Draft Tualatin Subbasin TMDL

Appendix 3B
Tualatin River Total Maximum Daily Loads for Total Phosphorus (4/20/2009) Phosphorus Control Period

State of Oregon
Department of Environmental Quality

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Tualatin River TMDL for Total Phosphorus

(4/20/2009)

1.0 Phosphorus Control Period

In its application for renewal of its NPDES permit, Clean Water Services (District) requested that the Department of Environmental Quality (DEQ) modify the time period for the application of the phosphorus TMDL to exclude the months of September and October. The modification request was based on a combination of physical factors including currently managed stream flows, residence time, stream temperatures, and solar insolation that combine to limit the amount of algal growth below levels that would result in exceedances of the pH standard. If approved, the District would continue to operate the AWTFs as efficiently as possible, using biological nutrient removal, but would not continue with chemical addition beyond the end of August when physical conditions would limit the amount of algal growth below levels that would result in exceedances of the pH standard. The modification of the total phosphorus target concentrations will enable the District to conserve resources and reduce the overall environmental impact of wastewater treatment. The following discussion presents supporting information for the requested action.

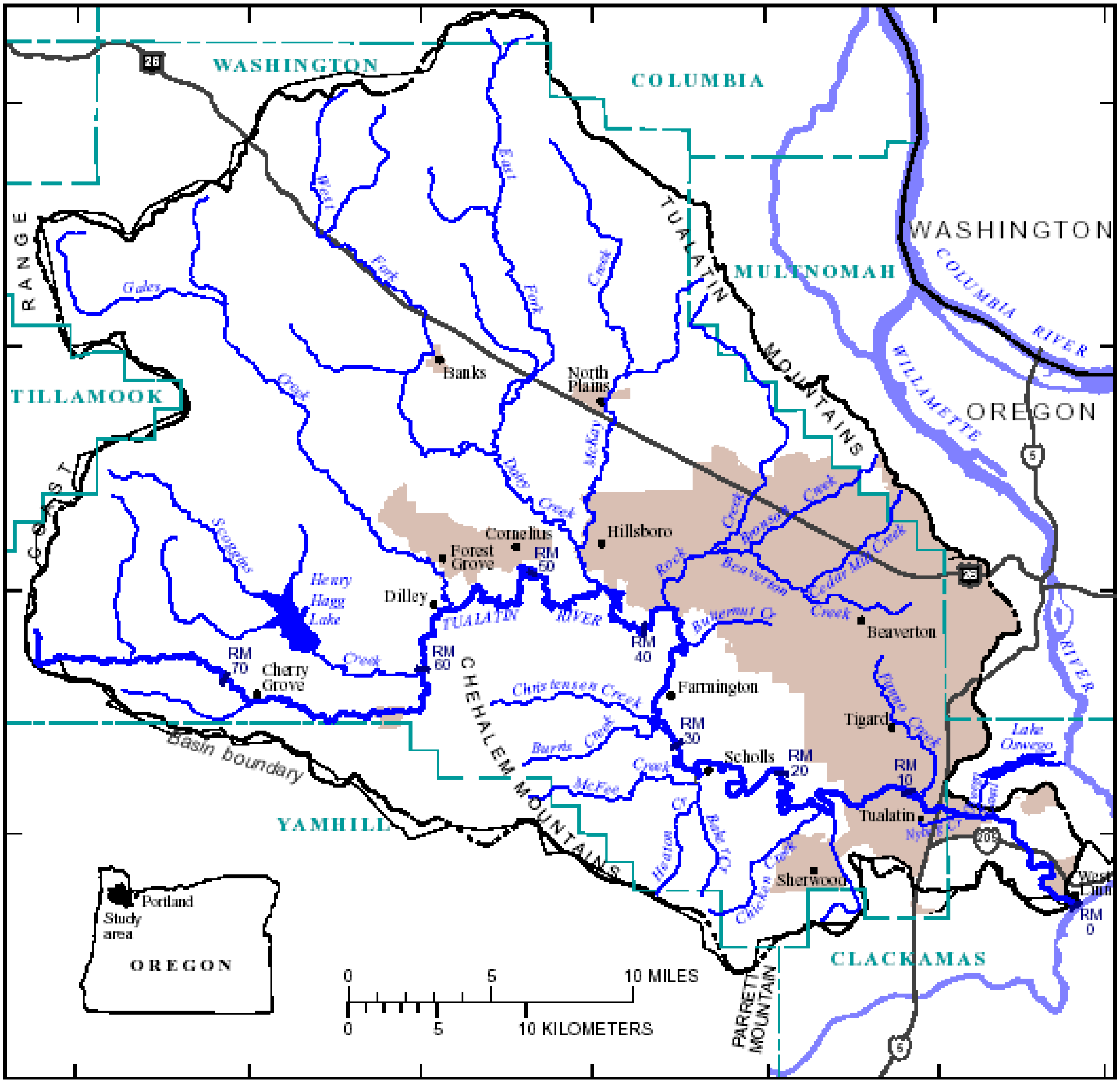
2.0 Tualatin River Sub-basin Overview

The drainage sub-basin of the Tualatin River and tributaries is about 712 square miles located in the northwestern part of the Willamette Valley, Oregon (Figure 1). The western boundary of the river basin is formed by the Coast Range, and the north and east boundaries are formed by a range of high hills bordering the Columbia and Willamette Rivers. On the south, the Tualatin River and Yamhill River sub-basins are separated by the Chehalem and Parrott Mountains and the adjoining low hills. The drainage area consists of a central plain ranging in elevation from about 100 to 300 feet above sea level, surrounded by hills or mountains that rise to much higher elevations. The Coast Range has a general elevation from 2000 to 3000 feet. The hills to the north and east have elevations ranging up to 1000 feet. In the south, the Chehalem and Parrott Mountains reach maximum elevations of 1630 and 1240 feet, respectively.

The Tualatin River is the northernmost major tributary to enter the north flowing Willamette River. It originates on the east slope of the Coast Range and flows southeasterly 80 miles to its confluence with the Willamette River upstream from Willamette Falls in Clackamas County about two miles above Oregon City. Topography of the upper reaches of the Tualatin River and tributaries is characterized by narrow valleys and steep ridges. Slopes of the streams are quite steep, and as they emerge from the foothills, the topography changes rather abruptly to comparatively flat valleys with fairly wide flood plains. There is about a 1,800 foot drop in elevation in the first 25 river miles as it flows through forests and scattered pasture lands in Oregon's Coast Range. The river then drops only 100 feet in elevation over the remaining 55 river miles, draining largely urban and agricultural lands, and flows into the Willamette River. Land uses in the Tualatin River watershed range from forests in the Coast Range, Tualatin Mountains, and Chehalem Mountains, to agricultural areas near Forest Grove, Scholls, Gaston, and North Plains, to densely populated areas such as Hillsboro, Tigard, and Beaverton. The basin supports a growing population of nearly 500,000.

The Tualatin River has eight large tributaries. Wapato Creek drains from the Chehalem Mountains; Scoggins Creek and Gales Creek drain part of the Coast Range; Dairy Creek and Rock Creek drain the Tualatin Mountains; McFee Creek and Chicken Creek drain the northeast slope of the Chehalem Mountains; and Fanno Creek drains the valley floor and Portland west hills. The climate of the sub-basin is characterized by mild, wet winters and warm, dry summers. The area experiences little if any snow accumulation. Temperature and precipitation are directly affected by air masses moving in from the Pacific Ocean. Rainfall ranges from 110 inches on the western slope of the Cascade Range to 35 - 40 inches in the southeastern area. The peak months for rainfall are November through February while the driest months, based on the percentage of precipitation occurring, are generally June through October.

Figure 1: Location Map



2.1 Water Storage

The Tualatin River was unregulated prior to construction of Scoggins Dam and Barney Reservoir in the mid-1970s. Tualatin River flows during the dry season are strongly influenced by the various management actions that occur during this season. Flow management is provided in part by two reservoirs. Scoggins Dam created Hagg Lake, which has an active storage capacity of 53,000 acre feet and regulates Scoggins Creek, a major tributary entering the Tualatin River at RM 60.0. Barney Reservoir is an impoundment on the Trask River which flows on the west side of the Coast Range. An aqueduct transports water from Barney Reservoir for discharge into the Tualatin River near its headwaters at River Mile (RM) 78. In 1998, Barney Reservoir's active storage capacity was increased from 4,000 acre-feet to 17,000 acre-feet.

Stored water in Hagg Lake is contracted to Tualatin Valley Irrigation District and other irrigation water users, municipal and industrial water suppliers, and the District. The District contracts 12,618 acre-feet annually from Hagg Lake and 1,667 acre-feet annually from Barney Reservoir for use in maintaining water quality in the Tualatin River. Stored water released from Hagg Lake is conveyed to the main-stem Tualatin River via Scoggins Creek. Much of the irrigation and municipal/industrial water released from Hagg Lake is withdrawn at the Spring Hill Pump Station at RM 56.1; however, the District's water releases continue all the way to the mouth of the Tualatin River.

2.2 Tualatin River Stream Flows

Records of stream flow for the Tualatin River near its mouth at the West Linn gauging station (RM 1.75) have been kept since 1928. Maximum and minimum daily discharges of the Tualatin River at West Linn for the period 1929 through 1973 preceding construction of Scoggins Dam were 29,300 cfs on December 23, 1933, and 10 cfs on September 5 and 6, 1967. Average annual runoff at the mouth during this same period was about 1.1 million acre feet. The average annual flow was about 1,500 cfs; the high monthly average of 4,100 cfs is in January and the low of about 65 cfs was in August.

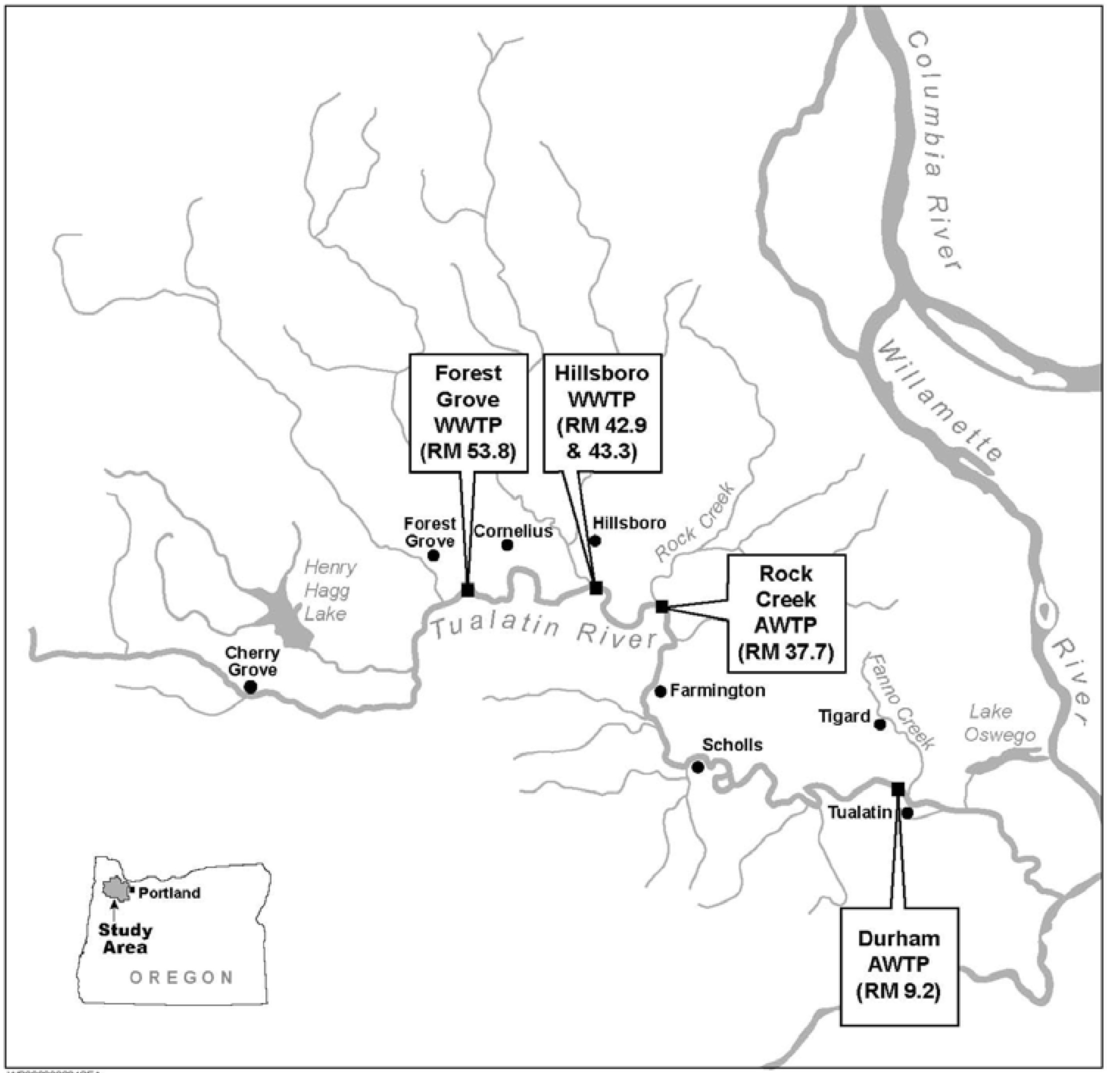
Following construction of Scoggins Dam and Barney Reservoir, the statistics for the post-construction period of 1977 through 2005 are as follows: maximum and minimum daily discharges at West Linn were 25,900 cfs on February 10, 1996, and 18 cfs on July 1, 1977. Average annual water year runoff for this 29-year period was 1.02 million acre feet. The annual high was 2.02 million acre feet in water year 1999 and the annual low was 0.20 million acre feet in water year 1977. The high average monthly discharge during the same 29-year period was about 3,540 cfs in February and the low was about 160 cfs in August.

2.3 Wastewater Treatment Facilities

Clean Water Services is a special service district that serves the urban portion of Washington County. The District has 12 member cities and owns and operates four wastewater treatment plants (WWTPs) in the Tualatin River basin at sites in Forest Grove, Hillsboro, and Tigard (Figure 2). The District's four facilities and outfalls are the Forest Grove WWTP (RM 53.8); the Hillsboro WWTP (RM 42.9 and 43.3); the Rock Creek advanced wastewater treatment facility (AWTF) (RM 37.7); and the Durham AWTF (RM 9.2). All four facilities discharge to the Tualatin River between Forest Grove and the confluence with the Willamette River. The District's facilities and discharges are permitted by DEQ under the watershed-based NPDES permit.

The Forest Grove and Hillsboro WWTPs currently only discharge during the wet season, which is defined in the current NPDES permit in relation to specific river flows at the Farmington gauge and the calendar date. Because they do not discharge during the dry season (the critical season for river water quality), they were not considered in the 1988 and 2001 Tualatin Sub-basin TMDLs. The 1988 and 2001 Tualatin Sub-basin TMDLs included wasteload allocations for the Rock Creek and Durham AWTFs because these two facilities discharge year-around.

Figure 2: Location of the District's Wastewater Treatment Facilities in the Tualatin River Basin



3.0 Total Maximum Daily Loads

In 1970, Clean Water Services was formed as the Unified Sewerage Agency of Washington County to address serious health and pollution problems in the Tualatin River and its tributaries. During the early to mid-1970s, operations of over 20 separately owned and operated small wastewater treatment plants and collection systems were consolidated. In 1976, the Durham AWTF began operating and replaced 14 small treatment plants; the Rock Creek AWTF began operating in 1977 and replaced six more small treatment plants. Both the Durham and Rock Creek AWTFs provided advanced wastewater treatment including phosphorus removal. With the completion of Scoggins Dam, the flow augmentation water was first released in 1975. The closure of the small treatment plants, construction of the Durham and Rock Creek AWTFs, and augmentation flows from Hagg Lake improved water quality in the Tualatin River sub-basin.

The improvements in the Tualatin River sub-basin in the 1970s were insufficient to meet water quality standards and support beneficial uses in the Tualatin River. Section 303(d) of the Federal Clean Water Act (CWA) requires that a list be developed of all waters within each state that do not meet water quality standards. This list is called the 303(d) list for the section of the CWA that requires it. If a river or stream does not meet water quality standards, it is identified as being "water quality limited" and is placed on Oregon's 303(d) list. DEQ calculates pollution load limits, known as TMDLs for each pollutant for which the stream is listed. TMDLs describe the amount of each pollutant a waterway can receive and still meet water quality standards. TMDLs are then implemented through NPDES permits.

TMDLs were first established in the Tualatin River sub-basin in 1988 for ammonia and total phosphorus to address low dissolved oxygen and elevated pH levels in the main-stem Tualatin River. The ammonia and total phosphorus TMDLs were among the first TMDLs in the nation. The purpose of the ammonia TMDL was to reduce ammonia loads from the AWTFs and improve dissolved oxygen levels in the Tualatin River. The purpose of the total phosphorus TMDL was to reduce the nuisance algal growth and resultant high pH levels in the lower portion of the Tualatin River. Unlike the ammonia TMDL, the total phosphorus TMDL had both point source and non-point source components. The point source wasteload allocation (WLAs) for ammonia and phosphorus were applicable during the dry season only.

Since the Rock Creek and Durham AWTFs discharge year-around, the 1988 TMDL included dry season WLAs for these two facilities. In the early 1990s, the Durham and Rock Creek AWTFs were upgraded to include nitrification (i.e. ammonia removal) and enhance phosphorus removal. These upgrades produced significant water quality improvements in the main-stem Tualatin River. The pH exceedances associated with nuisance algal growth were virtually eliminated and the dissolved oxygen levels in the main-stem Tualatin River improved. These improvements were the result of not only the dramatic reductions in the ammonia and phosphorus loadings from the Rock Creek and Durham AWTFs, but also due to the management of stored water releases from Hagg Lake for water quality purposes, and the implementation of nonpoint source controls for agriculture, forestry, and urban runoff. DEQ recognized these improvements and concluded that the dissolved oxygen and pH standards in the main-stem Tualatin River had been met most of the time.

However, the Tualatin River sub-basin had stream segments that were listed on the 1998 Oregon 303(d) list for: temperature, bacteria, dissolved oxygen, chlorophyll-a, toxics (arsenic, iron and manganese), biological criteria and low pH. As a result, DEQ determined that updated TMDLs for ammonia and total phosphorus and new TMDLs for temperature and bacteria were needed for the main-stem Tualatin River. These TMDLs, which were completed in August 2001, also addressed temperature, total phosphorus, bacteria, and dissolved oxygen (via settleable volatile solids) for the major tributary streams in the sub-basin.

The point source components of the 2001 Tualatin sub-basin TMDL applicable to the District were implemented with the issuance of the watershed-based NPDES permit, which includes the District's four wastewater treatment facilities and the District's municipal separate storm sewer system (MS4) programs. With the development and on-going implementation of the TMDLs, the Tualatin River sub-basin is no longer listed for temperature, bacteria, dissolved oxygen, chlorophyll-a, biological criteria and pH in the most recent 2004/2006 303(d) list but the TMDLs continue to be in place.

4.0 Tualatin River Water Quality

Historically, most water quality concerns in the main-stem Tualatin River manifested themselves during the warm and relatively dry summer period, and also during the fall if stream flows remain low. The warm summers cause the river's temperature to exceed water quality criteria for rearing and migration of fish such as salmon and steelhead (18ºC). In the reservoir-like reach of the river, (RM 33 to RM 3.4), the long travel times, nutrients (phosphorus and nitrogen), and sunny summer weather resulted in algal growth, which typically exceeded DEQ's action level for chlorophyll-a of 15 μg/L, but provided a substantial amount of dissolved oxygen to the river via algal photosynthesis during long summer daylight hours. This source of oxygen offsets the loss of oxygen resulting from organic sediments on the bottom of the river exerting a demand on dissolved oxygen in the water column (sediment oxygen demand, SOD). In the fall, when the oxygen from algal productivity is inhibited by shorter days and cooler temperatures, the SOD can lead to substantial dissolved oxygen sags in this reach. Consequently, algae (as measured by chlorophyll-a), pH, temperature, total phosphorus, and dissolved oxygen concentrations have historically been of concern in the Tualatin River, which led to the 303(d) listings and the TMDLs noted above.

The Tualatin River is one of the most studied streams in the nation. There has been a wealth of data gathered over the past 25 years. The District has an extensive monitoring program in the Tualatin sub-basin. The District monitors flow, dissolved oxygen, pH, temperature and specific conductance using continuous recording devices at select locations within the Tualatin watershed. The District also monitors water quality using discrete sampling techniques at many locations in the watershed.

With respect to the lower river water quality data, the District's discrete monitoring location at Stafford (RM 5.4 and data from 1983-present) and the continuous monitoring location at the Oswego Diversion Dam (RM 3.4 and data from 1991-present) are the relevant locations. With respect to flow, the West Linn gauge (RM 1.75) is used in the discussion below. The Farmington gauge (RM 33.3) is also widely used but does not account for the lower river inflows from the Durham AWTF (RM 9.2) and Fanno Creek (RM 9.1), and the withdrawal by the Lake Oswego Corporation (LOC) at the Oswego Diversion Dam (RM 3.4). The use of the flash boards by the LOC at the Oswego Diversion Dam has the added impact of increasing stream depth and residence time in the lower Tualatin River. These practices significantly affect flow regime and the residence time in the lower Tualatin River during the dry season. The West Linn gauge, which accounts for the lower river inflows and the withdrawal by the LOC is therefore used in preference to the flow at Farmington to evaluate the conditions in the lower Tualatin River.

In evaluating water quality and flow data in the lower Tualatin River over a 20+ year period, there are several considerations to take into account. These include significant upgrades at the Rock Creek and Durham AWTFs in the early 1990's, significant growth in the basin (reflected in the form of substantially higher effluent flows at the AWTFs), management of stored water releases from Hagg Lake and Barney Reservoir, the use of flash boards at the Oswego Diversion Dam, and the recent reductions in the withdrawal rate by the LOC. To account for these changes, the water quality monitoring data was divided into 4 distinct time periods:

- 1983-1989: Pre-TMDL period
- 1990-1993: Transition period
- 1994-2003: Post-TMDL period
- 2004-2007: Watershed-based NPDES permit period

One of the results of dividing the analysis into four distinct time periods is a variable sample size because of the unequal number of years that constitute each time period and different monitoring frequencies over the time periods. The following is a discussion of each of the four time periods:

The pre-TMDL period (1983-1989) is characterized by effluent total phosphorus concentrations of about 2 mg/L and the combined effluent flow from the two AWTFs of about 37 cfs (dry season average). LOC was withdrawing their full allotment of up to 57 cfs and low flows (10^{th} percentile) at West Linn were about 68 cfs during this period. Starting in 1987, the District started managing its stored water releases to meet an in-stream flow target of 150 cfs as a monthly average at Farmington.

The transition period (1990-1993) reflects the time frame given for the upgrade of the Rock Creek and Durham AWTFs to meet the 1988 Tualatin TMDL WLAs. The Rock Creek AWTF achieved full scale total phosphorus removal and met TMDL requirements in 1991 (i.e. effluent total phosphorus concentrations less than 0.1 mg/L). Durham AWTF achieved full scale total phosphorus removal and met TMDL requirements in 1994. The combined dry season average effluent flow from the two AWTFs was about 43 cfs. LOC continued to withdraw its full allotment of up to 57 cfs and the 10th percentile flows at West Linn were about 100 cfs. The District continued to manage its stored water released to meet a target in-stream flow of 150 cfs as a monthly average at Farmington.

The post-TMDL period (1994-2003) is characterized by the AWTFs achieving the WLAs for total phosphorus in the 1988 Tualatin TMDL. There was significant growth in the basin and is reflected by higher effluent flows at the AWTFs. The combined dry season average effluent flow from the two AWTFs was about 62 cfs. The District continued to release water from Hagg Lake and starting in 1998 from Barney Reservoir to meet the following in-stream flow targets at Farmington: 150 cfs in July/August; and 180 cfs in September/October. The flow regime was modified to maximize in-stream dissolved oxygen levels in the September/October period. LOC withdrawals at the Oswego Diversion Dam steadily decreased during the post-TMDL period. LOC continued to withdraw its full allotment of up to 57 cfs during the early portion of the post-TMDL period; however, LOC was withdrawing about 10 cfs towards the end of the post-TMDL period. Low flows (10th percentile) at West Linn increased from about 115 cfs during the early portion of the post-TMDL period (1994-95) to about 150 cfs during the latter portion of the post-TMDL period (2000-03).

The watershed-based NPDES permit period (2004-07) reflects the implementation of the 2001 Tualatin TMDL. Effluent total phosphorus levels were similar to the levels during the post-1988 TMDL period. The combined effluent flow from the two AWTFs was about 70 cfs. To meet temperature trading provisions in the watershed-based NPDES permit, the July/August stored water release goals were changed from meeting an in-stream flow target of 150 cfs at Farmington to releasing 35 cfs during July & August; the in-stream flow target for the September/October period was the same – 180 cfs. This period is also characterized by minimal withdrawals (<10 cfs) by the LOC at the Oswego Diversion Dam. Low flows (10th percentile) at West Linn were about 180 cfs during the watershed-based permit period.

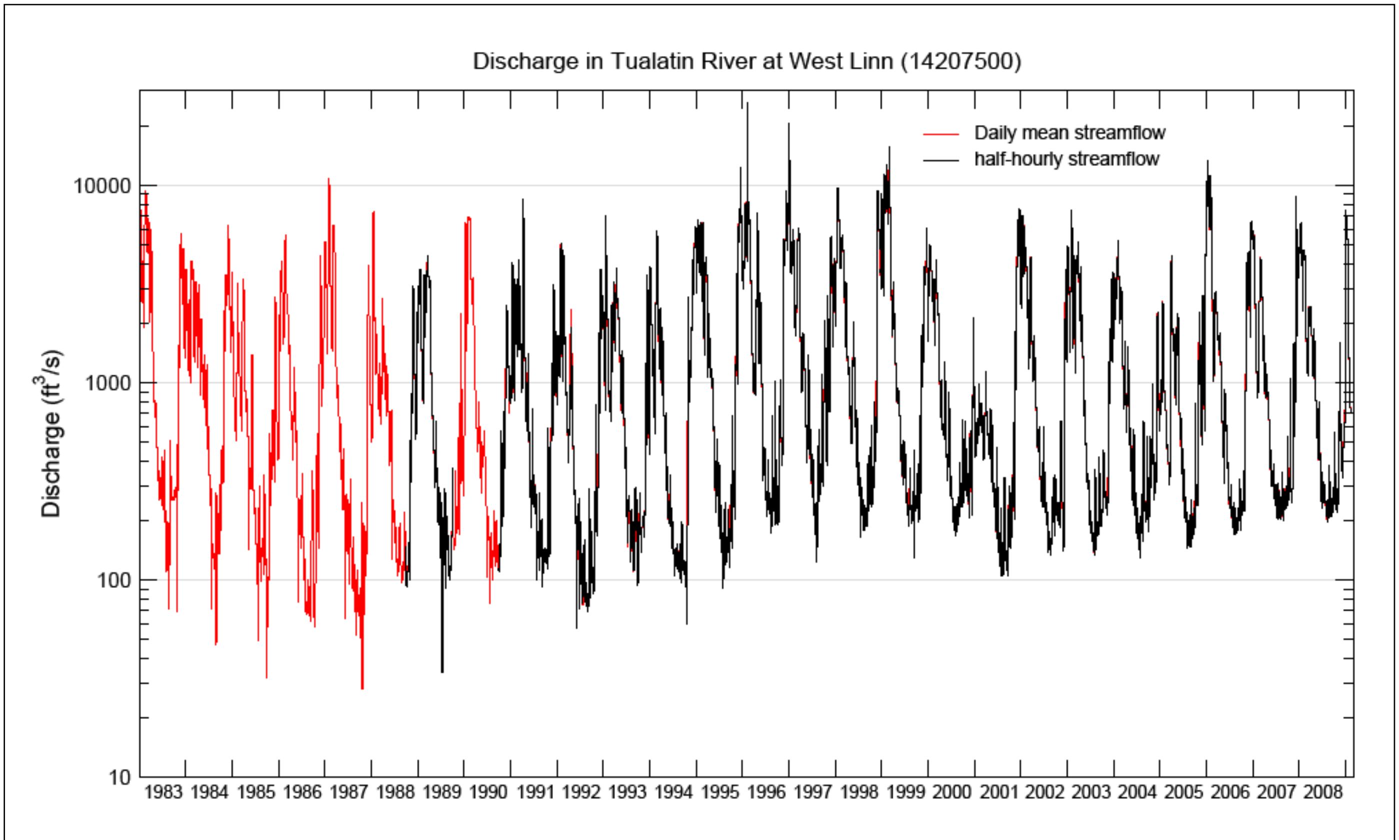
For each of these periods, critical parameters such as flow, dissolved oxygen, temperature, pH, total phosphorus, and chlorophyll-a were evaluated. The evaluation is based on both discrete and continuous water quality monitoring data. Continuous data is available for flow at West Linn (RM 1.75) for the four time periods defined above and continuous data is available for dissolved oxygen, temperature, and pH at the Oswego Diversion Dam (RM 3.4) from 1991 onwards. Discrete monitoring data for total phosphorus and chlorophyll-a from Stafford (RM 5.4) was available for the four periods noted above. Total phosphorus loads from the Rock Creek and Durham AWTF are also presented. The following sections discuss the changes in the stream flow, AWTF effluent quality, and water quality on a seasonal basis as well as during each of the four distinct time periods noted above.

4.1 Stream Flow Data

Figure 3 presents daily mean flow data at West Linn (RM 1.75). This chart shows higher minimum flows in recent years than during the 1980's and early 1990's. During the 1980's, minimum stream flows at West Linn periodically fell below 50 cfs. In the early 1990's, minimum stream flows periodically fell below 100 cfs during the dry season. In recent years

(2002-07), minimum stream flows at West Linn are about 140 cfs. The dramatic increase in the minimum flows is a result of the active management of stored water releases to meet target in-stream flow rates, higher effluent flows associated with growth in the basin (particularly at the Rock Creek AWTF), and reduction in the withdrawal rate by the LOC. The change in the flow regime and the removal of the flash boards at the Oswego Diversion Dam has dramatically reduced the residence time in the reservoir portion of the Tualatin River (RM 33 to 3.4).

Figure 3: Stream Flow @ West Linn (RM 1.75)



4.2 Rock Creek and Durham AWTF Effluent Phosphorus Data

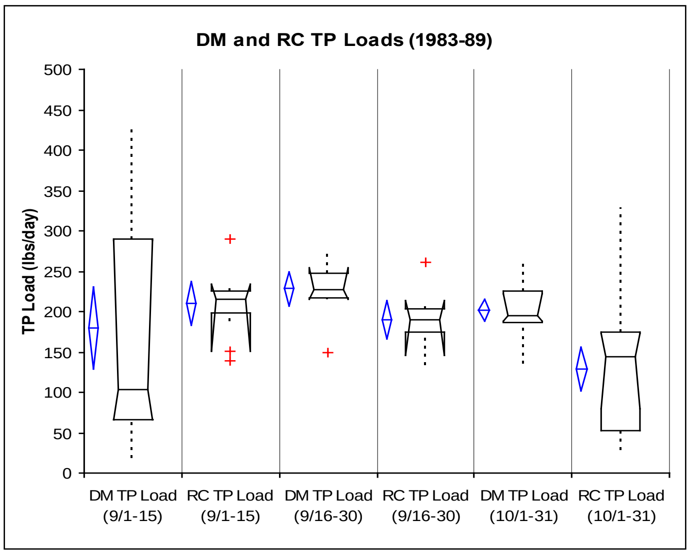
As noted earlier in the document, the Rock Creek and Durham AWTFs have undergone significant upgrades to meet the 1988 phosphorus and ammonia TMDL requirements. The table below shows the dramatic reductions in total phosphorus levels at the treatment plants following implementation of 1988 TMDL.

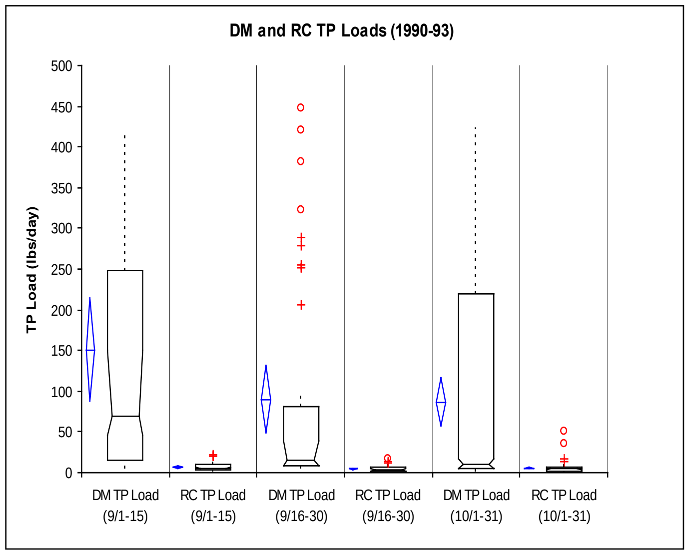
Table 2: Total Phosphorus Loads Discharged from the Rock Creek and Durham AWTFs

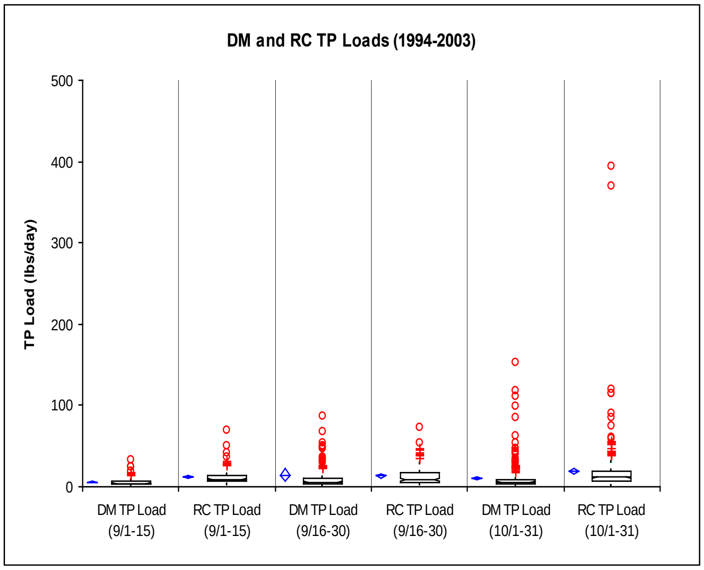
Year	Rock Creek AWTF (lbs/day) May - October	Durham AWTF May - October	Total AWTF Inputs May - October
1989	199	164	363
1990	57	244	301
1991	4	83	87
1992	4	7	11
1993	11	173	184
1994	14	8	22
1995	8	5	13
1996	13	6	19

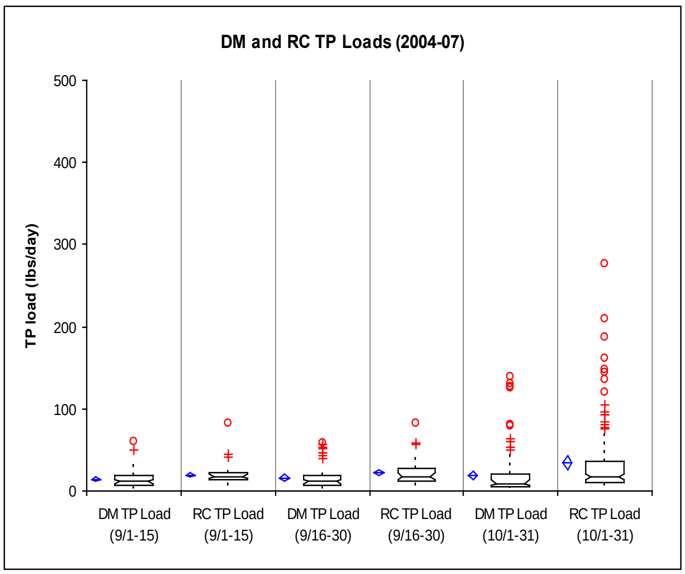
Rock Creek AWTF achieved full scale total phosphorus removal and met requirements of the 1988 TMDL in 1991. Durham AWTF achieved full scale total phosphorus removal and met TMDL requirements in 1994 (note that pilot testing was conducted at Durham in 1992 that enabled the facility to meet the TMDL requirements during that year).

The following charts present the total phosphorus loads from the Rock Creek (RC) and Durham (DM) AWTFs during early to mid-September (9/1-9/15), mid to late-September (9/16-9/30), and October (10/1-10/31) for the four time periods defined above (i.e. pre-TMDL, Transition, post-TMDL, and Watershed-based permit period). The broad ranges associated with the Durham and Rock Creek total phosphorus loads in the pre-TMDL period is a reflection of the phosphorus control technologies being explored during the latter portion of the pre-TMDL period. These charts also illustrate the dramatic reduction in effluent total phosphorus levels after implementation of the 1988 TMDL. These charts also show that effluent total phosphorus levels have continued to remain very low following the implementation of the watershed-based NPDES permit (2004-07).









Figures 4, 5, 6, & 7 – Durham and Rock Creek AWTF Total Phosphorus Loads for Various Time Periods

In its request for modification of the time periods associated with the total phosphorus TMDL, the District noted that it would continue to operate the Rock Creek and Durham AWTFs as efficiently as possible during September and October using biological nutrient removal but would cease further chemical addition after the end of August when existing physical conditions would limit the amount of algal growth below levels that would result in exceedances of the pH standard limit. The District estimated that the effluent total phosphorus levels would be less than 0.5 mg/L during September and 1.0 mg/L in October. At the permitted flow conditions for the Durham AWTF (i.e. 22.6 million gallons per day (MGD)), these concentrations equate to 75 lbs/day and 150 lbs/day in September and October, respectively. At the permitted flow conditions for the Rock Creek AWTF (i.e. 39 MGD)), the applicable loads would be 125 lbs/day and 250 lbs/day in September and October, respectively. The calculated *in-stream* concentration associated with these proposed future phosphorus loads near Stafford (below the Durham AWTF) would be 0.25 mg/L in September and 0.4 mg/L in October. The following sections present information that that shows that there would be no adverse effects on water quality conditions in the Tualatin River as a result of the higher total phosphorus concentrations from the Rock Creek and Durham AWTFs during September and October.

4.3 Water Quality Data

<u>4.3.1 Discrete Monitoring Data during Dry Season (May-October)</u>

Discrete monitoring is conducted at many locations in the Tualatin River. The District's Watershed Monitoring Plan specifies the sampling locations, frequencies, collection methodology, and parameters. In the lower Tualatin River, samples are depth and width integrated. Thus, the total phosphorus and chlorophyll-a data are depth and width integrated. For field parameters such as pH, depth specific measurements are taken in the lower Tualatin River. Thus, the pH data reflects field measurement at a depth of 3 feet.

Figure 8 presents dry season chlorophyll-a levels at several locations in the lower Tualatin River. From this figure, it is appears that the Tualatin River @ Stafford (RM 5.4) provides a representative location of the lower Tualatin which highest algal growth levels are experienced.

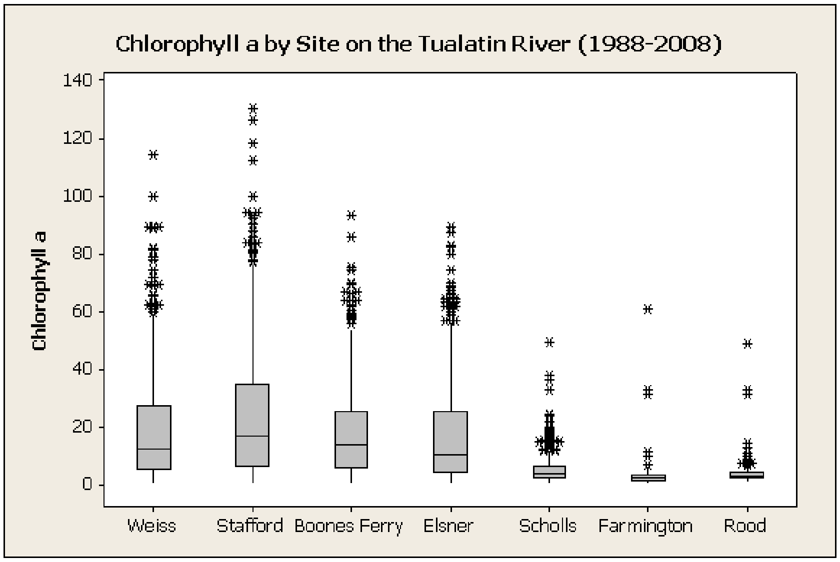
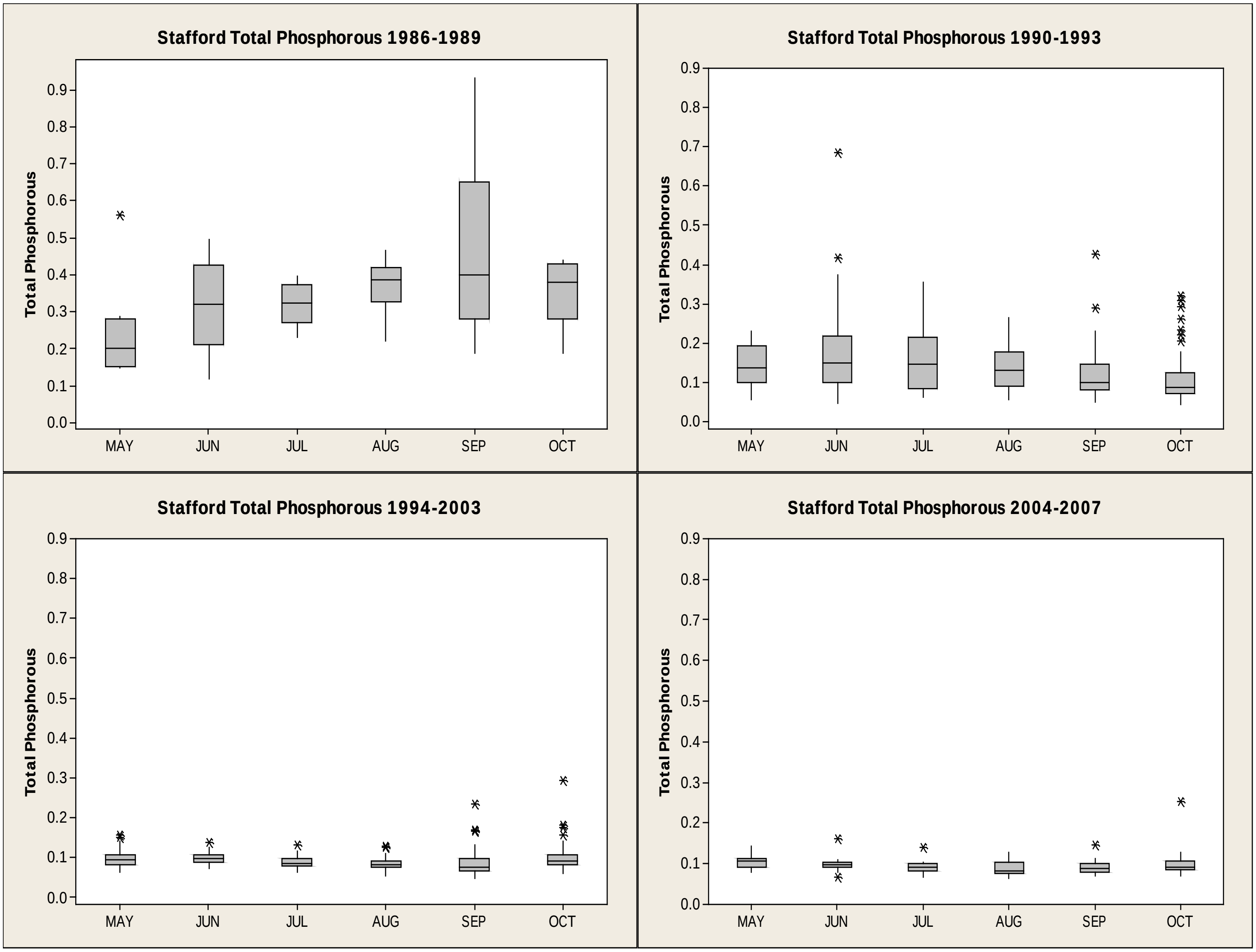


Figure 8 – Chlorophyll-a Levels (µg/L) at Various Locations in the Lower Tualatin River

Discrete monitoring data for total phosphorus, chlorophyll-a, and pH at Stafford (RM 5.4) is presented for the four time periods noted in Section 4.0 Box plots by month for these parameters are presented below; box plots are presented for the four distinct time periods noted in Section 4.0. From Figures 9 – 12, the following observations are noted:

- The September total phosphorus levels at Stafford during the pre-TMDL period (1986-89) are well above the calculated in-stream concentration associated with proposed future total phosphorus loads from the AWTFs; the calculated in-stream total phosphorus levels associated with proposed future total phosphorus loads from the AWTFs in October are within the range of the measured total phosphorus levels during the pre-TMDL period.
- The total phosphorus levels in September and October during the transition period (1990-93) are below the calculated in-stream concentration associated with proposed future total phosphorus loads from the AWTFs;
- The charts show the dramatic reduction in in-stream total phosphorus levels from the 1980's to the post-TMDL period (1994-03).
- In the post-TMDL period and the watershed-based permit period (2004-07), the in-stream total phosphorus levels are nearly the same across all the months.

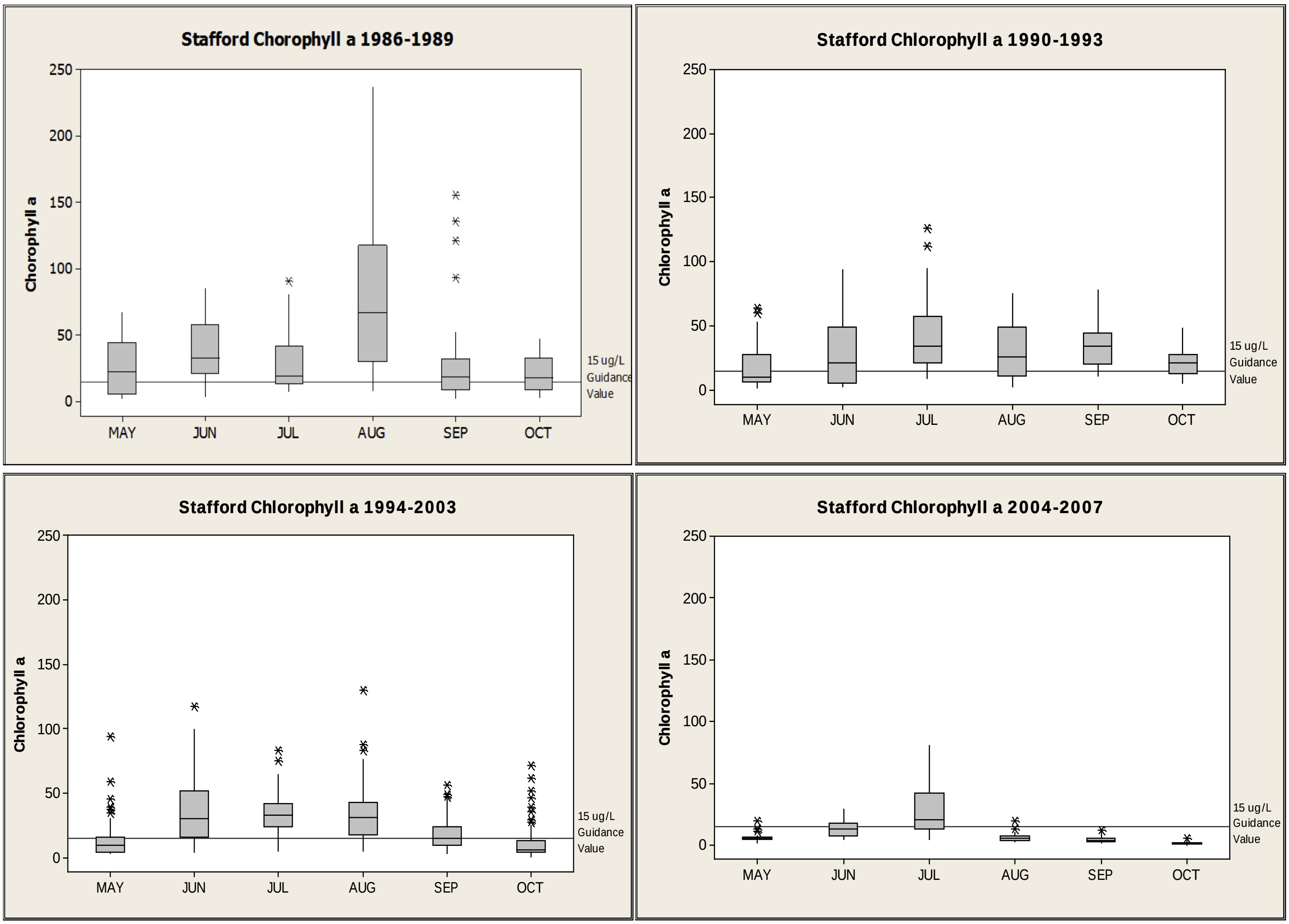


Figures 9, 10, 11, & 12 – Total Phosphorus Levels (mg/L) at Stafford (RM 5.4) for Various Time Periods

Figures 13-16 presents chlorophyll-a data from the District's discrete monitoring program. The following observations are noted from these charts.

- While the reduction in in-stream total phosphorus levels in the post-TMDL period (1994-2003) are striking and apply to all the dry season months, the chlorophyll-a reductions while significant, the magnitude of the reductions appear dependent on the month (Figures 13 – 16).
- The months of June, July and August experience the highest chlorophyll-a levels.
- Even during the post-TMDL period when total phosphorus WLAs were achieved, median chlorophyll-a levels continued to remain well above the DEQ action level of 15 µg/L.
- During the pre-TMDL period (1986-89), chlorophyll-a levels were much lower in September and October compared to the levels occurring August even though total phosphorus levels were high (Figures 9 and 13). Reduction in chlorophyll-a levels is not significant in September and October during the post-TMDL period as compared to the Pre-TMDL period even with the significant reductions in total phosphorus. This is an indication that physical factors and not total phosphorus levels are affecting algal growth during these months.

- Total phosphorus levels at Stafford have continued to remain at low levels following the implementation of the watershed-based NPDES permit (2004-07). However, there has been a notable reduction in chlorophyll-a levels compared to the post-TMDL period even though phosphorus concentrations remained constant. These observations suggest that reductions are likely due to physical changes that influence the amount of algae, including changes in the river flow regime caused by earlier releases of stored water by the District to meet temperature trading provisions, the removal of flashboards at the Oswego Diversion Dam, and the reductions in the withdrawal rate by the LOC. These actions have dramatically reduced the residence time in the reservoir portion of the Tualatin River (RM 33 to 3.4) and have reduced algal growth.

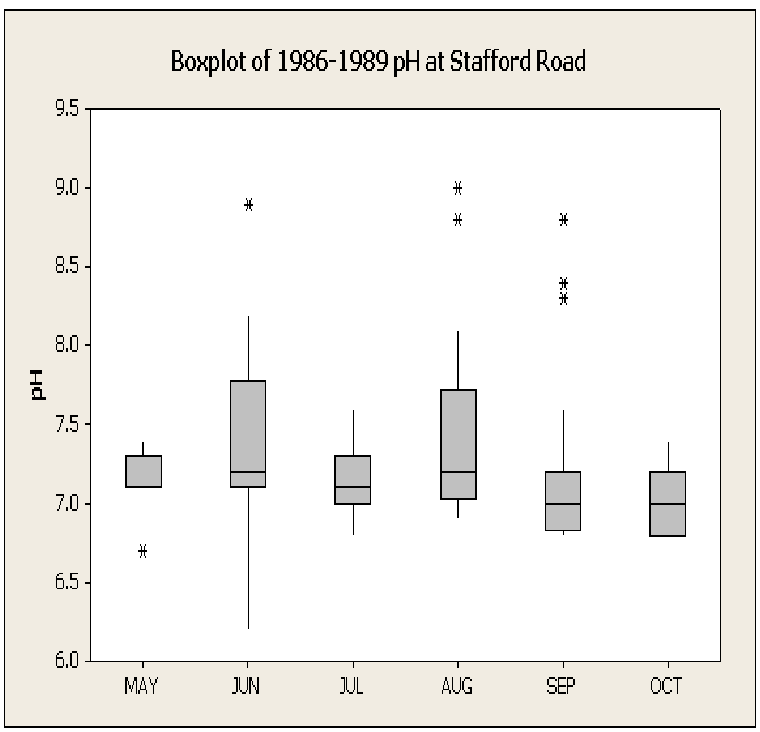


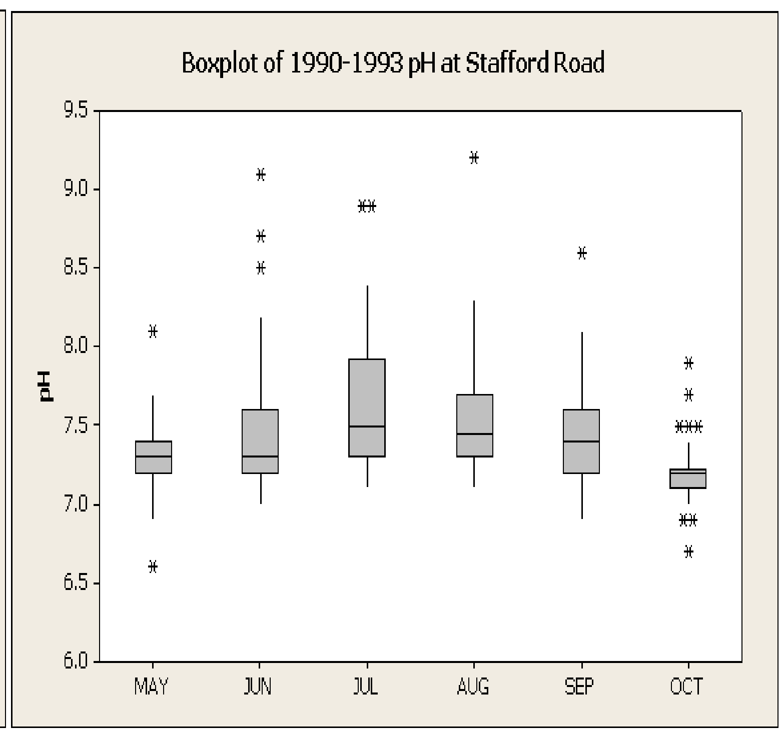
Figures 13, 14, 15 & 16 – Chlorophyll-a Levels (µg/L) at Stafford (RM 5.4) for Various Time Periods

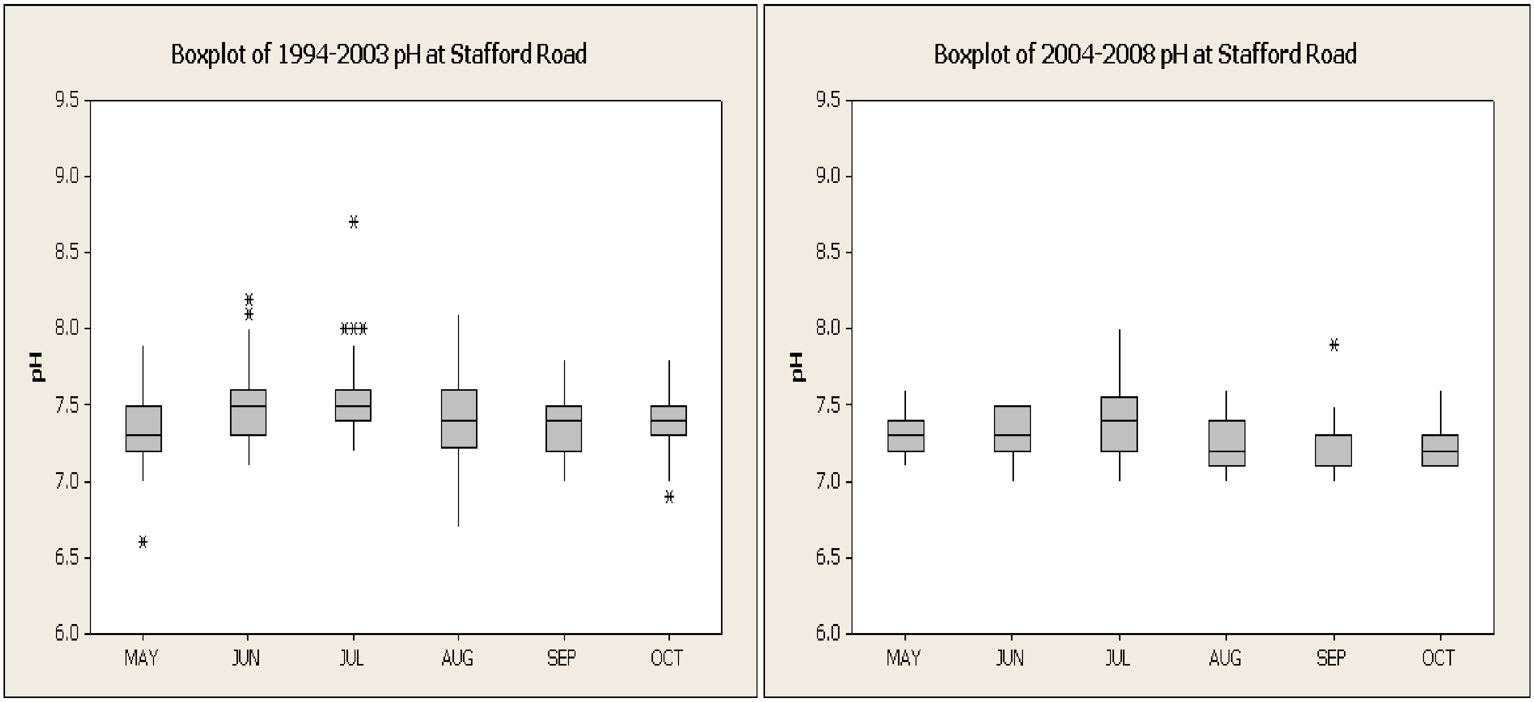
Figures 17-20 present pH data collected from the District's discrete monitoring program. The water quality criterion for pH is 6.5 – 8.5. Excessive algal growth can cause exceedances of the pH criterion. Excessive algae concentrations also cause large diurnal dissolved oxygen fluctuations. Such streams generally exhibit supersaturated dissolved oxygen concentrations during the day and lower dissolved concentrations at night.

Data from the discrete monitoring program are the only pH data that is available prior to 1991, when the District (through USGS) began collecting pH data using a continuous recording device at the Oswego Diversion Dam. Since that time, the continuous data has been used to assess exceedances of the pH criteria. For completeness, discrete monitoring data is presented for the four time periods noted in section 4.0 and the following observations are noted:

- The pH range is much greater during the pre-TMDL period (1986-89) and Transition period (1990-93) than in the post-TMDL period (1994-2003) and Watershed-based Permit period (2004-07).
- pH exceedances occurred in the 1980s and early 1990s. There were no pH exceedances in the Watershed-based Permit period (2004-07).
- pH exceedances occurred primarily during the months of June – August although a single exceedance of the pH criterion was observed in grab samples in September in both the pre-TMDL and the Transition periods (Figures 17 and 18).
- The single pH exceedance in September during the pre-TMDL period occurred on September 1, 1987 and was a continuation of an algal bloom that occurred in late August 1987. Daily stream flows at West Linn for that week ranged from 69 to 101 cfs, well below the current flow target for September of 180 cfs at Farmington, which equates to over 200 cfs at West Linn. No other exceedances were noted in September during the pre-TMDL period even though total phosphorus levels were well above the calculated in-stream concentration of 0.25 mg/L associated with proposed future total phosphorus loads from the AWTFs.
- The single pH exceedance in September during the Transition period occurred on September 2, 1992. Daily stream flows at West Linn for that week ranged from 72 to 82 cfs, well below the current flow target for September of 180 cfs at Farmington, which equates to over 200 cfs at West Linn. No other exceedances were noted in September during the Transition period.
- No exceedances occurred in October during the pre-TMDL period even with in-stream total phosphorus levels associated with potential future total phosphorus loads from the AWTFs within the range of the measured total phosphorus levels during the pre-TMDL period.







Figures 17, 18, 19 & 20 – pH levels at Stafford (RM 5.4) for Various Time Periods

4.3.2 Continuous Monitoring Data (May – October)

Continuous (i.e. hourly measurements) data has been collected from 1991 onwards at the Oswego Diversion Dam (RM 3.4) just below the Stafford location, where the discrete monitoring data is collected. When initially deployed, the continuous monitors recorded stream temperature, dissolved oxygen, pH, and specific conductance; probes to measure chlorophyll-a and turbidity were added in 2001 and 2004, respectively. The continuous recording device takes measurements at a nominal depth of 3 feet.

Dissolved oxygen, pH, and temperature data from 1991 to 2007 were evaluated. The continuous data at the Oswego Diversion Dam were evaluated in conjunction with the stream flow at West Linn (Figure 3) and solar insolation at the Durham AWTF. As shown in Figure 3, West Linn flow data is available for the entire period of interest (1983-2007). Solar insolation data at the Durham AWTF is available from 1991 onwards. The following observations are made based on a review of figures 3, and 21-24:

- As noted earlier, minimum stream flows at West Linn (Figure 3) are higher during recent years (2002-07) as compared to flows during the early to mid-1990s (1990-95); minimum stream flows during 2002-07 were about 130-140 cfs as compared to about 100 cfs or lower during the early to mid-1990s.
- Figure 21 presents a time series chart of dissolved oxygen and dissolved oxygen percent saturation. As noted above, algal photosynthesis is a source of dissolved oxygen to the river. The very high dissolved oxygen levels (above about 15 mg/l) and the high oxygen percent saturation levels (above about 160 to170%) are the result of large algal blooms that occurred in early to mid-1990s. The magnitude and frequency of the supersaturated dissolved oxygen levels have diminished since that time (the drought year 2001 being the exception).
- Figure 22 presents a time series chart of daily maximum dissolved oxygen and pH. This chart shows that exceedances of the pH water quality criteria occur during *highly* supersaturated dissolved oxygen conditions (above about 15 mg/L). Figure 23 presents daily maximum pH as a function of dissolved oxygen. This chart shows that pH values

are closely correlated with dissolved oxygen (R^2=0.84). The magnitude and frequency of the pH exceedances have diminished since the mid- 1990s (Figure 22).

- In addition to being closely correlated with supersaturated dissolved oxygen levels, pH exceedances were also associated with high stream temperatures near the annual peak which typically occur in July/August as illustrated in Figure 24.
- The pH exceedances have primarily occurred in June, July and August. A single pH exceedance (i.e. for one hour period) occurred in September during this period (1991-2007) and there were no exceedances in October. The single pH exceedance occurred at flow conditions (129 cfs at Farmington) that are much lower than the District's current target flow level for September of 180 cfs at Farmington, which equates to over to 200 cfs at West Linn.
- During recent years (2003-07), there have been only two pH exceedances noted by the hourly data from the continuous recording devices; these exceedances occurred on July 5, 2003 for a 3-hour period and on July 5, 2006 for a 1-hour period; no exceedances of the pH criteria occurred in September and October during this 5-year period.

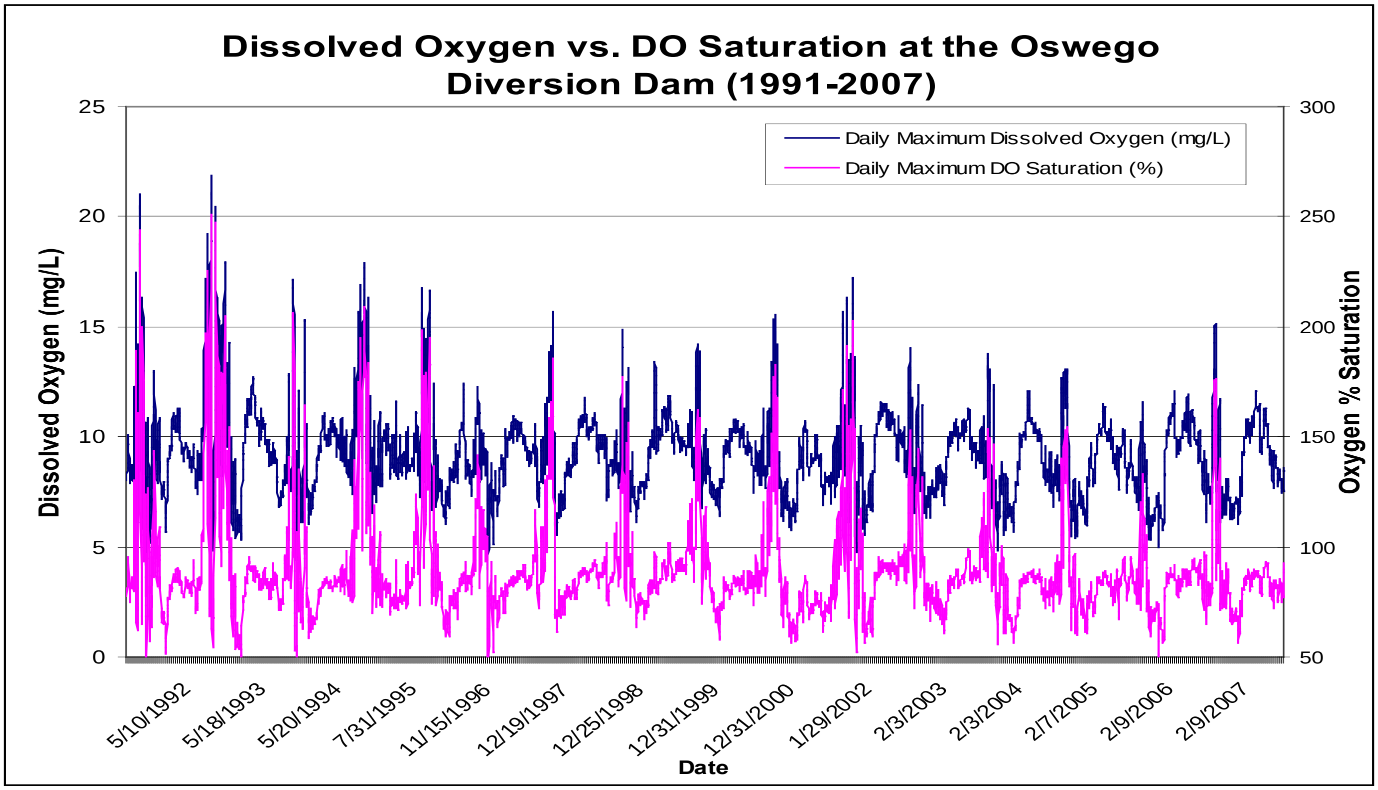


Figure 21 – Daily Maximum Dissolved Oxygen and DO Saturation at the Oswego Diversion Dam from 1991-2007

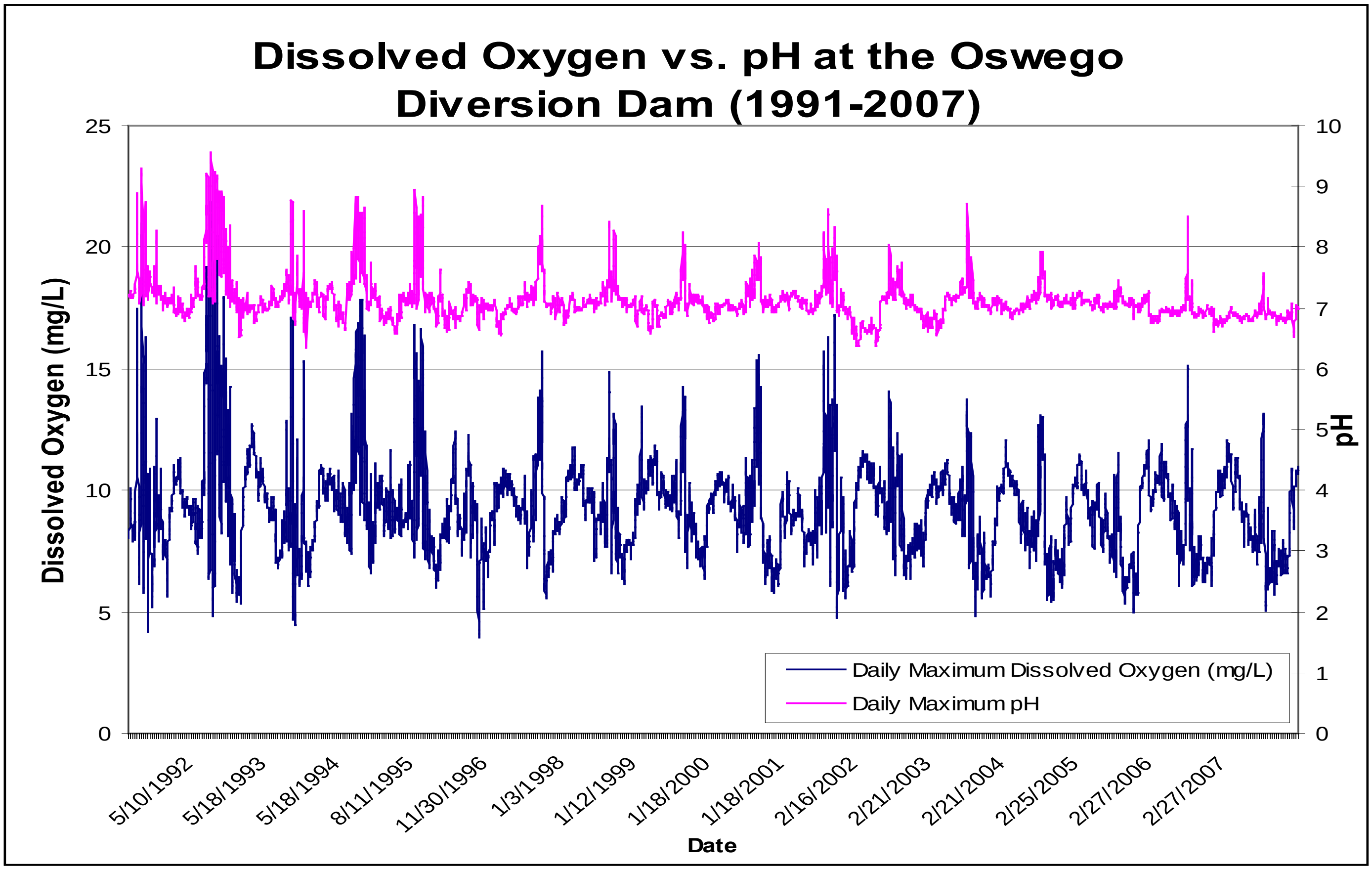


Figure 22 – Daily Maximum Dissolved Oxygen and pH at the Oswego Diversion Dam from 1991-2007

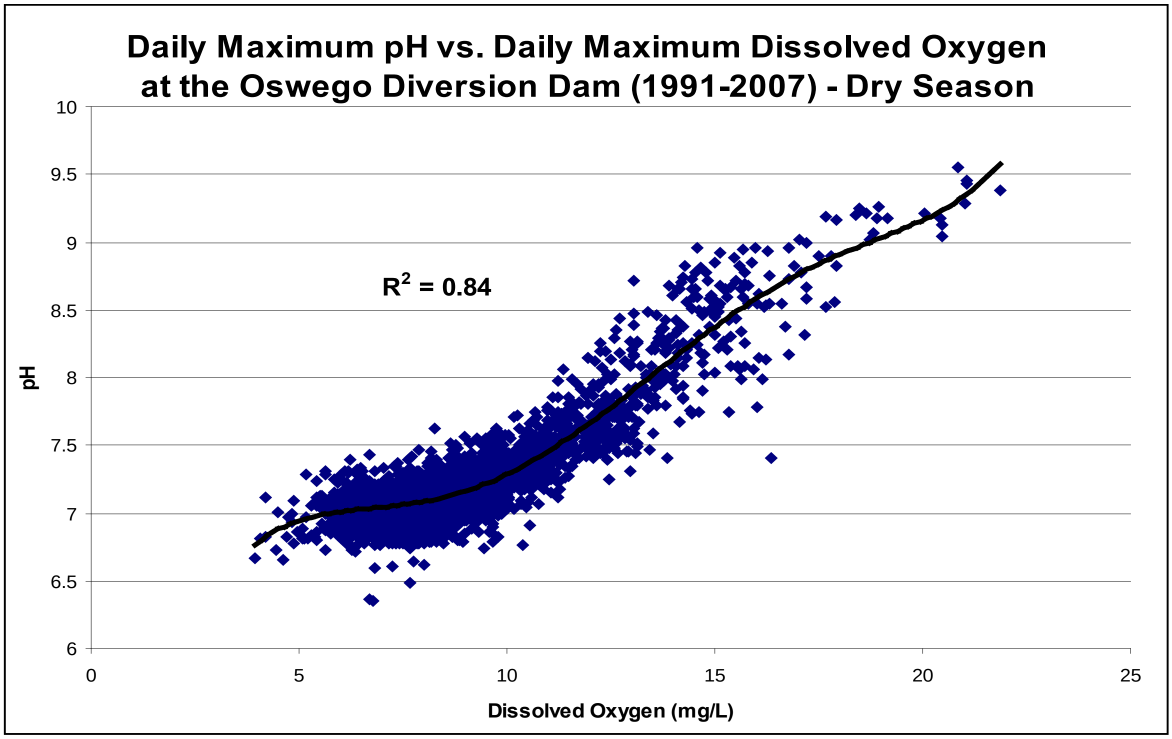


Figure 23 –pH vs. Dissolved Oxygen at the Oswego Diversion Dam from 1991-2007 (May-Oct)

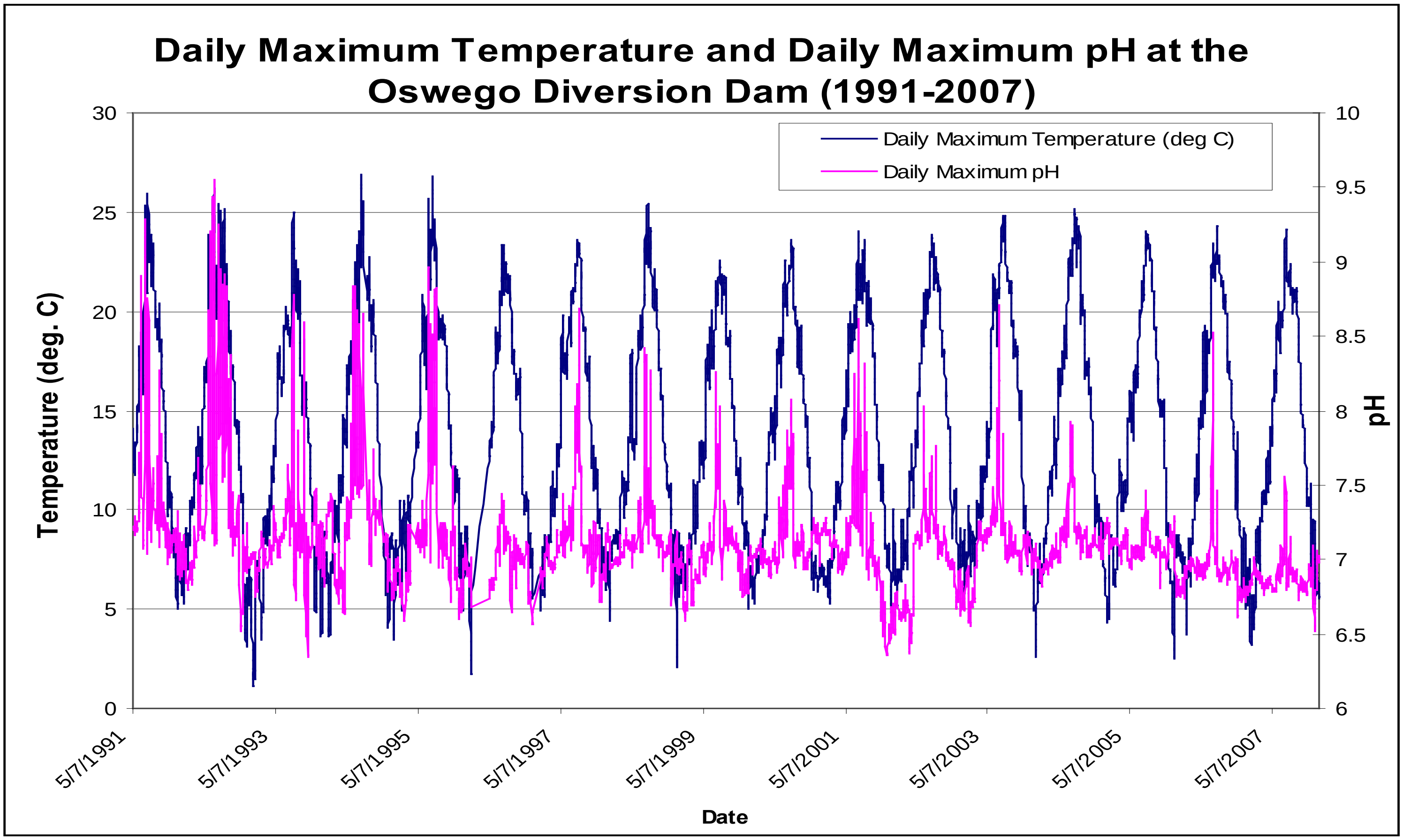


Figure 24 – Daily Maximum Temperature and Daily Maximum pH at the Oswego Diversion Dam from 1991-2007

As noted earlier, the months of June, July and August experience the highest chlorophyll-a levels. As Figure 25 shows, solar insolation is at or near its peak in June, July and August. By early September, the daily average solar insolation is well below its annual high values. Thus, the physical factors limit algal growth in September and October.

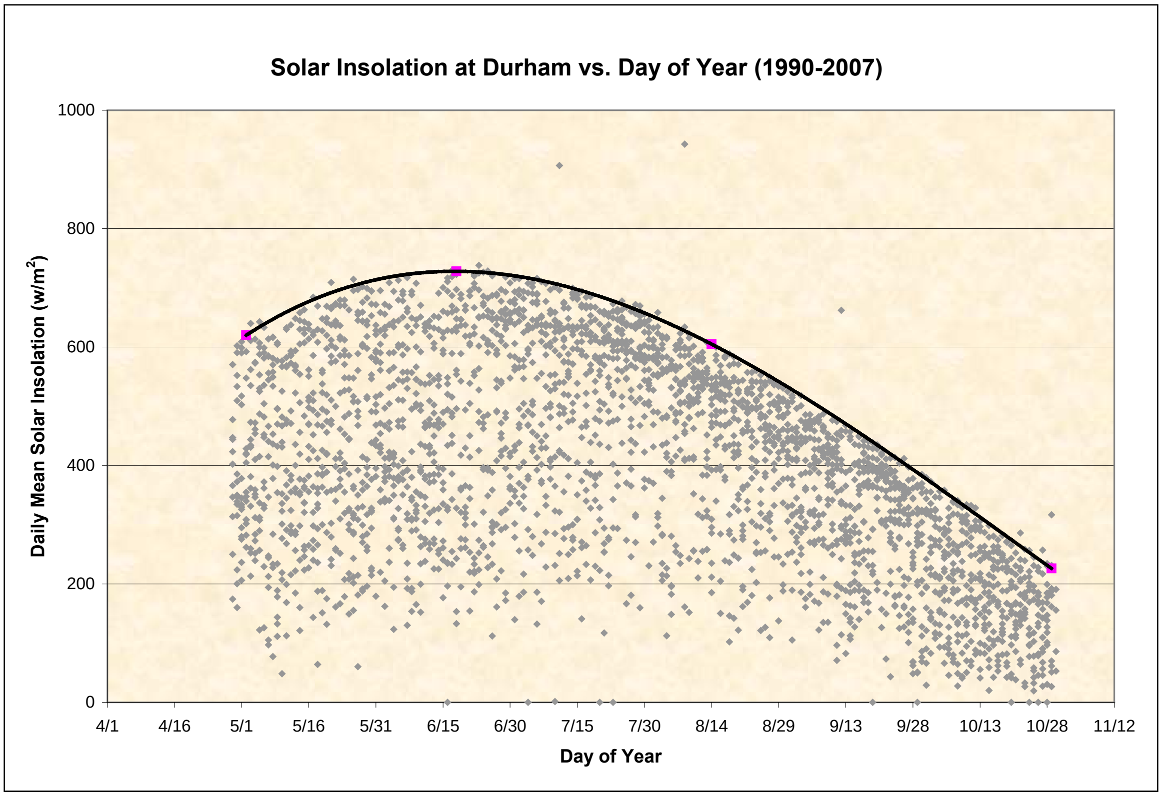


Figure 25 – Daily Mean Solar Insolation at Durham (1991-2007)

The following graph shows the number of hours by year with pH levels above 8.5 as measured by the continuous recording device at the Oswego Diversion Dam. The data period that was evaluated was from 1991-2007. Figure 26 shows that pH exceedances occurred in the early to mid- 1990's; however, pH criteria have been met from 1996 onwards. Figure 27 presents the number of hours by month with pH values above 8.5 as measured by the continuous recording device at the Oswego Diversion Dam. This figure shows that pH exceedances have occurred June, July and August. There has been only one hour where a pH value above 8.5 was measured in September over the 17-year period. There were no pH exceedances in October over that period.

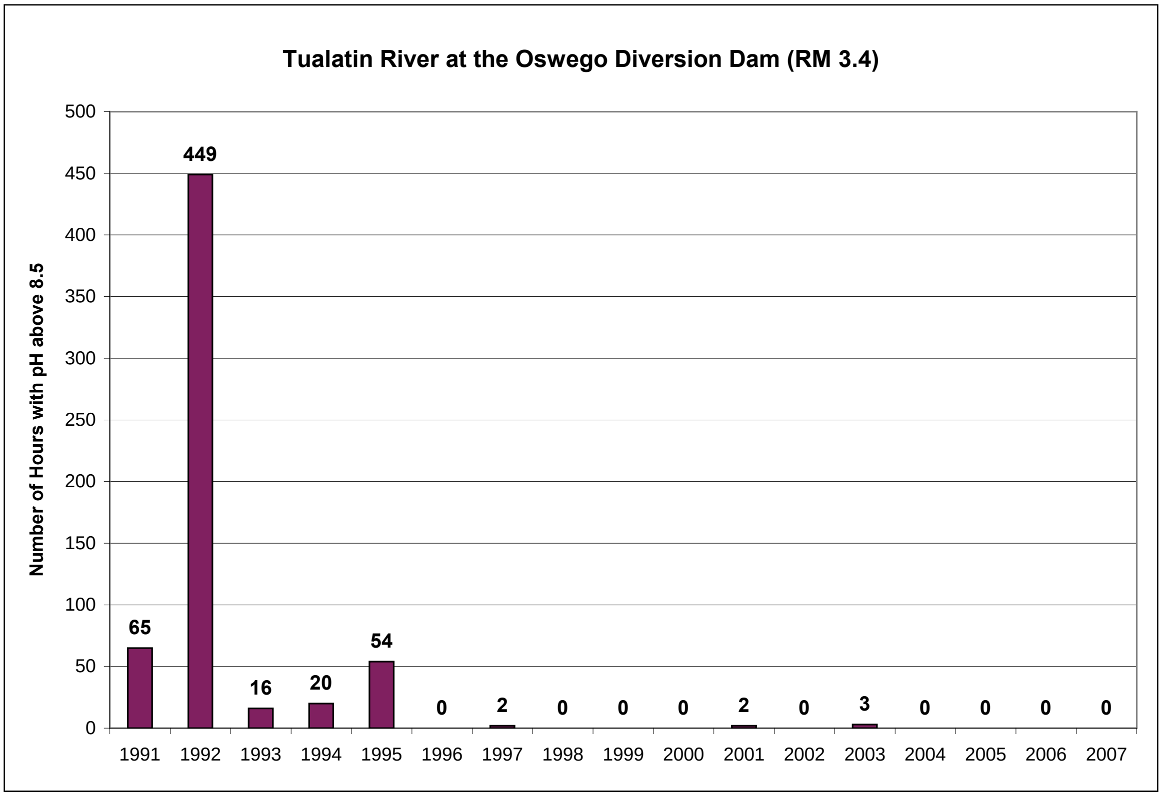


Figure 26: Number of Hours with pH Values above 8.5 at the Oswego Diversion Dam from 1991-2007

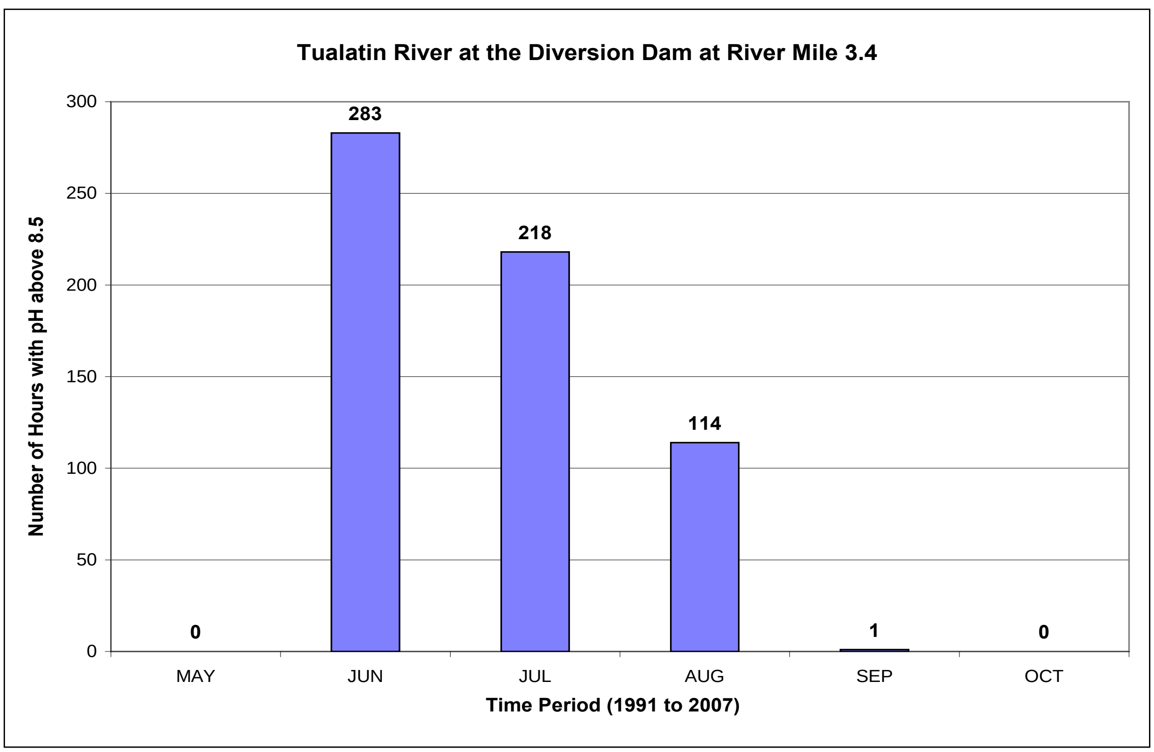


Figure 27: Number of Hours with pH Values above 8.5 at the Oswego Diversion Dam from 1991-2007

The daily maximum pH is closely ($R^2 = 0.85$) related to dissolved oxygen saturation. As shown in Figure 28, the pattern of high pH associated with high dissolved oxygen saturation levels is consistent over the time periods where continuous monitoring is available (i.e. Transition Period, Post-TMDL Period, and Watershed-based Permit Period). For the high algal growth period or fall (September – October) elevated pH above 8.5 occurs only when daily maximum oxygen exceeds about 160% saturation. As shown in Figures 28 & 29 below, daily maximum saturation rarely exceeds 160% in September and October and thus, pH exceedances in September and October are rare.

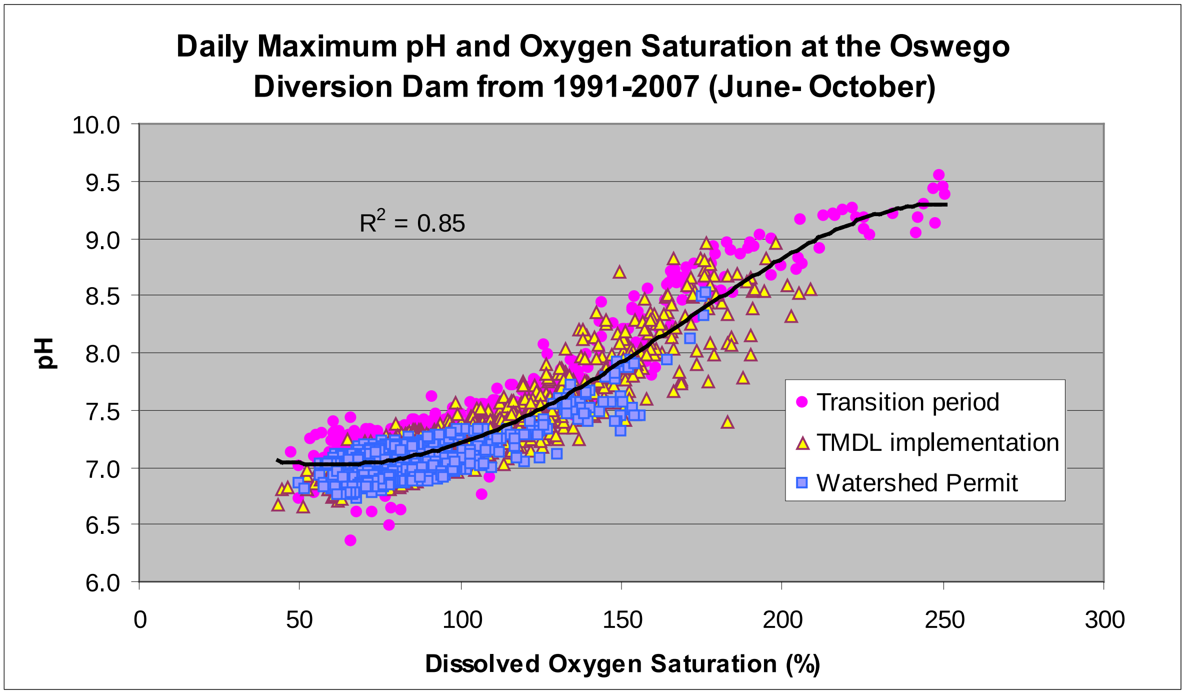


Figure 28: Daily Maximum pH and Oxygen Saturation at the Oswego Diversion Dam from 1991-2007

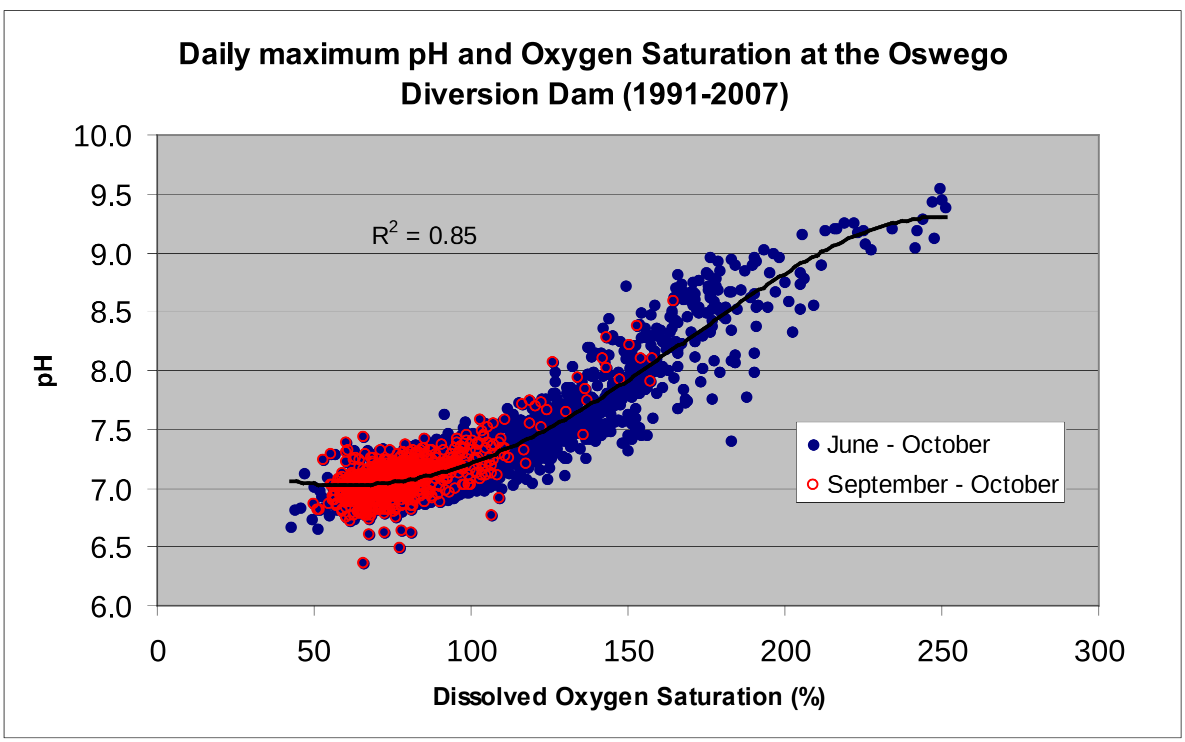
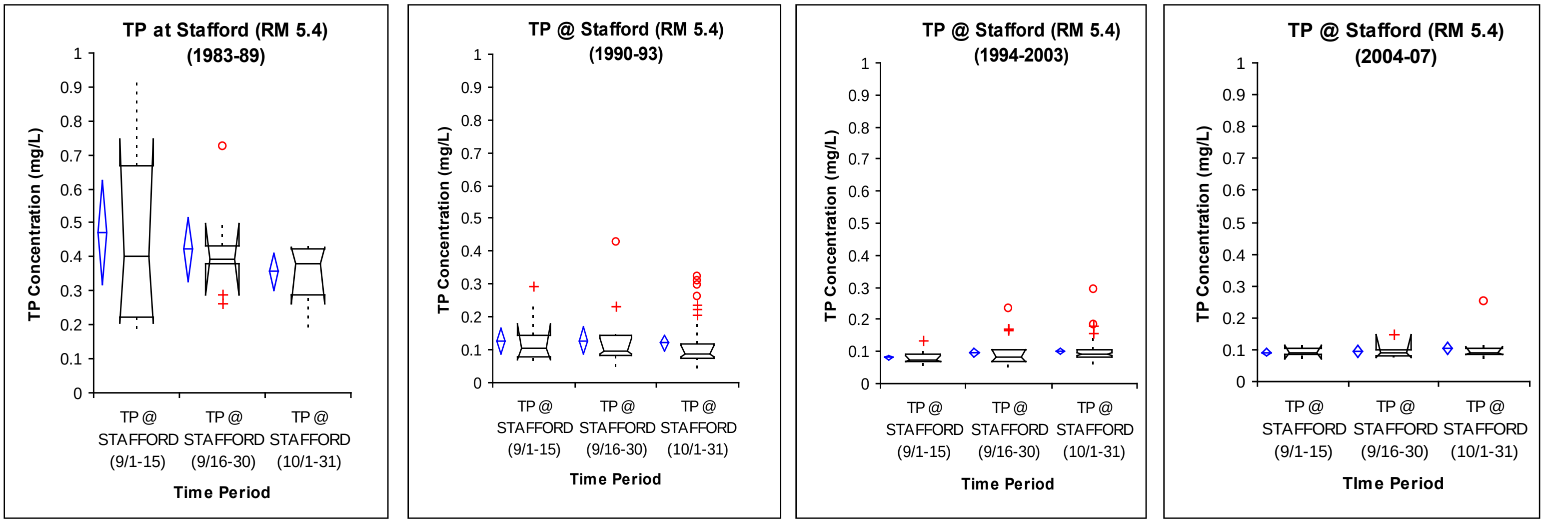


Figure 29: Daily Maximum pH and Oxygen Saturation at the Oswego Diversion Dam from 1991-2007

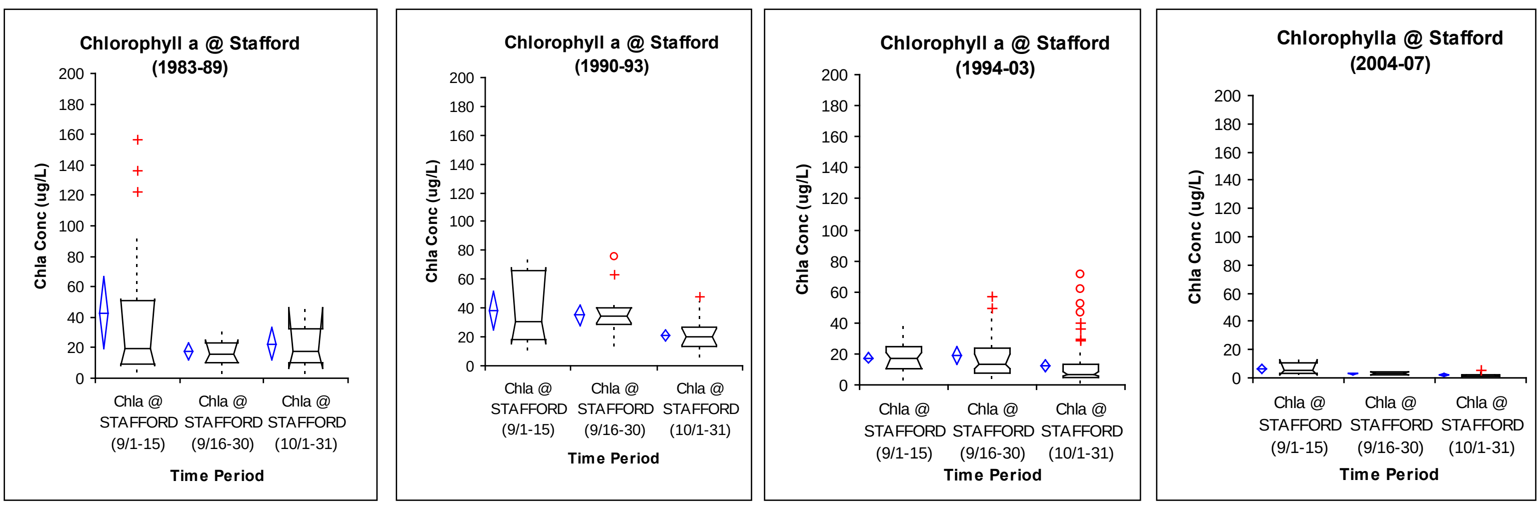
4.3.3 Late Season Data Evaluation (September/October)

The following charts present total phosphorus, chlorophyll-a, and pH discrete monitoring data at Stafford, and continuous monitoring pH data at the Oswego Diversion Dam during early September, late September, and October for the four time periods (pre-TMDL, transition period, post-TMDL, and watershed-based NPDES permit). The following observations are made from a review of these charts:

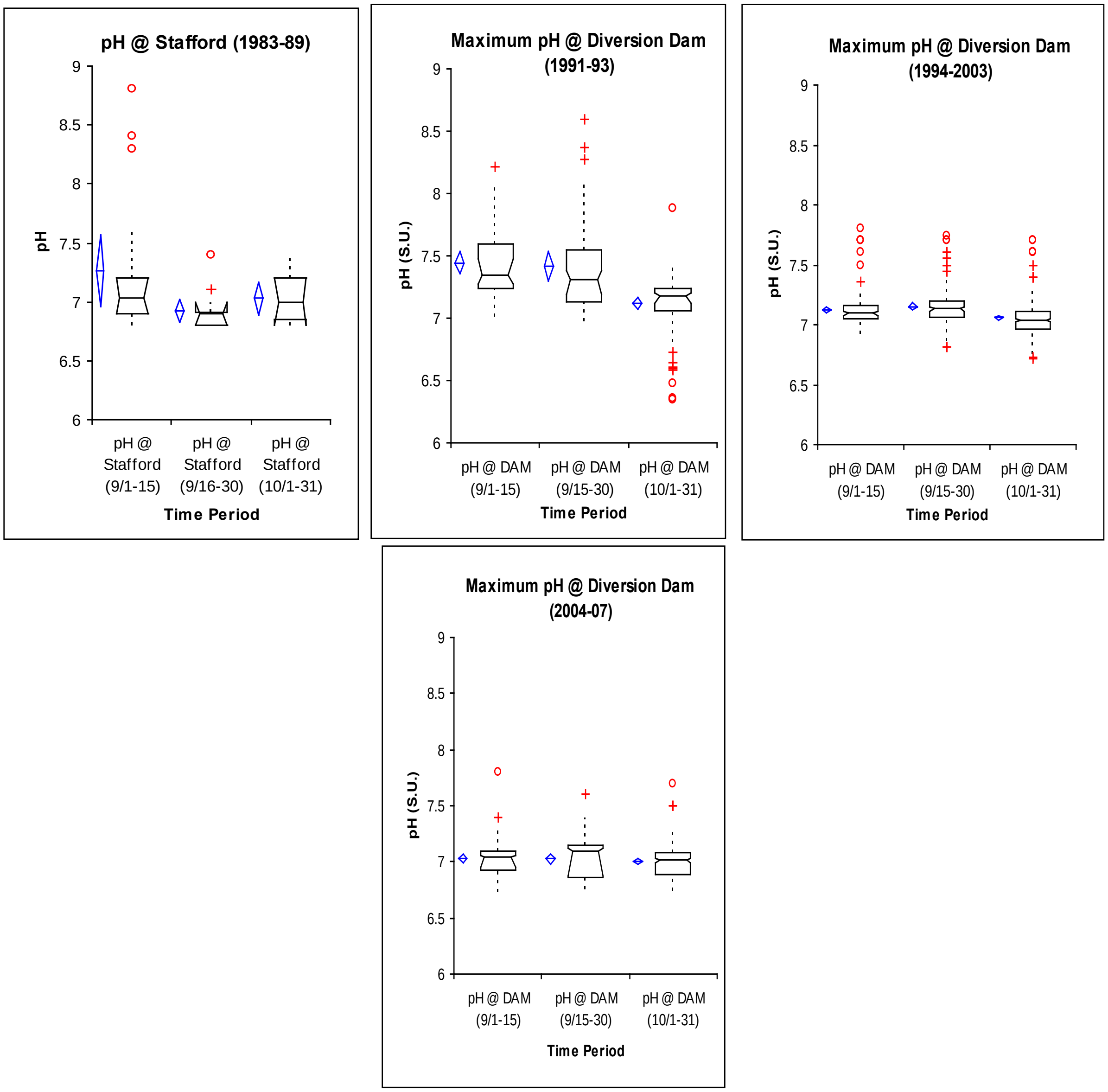
- As noted in the earlier charts, the reduction in total phosphorus levels at Stafford is quite dramatic from the pre-TMDL period (1983-1989) to the post-TMDL period (1994-2003). The total phosphorus concentrations during the implementation of the watershed-based NPDES permit (2004-07) have continued to remain very low and are similar to the levels noted in the post-TMDL period.
- The reduction in chlorophyll-a levels at Stafford is also noticeable from the pre-TMDL period to the post-TMDL period. However, reductions in chlorophyll-a levels are more modest than the total phosphorus reductions noted above.
- Even after the total phosphorus TMDL was achieved, *median* chlorophyll-a levels continued to remain above the DEQ action level of 15 μg/L during September. There were several chlorophyll-a measurements that were above the action level even in October even after attainment of the total phosphorus TMDL.
- The chlorophyll-a levels during the implementation of the watershed-based NPDES permit are even lower than the levels in the post-TMDL period. Since the total phosphorus levels from the AWTFs and at Stafford are similar to the post-TMDL period, the additional reductions in the chlorophyll-a levels may be due changes in the Tualatin River flow regime caused by earlier releases of stored water by the District to meet temperature trading provisions as well as reductions in the withdrawal rate by the LOC and the removal of the flash boards at the Oswego Diversion Dam. These actions reduce the residence time and reduce algal growth in the reservoir portion of the Tualatin River (RM 33 to 3.4).
- Discrete monitoring data collected during the pre-TMDL period shows that there was a single pH exceedance in September (Figure 38); the exceedance occurred on September 1, 1987. Daily stream flows at West Linn for that week ranged from 69 to 101 cfs, well below the current flow target for September of 180 cfs at Farmington, which equates to over 200 cfs at West Linn. No other exceedances were noted in September during the pre-TMDL period even though total phosphorus levels as shown in Figure 29 were well above the calculated in-stream concentration of 0.25 mg/L associated with potential future total phosphorus loads from the AWTFs.
- During the pre-TMDL period, there were no pH exceedances in October even though in-stream total phosphorus levels were within the range associated with the proposed future total phosphorus loads from the AWTFs.



Figures 30, 31, 32 & 33 – Total Phosphorus Levels at Stafford during Various Time Periods (discrete data)



Figures 34, 35, 36 & 37 – Chlorophyll-a Levels at Stafford during Various Time Periods (discrete data)



Figures 38, 39, 40 & 41 – pH Levels at the Oswego Diversion Dam during Various Time Periods (Discrete Data from 1983-89 & Continuous Data from 1991-2007)

The following section discusses the pH exceedances noted in the early to mid-1990s and the conditions and the time of year associated with these exceedances. Figure 42 presents the product of solar insolation (at Durham) and in-stream temperatures (at the Oswego Diversion Dam) vs. pH at the Oswego Diversion Dam. The following observations are made from this chart:

- pH exceedances occurred during the period that had the highest combination of solar insolation and in-stream temperatures. This occurred during the months of June, July, and August.
- The September/October time period does not have the combination of solar insolation and in-stream temperatures to cause pH exceedances. A ***single one-hour pH exceedance*** was noted in September 1993; the pH exceedance occurred at stream flows that are well below the District current target flows for September and October as noted above. There were no exceedances in October.

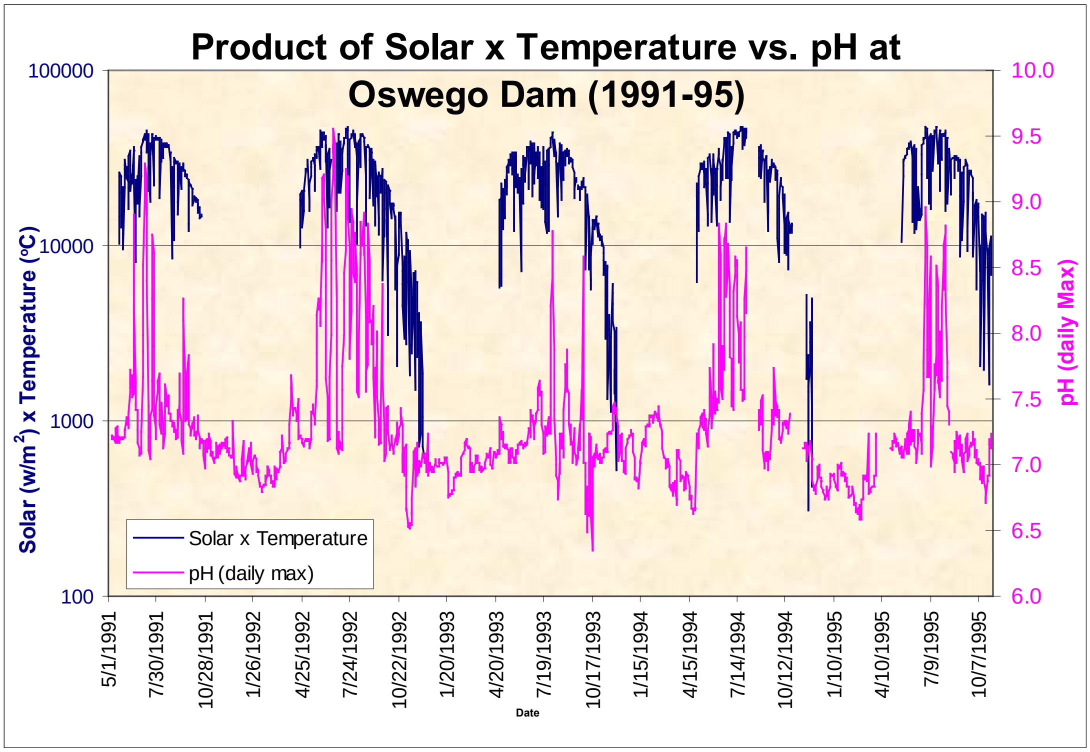


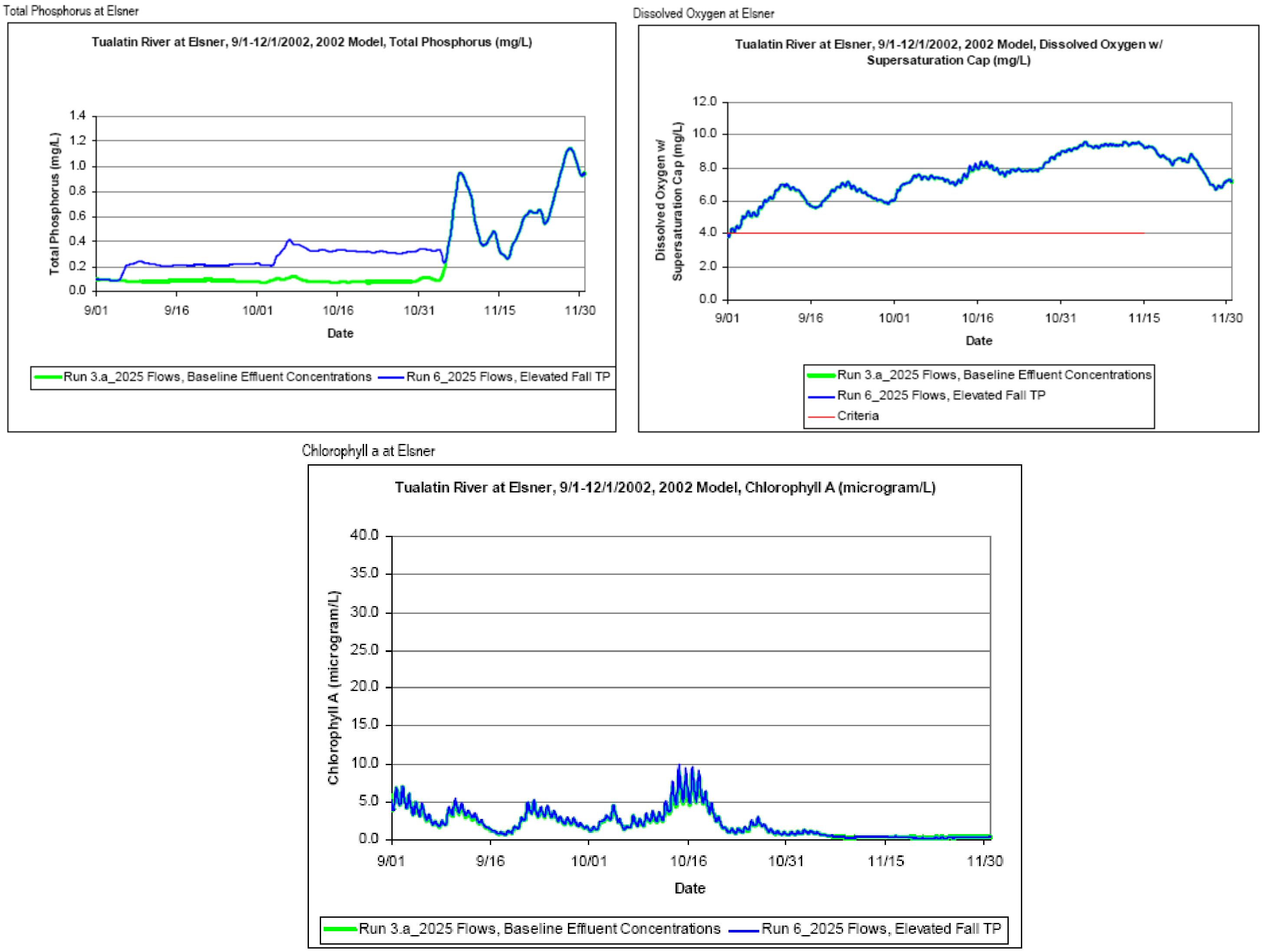
Figure 42: Product of Solar Insolation and Temperature vs. pH at the Oswego Diversion Dam

5.0 River Water Quality Modeling

The District also simulated the response the river would have to higher effluent phosphorus concentrations for September and October. For modeling purposes, the District developed alternative effluent concentrations that would be readily achievable by operating the two AWTFs under biological phosphorus removal processes (i.e., 0.5 mg/L for September and 1.0 mg/L for October). To further evaluate if these alternative total phosphorus concentrations would be protective of the river in the fall season, the District ran the latest calibrated USGS CE-QUAL-W2 model of the Tualatin River. The latest calibration is based on a portion of the post TMDL period (2000-03). The results of the modeling are shown in the figures below for total phosphorus, dissolved oxygen and chlorophyll-a at two key locations in the lower river: (1) downstream of the Rock Creek AWTF at Elsner (RM 16.5) and (2) downstream of the Durham AWTF at Stafford (RM 5.4). These locations have been shown in previous modeling (including that for the 2001 TMDL) to be critical locations for eutrophication effects evaluation. Results for 2002, which was a very low flow year during critical summer and early fall time periods, are shown below because they are conservative. The model does not simulate the natural buffering capacity of organic matter and suspended materials in the Tualatin River, and therefore cannot reliably simulate the higher pH values that can occur during an algal bloom. Therefore, pH results are not presented in the charts below. However, as previously noted, elevated pH values are closely related to dissolved oxygen/dissolved oxygen saturation (Figures 23, 28 & 29). Dissolved oxygen is one of the parameters for which results are presented in the charts below. Run 3.a represents 2025 effluent flow conditions at Rock Creek and Durham AWTFs, actual total phosphorus levels from the AWTFs, actual ammonia levels at the AWTFs and 2002 stream flow and meteorological conditions. Run 6 represents the same conditions as Run 3.a except the effluent total phosphorus levels at the AWTFs are 0.5 mg/L and 1.0 mg/L in September and October, respectively.

Figures 43 through 45 show the resulting total phosphorus, dissolved oxygen and chlorophyll-a levels at Elsner, downstream of the Rock Creek AWTF and within the reservoir portion of the

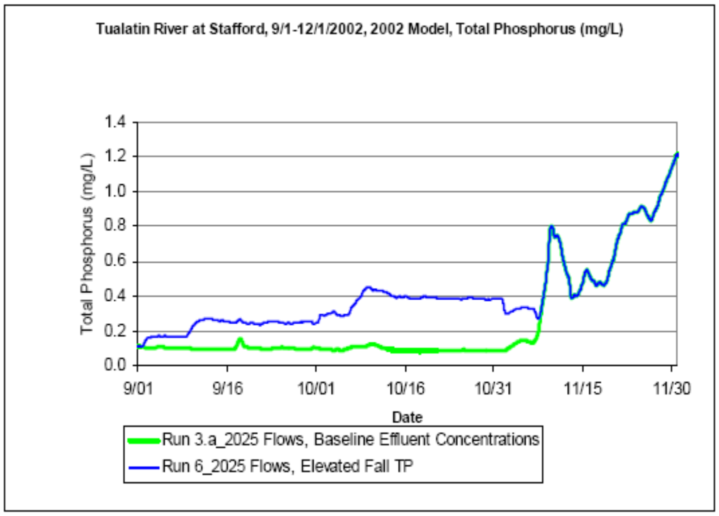
Tualatin River where algal growth is a concern (Figure 8). These figures show that the increase in total phosphorus levels in September and October would not be predicted to change the dissolved oxygen and chlorophyll-a levels at Elsner under watershed based NPDES permit stream flow management conditions. Note that the dissolved oxygen (Figure 44) and chlorophyll-a (Figure 45) levels are nearly identical (lines are on top of each other) in both scenarios.



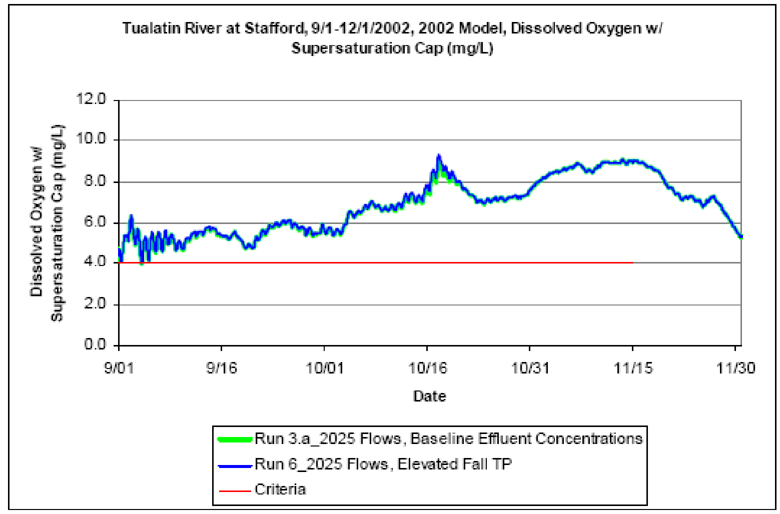
Figures 43, 44 & 45 – Total Phosphorus, Dissolved Oxygen and Chlorophyll-a Levels at Elsner

Figures 46 through 48 show the resulting total phosphorus, dissolved oxygen and chlorophyll-a levels at Stafford, downstream of the Durham AWTF. The increase in total phosphorus levels in September and October does not materially affect dissolved oxygen and chlorophyll-a levels at Stafford. Similar to the findings at Elsner, the dissolved oxygen and chlorophyll-a levels are nearly identical (lines are on top of each other) in both scenarios at Stafford.

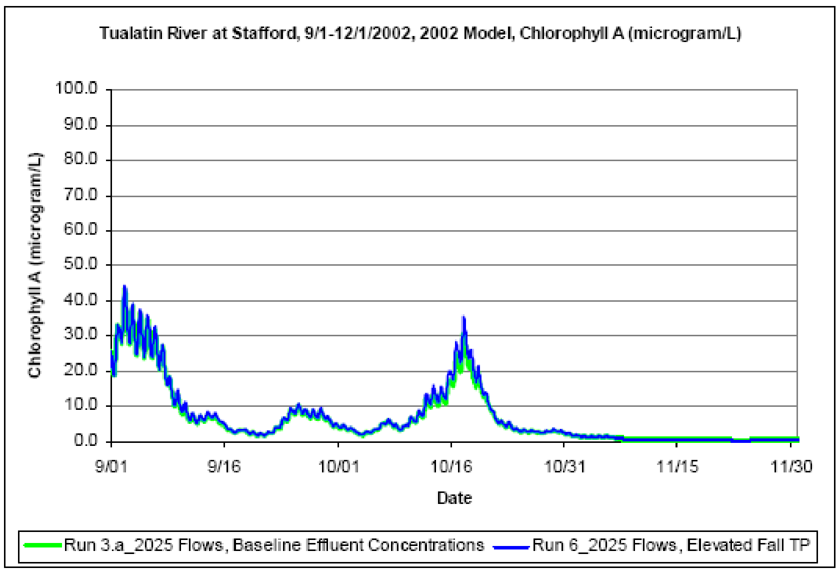
Total Phosphorus at Stafford



Dissolved Oxygen at Stafford



Chlorophyll a at Stafford



Figures 46, 47 & 48 – Total Phosphorus, Dissolved Oxygen and Chlorophyll-a Levels at Stafford

6.0 Summary

The following is a summary of the key findings in this report:

- The peak algal growth period and exceedances of the pH criteria primarily occur in June, July and August.
- Adverse water quality related to algal growth (i.e. pH exceedances) was rare in September and non-existent in October even when ambient total phosphorus levels were high.
- The rare circumstances where pH exceedances were noted in September occurred during stream flow conditions that are well below current target flow rates for the Tualatin River.
- As presently managed, the Tualatin River is less conducive to algal growth that could lead to pH exceedances than during historical conditions due to current stream flow management, increased flow from the AWTFs, and changes to operations (flash boards) at the diversion canal.
- Under current stream flow management, the observed levels of dissolved oxygen, pH, and chlorophyll-a indicate low algal growth especially as managed in recent years even though total phosphorus levels have remained constant.

- A review of the data indicates that exceedances of the pH criteria could occur if:
  - Tualatin River flow is less than 120 cfs; and
  - Daily average solar insolation is greater than 550 watts/m^2; and
  - Chlorophyll-a levels greater than 100 μg/L

  This combination of factors is not expected to occur in September and October.
- Water quality modeling shows that the increase in total phosphorus levels at Rock Creek and the Durham AWTFs in September and October does not materially affect dissolved oxygen and chlorophyll-a levels in the Tualatin River.

7.0 Conclusions

Water quality data available for the Tualatin River shows that the September/October time period does not have the combination of solar insolation, in-stream temperatures, and stream flows as currently managed to cause nuisance algal growth leading to exceedances of the pH criteria. Water quality modeling using the latest calibrated USGS CE-QUAL-W2 model of the Tualatin River shows that there are no adverse effects on water quality conditions in the lower river as a result of higher effluent total phosphorus concentrations for the Rock Creek and Durham AWTFs during September and October. Thus, the District requests a modification of the time period for the application of the phosphorus TMDL to exclude the months of September and October.