1983-1993.

SWAT Modeling

Assumptions

Hydrology Calibration

A spatial calibration approach was adopted for GCRP-SWAT modeling for the New England Coastal basin. A systematic adjustment of parameters has been adopted and some adjustments are applied throughout the basin. Most of the calibration efforts were geared toward getting a closer match between simulated and observed flows at the outlet of calibration focus area.

Land Use / Soil / Slope Definition

A 5/10/5 percent threshold was used for land use/soil/slope in the SWAT model while defining the HRUs. Urban land use classes were exempted from the HRU overlay thresholds.

The calibration focus area (Saco River) includes nine subwatersheds and is generally representative of the general land use characteristics of the overall watershed. The parameters were adjusted within the practical range to obtain reasonable fit between the simulated and measured flows in terms of Nash-Sutcliffe modeling efficiency and the high flow and low flow components as well as the seasonal flows.

The water balance of whole New England Coastal basin predicted by the SWAT model over the 32-year simulation period is as follows:

```
PRECIP =   1188.0 MM
SNOW FALL =  250.83 MM
SNOW MELT =   232.97 MM
SUBLIMATION =    16.71 MM
SURFACE RUNOFF Q =   236.32 MM
LATERAL SOIL Q =  144.44 MM
TILE Q =     0.00 MM
GROUNDWATER (SHAL AQ) Q =   214.89 MM
REVAP (SHAL AQ => SOIL/PLANTS) =   20.61 MM
DEEP AQ RECHARGE =    29.40 MM
TOTAL AQ RECHARGE =  265.08 MM
TOTAL WATER YLD =   571.26 MM
PERCOLATION OUT OF SOIL =  241.22 MM
ET =    555.8 MM
PET =   1041.6MM
TRANSMISSION LOSSES =    24.39 MM
```

Hydrologic calibration adjustments focused on the following parameters:

- CN2 (initial SCS runoff curve number for moisture condition II)
- ESCO (soil evaporation compensation factor)
- SURLAG (surface runoff lag coefficient)
- SOL_AWC (available water capacity of the soil layer, mm water/mm of soil)
- ALPHA_BF (baseflow alpha factor, days)
- GW_DELAY (groundwater delay time, days)

- GWQMIN (threshold depth of water in the shallow aquifer required for return flow to occur, mm)
- GW_REVAP (groundwater "revap" coefficient)
- CH_N1 (Manning's "n" value for tributary channels)
- CH_N2 (Manning's "n" value for main channels)

Calibration results for the Saco River are summarized in Figure 4, Figure 5, Figure 6, Figure 7 and Table 6.

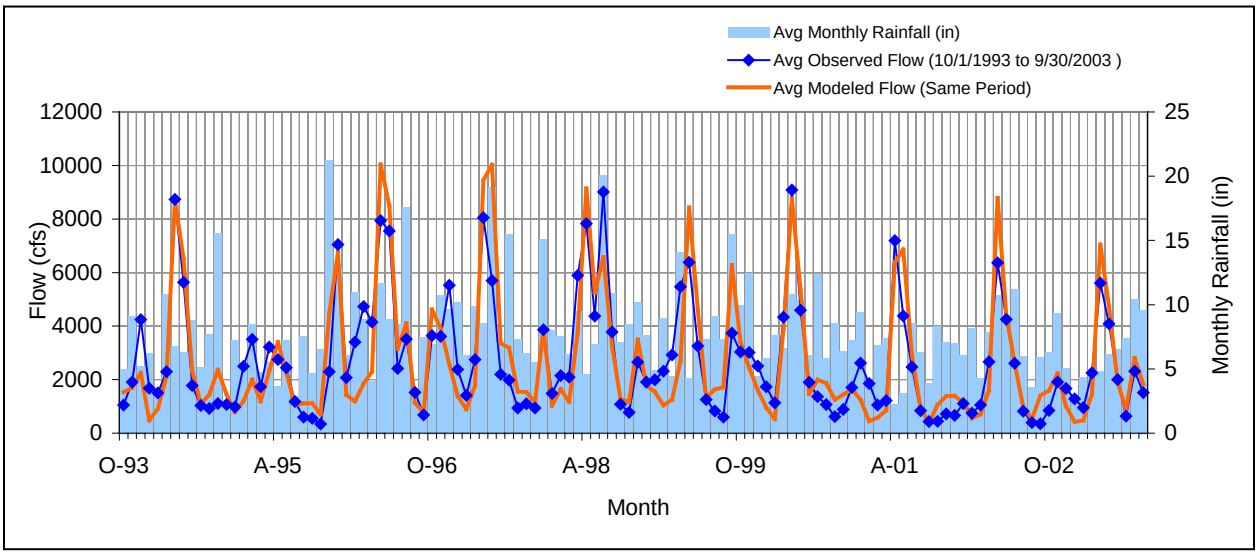

Figure 4. Mean monthly flow at USGS 01066000 Saco River at Cornish, Maine – calibration period.

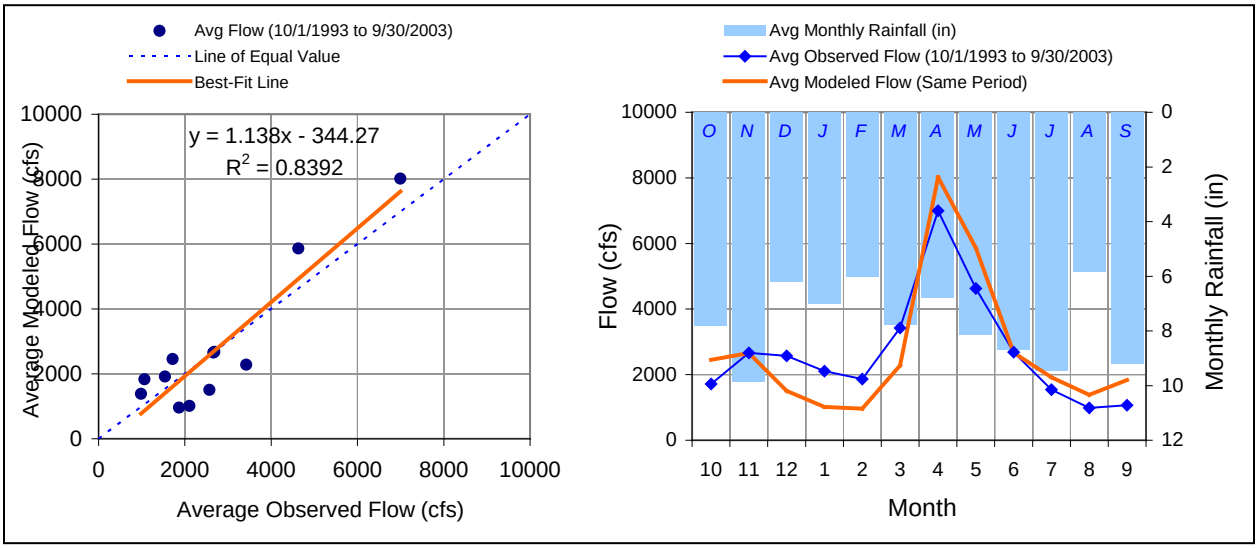

Figure 5. Seasonal regression and temporal aggregate at USGS 01066000 Saco River at Cornish, Maine – calibration period.

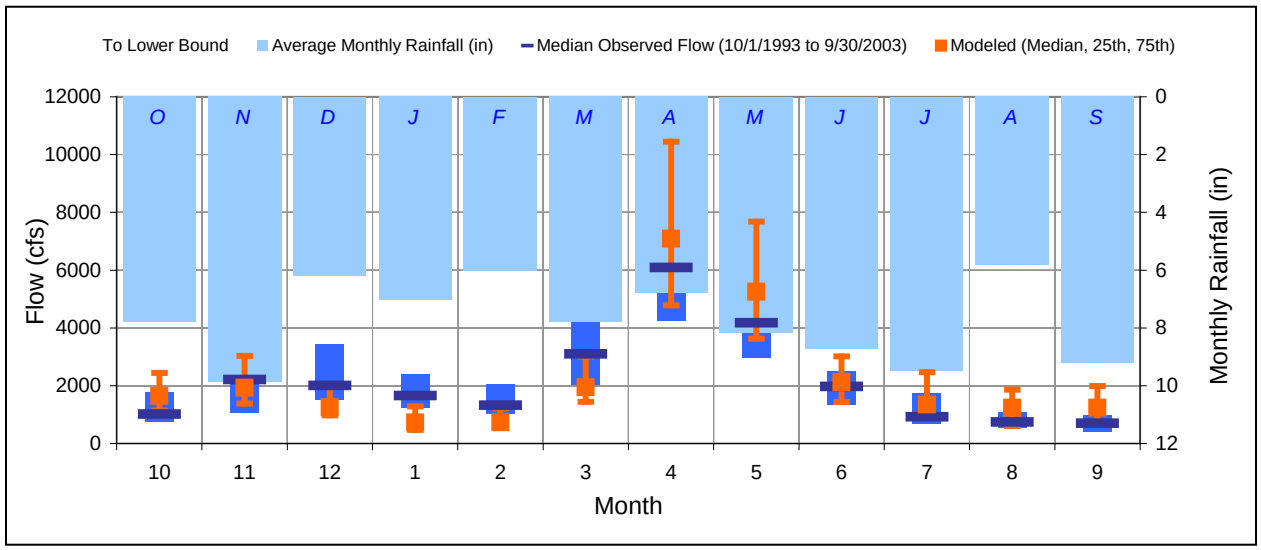

Figure 6. Seasonal medians and ranges at USGS 01066000 Saco River at Cornish, Maine – calibration period.

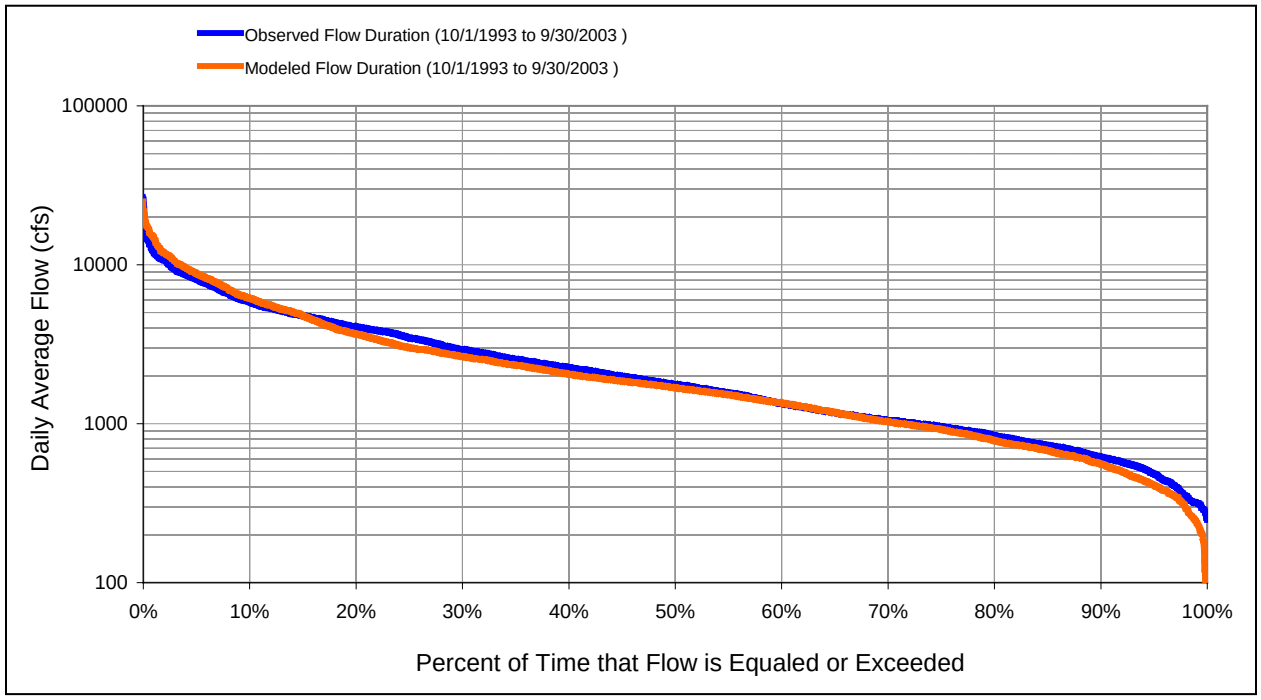

Figure 7. Flow exceedance at USGS 01066000 Saco River at Cornish, Maine – calibration period.

Table 6. Summary statistics at USGS 01066000 Saco River at Cornish, Maine – calibration period

SWAT Simulated Flow		Observed Flow Gage	
REACH OUTFLOW FROM OUTLET(S) 4, 5 10-Year Analysis Period: 10/1/1993 - 9/30/2003 Flow volumes are (inches/year) for upstream drainage area		USGS 01066000 Saco River at Cornish, Maine Hydrologic Unit Code: 1060002 Latitude: 43.80805556 Longitude: -70.7816667 Drainage Area (sq-mi): 1293	
Total Simulated In-stream Flow:	**28.52**	Total Observed In-stream Flow:	**28.21**
Total of simulated highest 10% flows:	**10.55**	Total of Observed highest 10% flows:	**9.38**
Total of Simulated lowest 50% flows:	**5.01**	Total of Observed Lowest 50% flows:	**5.17**
Simulated Summer Flow Volume (months 7-9):	**4.53**	Observed Summer Flow Volume (7-9):	**3.17**
Simulated Fall Flow Volume (months 10-12):	**5.82**	Observed Fall Flow Volume (10-12):	**6.12**
Simulated Winter Flow Volume (months 1-3):	**3.71**	Observed Winter Flow Volume (1-3):	**6.44**
Simulated Spring Flow Volume (months 4-6):	**14.45**	Observed Spring Flow Volume (4-6):	**12.48**
Total Simulated Storm Volume:	**6.37**	Total Observed Storm Volume:	**6.11**
Simulated Summer Storm Volume (7-9):	**1.17**	Observed Summer Storm Volume (7-9):	**0.83**
Errors (Simulated-Observed)	*Error Statistics*	*Recommended Criteria*	
Error in total volume:	1.08	10	
Error in 50% lowest flows:	-3.20	10	
Error in 10% highest flows:	12.54	15	
Seasonal volume error - Summer:	**42.85**	**30**	
Seasonal volume error - Fall:	-4.86	30	
Seasonal volume error - Winter:	**-42.36**	**30**	
Seasonal volume error - Spring:	15.83	30	
Error in storm volumes:	4.18	20	
Error in summer storm volumes:	39.96	50	
Nash-Sutcliffe Coefficient of Efficiency, E:	0.611	Model accuracy increases	
Baseline adjusted coefficient (Garrick), E':	0.471	as E or E' approaches 1.0	

Hydrology Validation

Hydrology validation for Saco River was performed for the period 10/1/1983 through 9/30/1993. Results are presented in below. The validation achieves a moderately high coefficient of model fit efficiency, but is over on summer flow volumes (Figure 8, Figure 9, Figure 10, Figure 11 and Table 7).

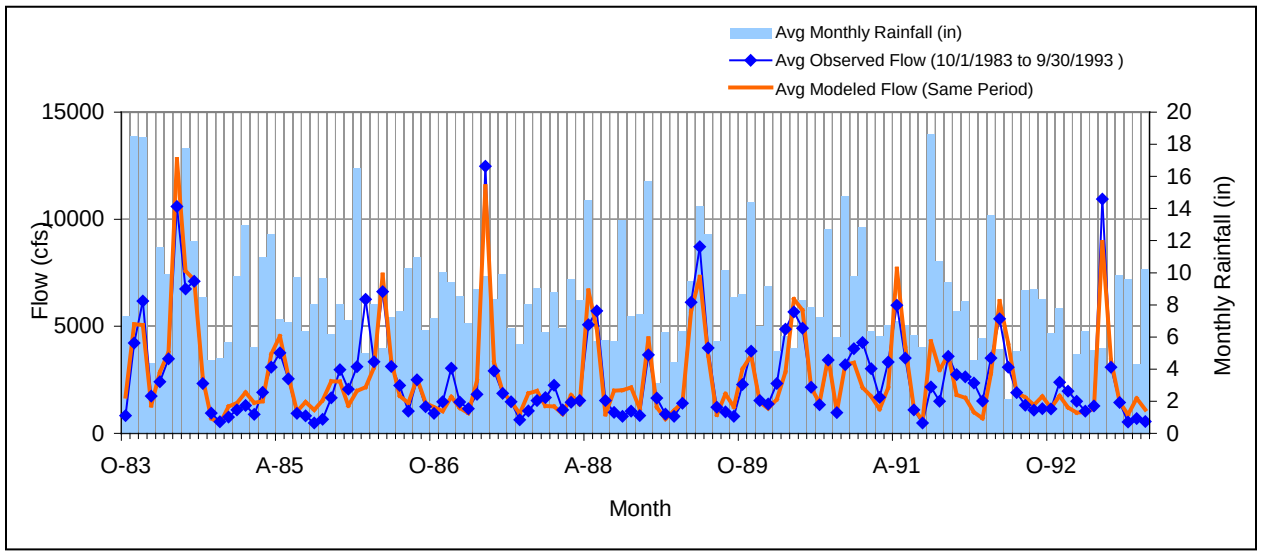

Figure 8. Mean monthly flow at USGS 01066000 Saco River at Cornish, Maine – validation period.

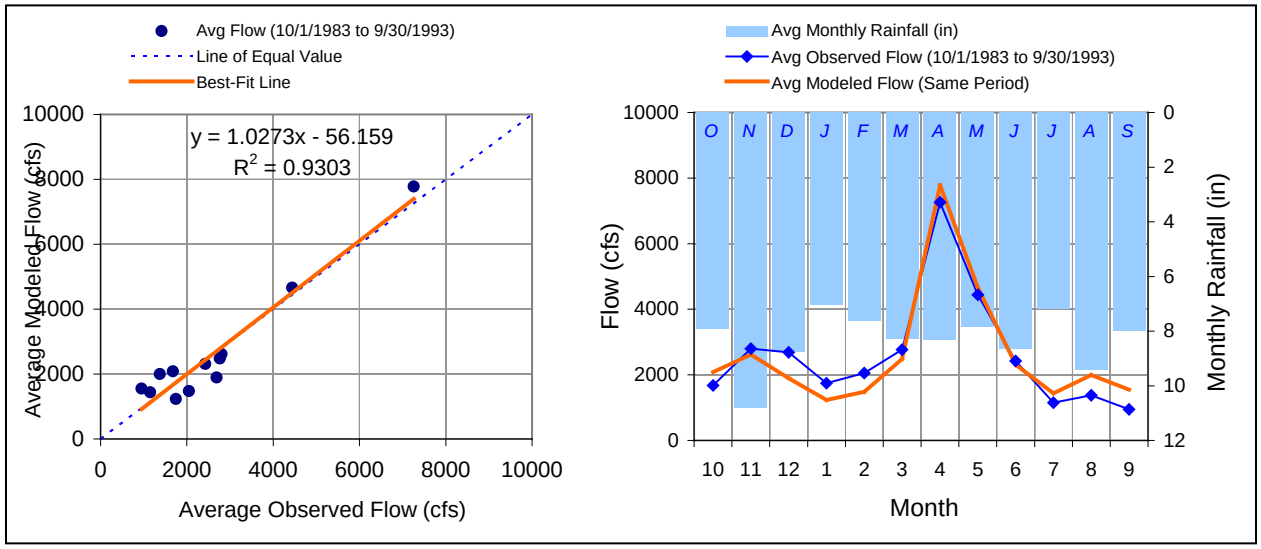

Figure 9. Seasonal regression and temporal aggregate at USGS 01066000 Saco River at Cornish, Maine – validation period.

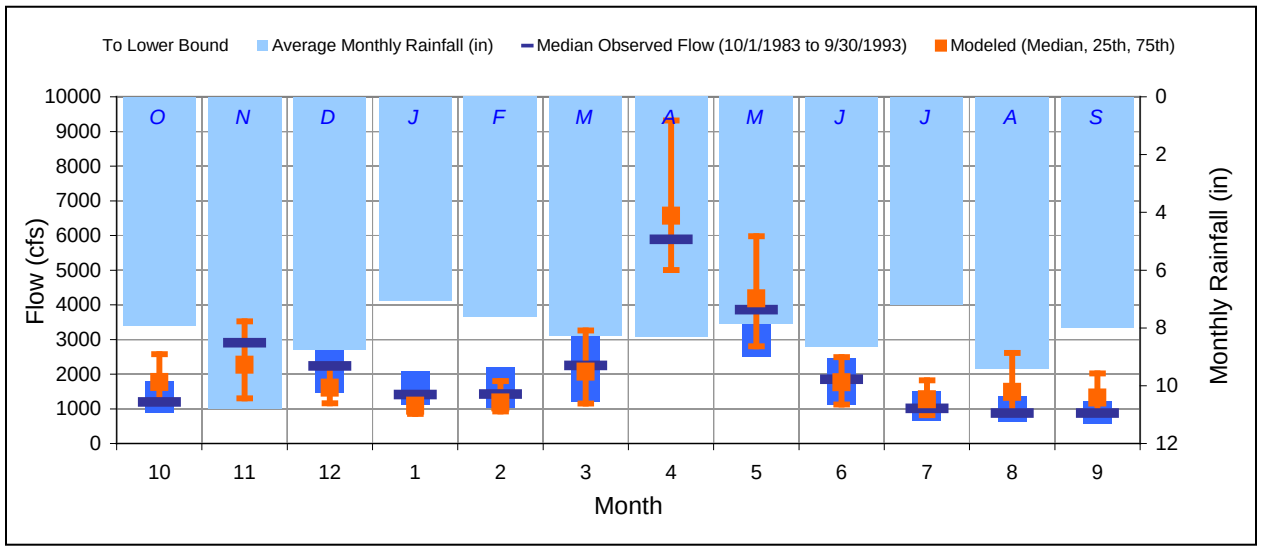

Figure 10. Seasonal medians and ranges at USGS 01066000 Saco River at Cornish, Maine – validation period.

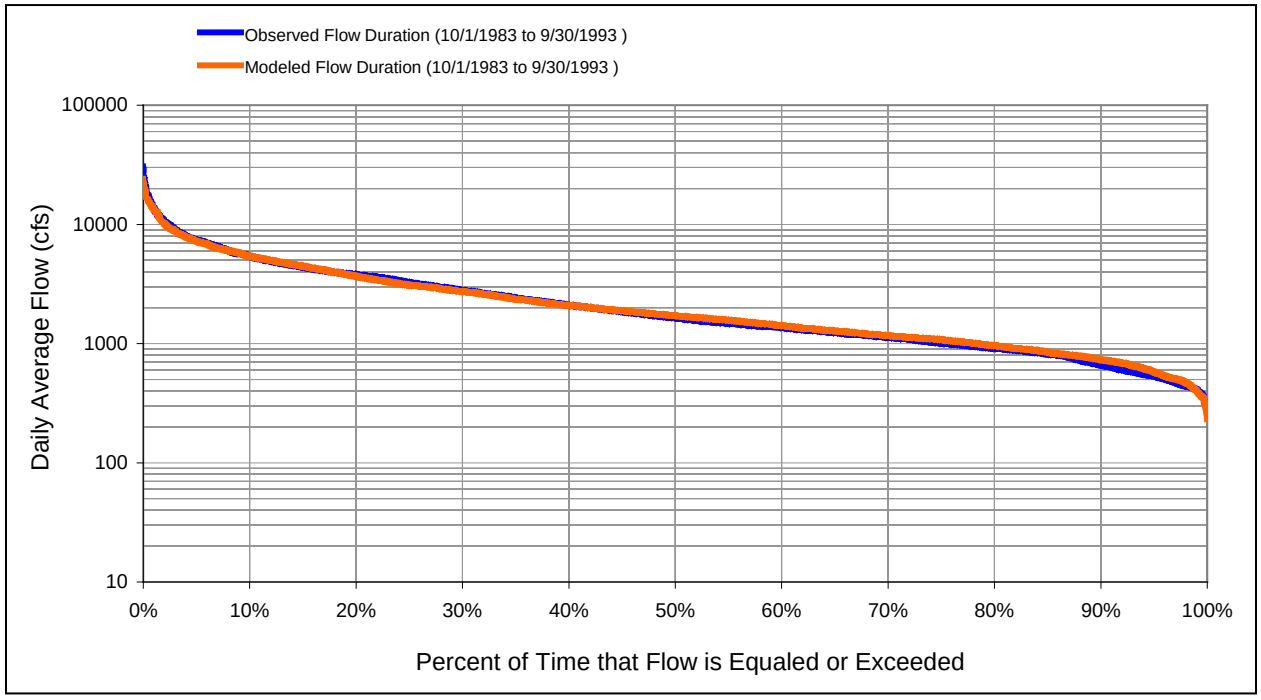

Figure 11. Flow exceedance at USGS 01066000 Saco River at Cornish, Maine – validation period.

Table 7. Summary statistics at USGS 01066000 Saco River at Cornish, Maine – validation period

SWAT Simulated Flow		Observed Flow Gage	
REACH OUTFLOW FROM OUTLET(S) 4, 5 10-Year Analysis Period: 10/1/1983 - 9/30/1993 Flow volumes are (inches/year) for upstream drainage area		USGS 01066000 Saco River at Cornish, Maine Hydrologic Unit Code: 1060002 Latitude: 43.80805556 Longitude: -70.7816667 Drainage Area (sq-mi): 1293	
Total Simulated In-stream Flow:	**27.57**	Total Observed In-stream Flow:	**27.39**
Total of simulated highest 10% flows:	**9.12**	Total of Observed highest 10% flows:	**9.32**
Total of Simulated lowest 50% flows:	**5.69**	Total of Observed Lowest 50% flows:	**5.35**
Simulated Summer Flow Volume (months 7-9):	**4.40**	Observed Summer Flow Volume (7-9):	**3.07**
Simulated Fall Flow Volume (months 10-12):	**5.81**	Observed Fall Flow Volume (10-12):	**6.31**
Simulated Winter Flow Volume (months 1-3):	**4.51**	Observed Winter Flow Volume (1-3):	**5.69**
Simulated Spring Flow Volume (months 4-6):	**12.86**	Observed Spring Flow Volume (4-6):	**12.31**
Total Simulated Storm Volume:	**5.75**	Total Observed Storm Volume:	**6.39**
Simulated Summer Storm Volume (7-9):	**1.04**	Observed Summer Storm Volume (7-9):	**0.79**
Errors (Simulated-Observed)	*Error Statistics*	*Recommended Criteria*	
Error in total volume:	0.67	10	
Error in 50% lowest flows:	6.45	10	
Error in 10% highest flows:	-2.12	15	
Seasonal volume error - Summer:	**43.06**	**30**	
Seasonal volume error - Fall:	-7.98	30	
Seasonal volume error - Winter:	-20.75	30	
Seasonal volume error - Spring:	4.43	30	
Error in storm volumes:	-9.91	20	
Error in summer storm volumes:	31.54	50	
Nash-Sutcliffe Coefficient of Efficiency, E:	0.764	Model accuracy increases	
Baseline adjusted coefficient (Garrick), E':	0.555	as E or E' approaches 1.0	

Hydrology Results for Larger Watershed

As described above, parameters determined for the gage at Saco River were initially transferred to other gages in the watershed. However, changes to subbasin level parameter were required to fit the model to the observed flows. In all, calibration and validation was pursued at a total of eight gages throughout the watershed. Results of the calibration and validation exercise are summarized in Table 8 and Table 9, respectively. Calibration and validation results were acceptable at most gages.

Table 8. Summary statistics (percent error): all Stations - calibration period

Station	01066000	01096500	01099500	01100000
Error in total volume:	1.08	-7.58	-4.83	1.83
Error in 50% lowest flows:	-3.20	-26.88	7.26	4.19
Error in 10% highest flows:	12.54	-2.19	-6.16	-1.16
Seasonal volume error - Summer:	42.85	14.23	58.91	63.71
Seasonal volume error - Fall:	-4.86	2.20	25.28	19.04
Seasonal volume error - Winter:	-42.36	-20.66	-21.25	-22.06
Seasonal volume error - Spring:	15.83	-5.49	-19.03	-3.67
Error in storm volumes:	4.18	-18.32	2.38	-1.23
Error in summer storm volumes:	39.96	6.63	44.46	48.94
Nash-Sutcliffe Coefficient of Efficiency, E:	0.611	0.627	0.715	0.714
Baseline adjusted coefficient (Garrick), E':	0.471	0.455	0.520	0.514

Table 9. Summary statistics (percent error): all stations - validation period

Station	01066000	01096500	01099500	01100000
Error in total volume:	0.67	-6.51	-9.06	-8.01
Error in 50% lowest flows:	6.45	-17.04	-8.56	-2.95
Error in 10% highest flows:	-2.12	-7.27	-1.91	-15.94
Seasonal volume error - Summer:	43.06	29.39	52.96	63.08
Seasonal volume error - Fall:	-7.98	0.24	8.74	3.27
Seasonal volume error - Winter:	-20.75	-16.04	-28.69	-30.46
Seasonal volume error - Spring:	4.43	-13.04	-21.37	-20.07
Error in storm volumes:	-9.91	-25.22	0.61	-17.38
Error in summer storm volumes:	31.54	-0.50	38.02	32.46
Nash-Sutcliffe Coefficient of Efficiency, E:	0.764	0.700	0.759	0.719
Baseline adjusted coefficient (Garrick), E':	0.555	0.487	0.508	0.458

Water Quality Calibration and Validation

Initial calibration and validation of water quality was done on the Saco River (USGS 01066000), using 1993-2003 for calibration and 1983-1993 for validation. As with hydrology, calibration was performed on the later period as this better reflects the land use included in the model.

Calibration adjustments for sediment focused on the following parameters:

- SPCON (linear parameter for estimating maximum amount of sediment that can be re-entrained during channel sediment routing)

- SPEXP (exponential parameter for estimating maximum amount of sediment that can be re-entrained during channel sediment routing)
- CH_COV (channel cover factor)
- CH_EROD (channel erodibility factor)
- USLE_P (USLE support practice factor)

Simulated and estimated sediment loads at the Saco River station for both the calibration and validation periods are shown in Figure 12 and statistics for the two periods are provided separately in Table 10. The key statistic in Table 10 is the relative percent error, which shows the error in the prediction of monthly load normalized to the estimated load. Table 10 also shows the relative average absolute error, which is the average of the relative magnitude of errors in individual monthly load predictions. This number is inflated by outlier months in which the simulated and estimated loads differ by large amounts (which may be as easily due to uncertainty in the estimated load due to limited data as to problems with the model) and the third statistic, the relative median absolute error, is likely more relevant and shows better agreement.

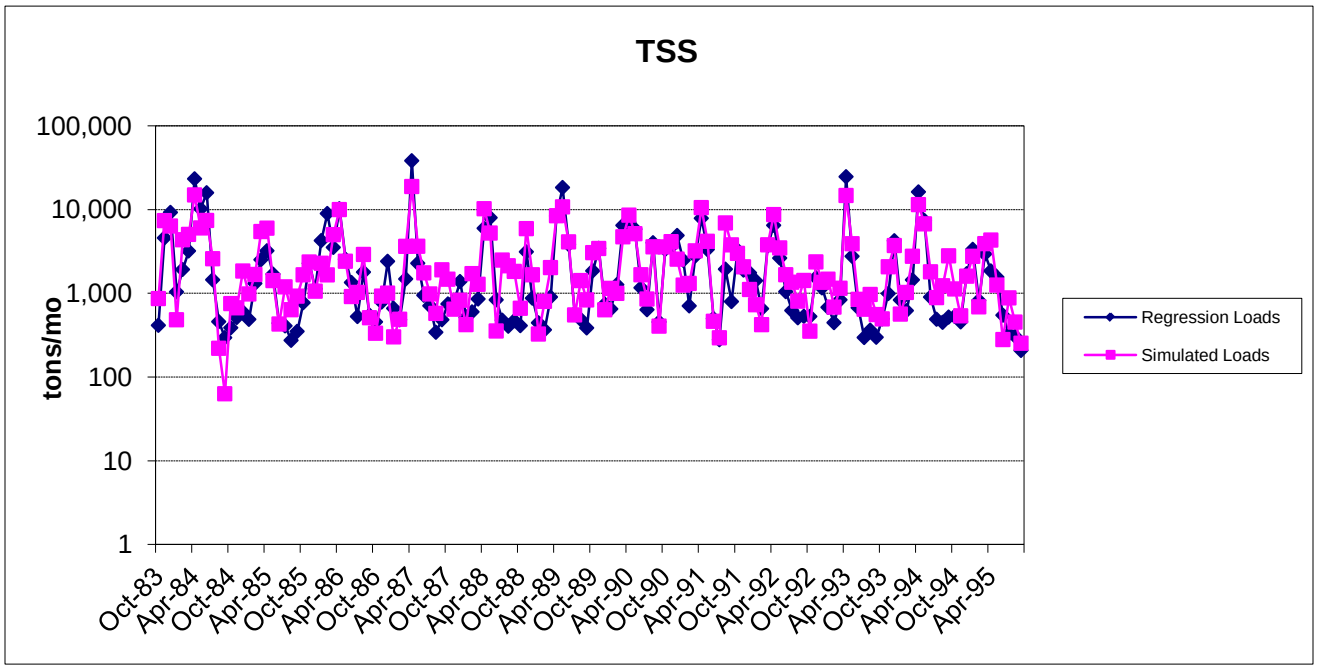

Figure 12. Fit for monthly load of TSS at USGS 01066000 Saco River at Cornish, Maine.

Table 10. Model fit statistics (observed minus predicted) for monthly sediment loads using stratified regression at USGS 01066000 Saco River at Cornish, Maine

Statistic	Calibration period (1993-1995)	Validation period (1983-1993)
Relative Percent Error	-9.0%	3.2%
Relative Average Absolute Error	39.9%	45.9%
Relative Median Absolute Error	26.2%	18.8%

Calibration adjustments for total phosphorus and total nitrogen focused on the following parameters:

- RHOQ (algal respiration rate at 20° C)
- PHOSKD (phosphorus soil partitioning coefficient)
- PSP (phosphorus availability index)
- RS2 (benthic source rate for dissolved P in the reach at 20° C)
- RS5 (organic P settling rate in the reach at 20° C)
- BC4 (rate constant for mineralization of organic P to dissolved P in the reach at 20° C)
- RS4 (rate coefficient for organic N settling in the reach at 20° C)

Results for the phosphorus simulation are shown in Figure 13 and Table 11. Results for the nitrogen simulation are shown in Figure 14 and Table 12. The model fit is generally acceptable.

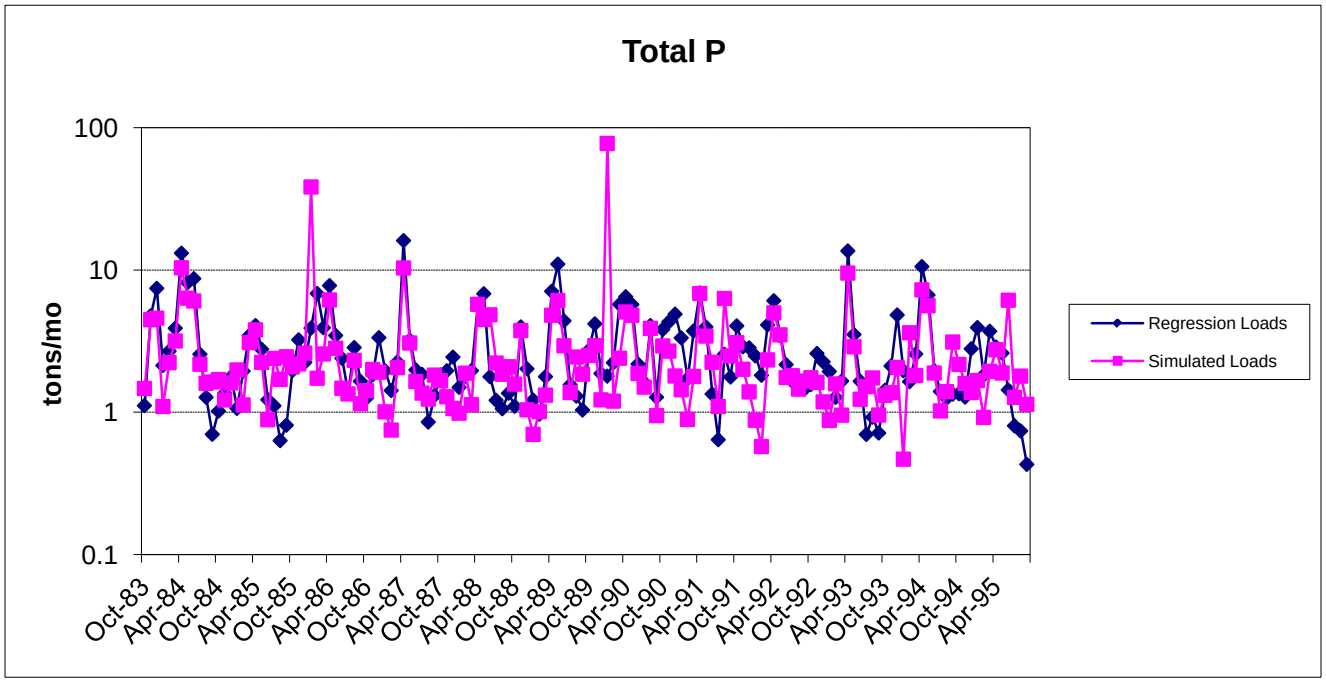

Figure 13. Fit for monthly load of total phosphorus at USGS 01066000 Saco River at Cornish, Maine.

Table 11. Model fit statistics (observed minus predicted) for monthly phosphorus loads using stratified regression at USGS 01066000 Saco River at Cornish, Maine

Statistic	Calibration period (1993-1995)	Validation period (1983-1993)
Relative Percent Error	9.6%	-11.5%
Average Absolute Error	48.5%	33.5%
Median Absolute Error	62.0%	23.6%

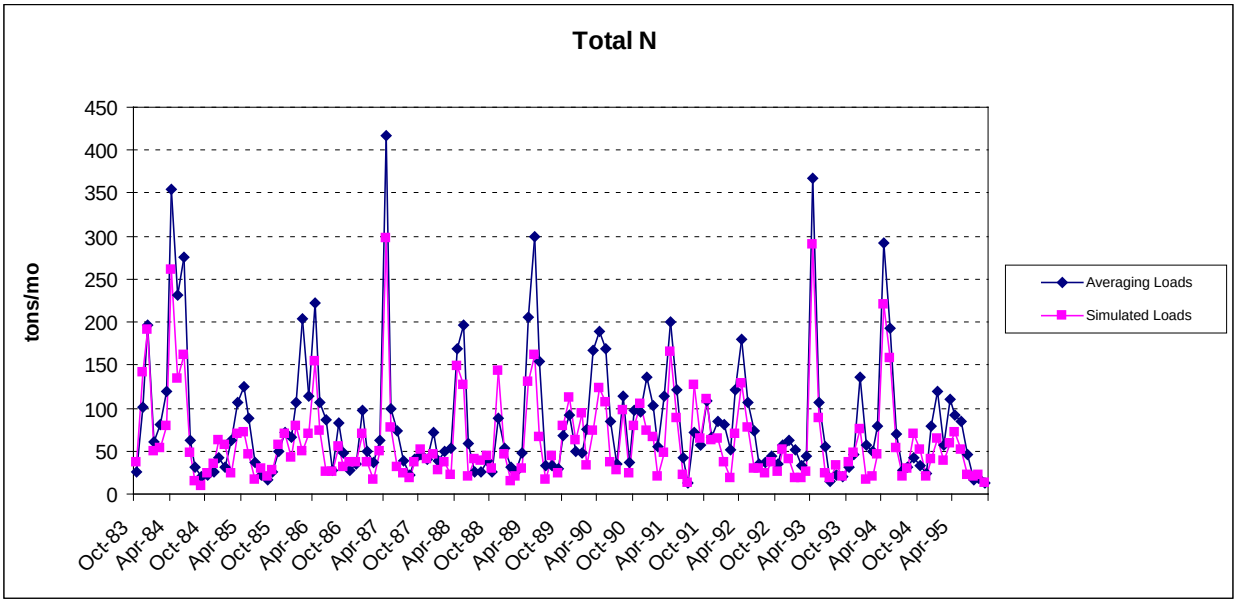

Figure 14. Fit for monthly load of total nitrogen at USGS 01066000 Saco River at Cornish, Maine.

Table 12. Model fit statistics (observed minus predicted) for monthly total nitrogen loads using averaging estimator at USGS 01066000 Saco River at Cornish, Maine

Statistic	Calibration period (1993-1995)	Validation period (1983-1993)
Relative Percent Error	27.5%	26.3%
Average Absolute Error	34.4%	29.9%
Median Absolute Error	34.6%	22.9%

Water Quality Results for Larger Watershed

As with hydrology, a spatial calibration approach was adopted. Saco River watershed SWAT model parameters for water quality were transferred to other portions of the watershed with necessary changes to subbasin level parameters. Summary statistics for the SWAT water quality calibration and validation at other stations in the watershed are provided in Table 13 and Table 14.

Table 13. Summary statistics for water quality at all stations – calibration period 1993-2003

Station	01066000	01100000
Relative Percent Error TSS Load	-9.0%	19.9%
Relative Percent Error TP Load	9.6%	-16.2%
Relative Percent Error TN Load	27.5%	-23.7%

Table 14. Summary statistics for water quality at all stations – validation period 1983-1993

Station	01066000	01100000
Relative Percent Error TSS Load	3.2%	-
Relative Percent Error TP Load	-11.5%	-
Relative Percent Error TN Load	26.3%	-

References

USEPA. 2008. Using the BASINS Meteorological Database (Version 2006). BASINS Technical Note 10. Office of Water, U.S. Environmental Protection Agency, Washington, DC.