EVALUATION OF THE INFLUENCE OF RAINFALL ON PHOSPHORUS LOADIN G IN LAKE SIMCOE

by

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Abstract

Lake Simcoe is a major source of fresh water supply and serves as a favorite hub for recreational activities in southern Ontario. The cold water aquatic life of this Lake is facing serious threats due to depleted levels of oxygen caused by excessive growth of algal plants. The major reason for this growth is the entrance of high phosphorus loads through heavy stream discharges in the months of January until April. The results of analysis of phosphorus concentration and flows conducted in this project shows a direct dependence of phosphorus load on the flow. Although the relation of rainfall and phosphorus load could not be supported by strong statistical evidence, the flow variations have been shown to be the major cause of variations in phosphorus load. The control strategies should be focused on reducing the generation of phosphorus at source level and preventing the direct entry of heavy flushes in the lake through Best Management Practices (BMPs), including detention facilities.

Acknowledgements

The author acknowledges his indebtedness and sincere gratitude to his supervisor Dr. James Li, P.Eng, Professor, Dr. Darko Joksimovic, P.Eng, Professor, Department of Civil Engineering, Ryerson University, and Ms. Mina Mirzajani, M.Eng for their continuous guidance, assistance and inspired encouragement through the entire course of this project work.

Table of Contents

List of Figures

List of Tables

List of Abbreviations:

ADF	Annual Daily Flow
TPC	Total Phosphorus Cocentration
ADTPC	Average Daily Total Phosphorus Concentration
TPL	Total Phosphorus Load
LSRCA	Lake Simcoe Region and Conservation Authority
FUN	Function Method
MID	Mid Point Method
STP	Sewage treatment plant

List of Appendices

CHAPTER 1

INTRODUCTION

1.1 General

Phosphorus is an important nutrient necessary for the growth of plants and animals, but its higher concentration in freshwater lakes can cause serious negative effects on the aquatic ecosystems. Eutrophication is one of the most common problems so caused (Carpenter et al., 1998). The increase in the phosphorous load in a lake can cause the excessive growth of algae and subsequent depletion in the dissolved oxygen level, which in turn disturbs the freshwater aquatic life.

Phosphorus occurs naturally in the environment and never goes away; it simply changes its forms, cycling through the environment. In our rivers and streams, phosphorus can be found dissolved, or attached to particles in the water. It is an important nutrient that plants and animals need to grow. When taken up by plants or consumed by animals, it becomes part of their tissue. When the plants and animals excrete waste or die, phosphorus returns to the environment where bacteria breaks it down so it is once again available for other plants and animals, and the cycle begins again. When plants are abundant, their decomposition creates an oxygen shortage at the bottom of the lake.

Lake Simcoe's cold water fish live in deeper, colder waters, especially when they are young. Oxygen concentrations drops significantly at the bottom of lake during late summer, and the water get warmer at top. This forces the young fish to move towards shallower depths, where many lake trout are eaten up by bigger fish even before their maturity, and the cold water fish community is unable to sustain by itself (LSRCA, 2004-2007).

1.2 Background

Lake Simcoe is the largest lake in southern Ontario after the Great Lakes. Being located within a commutable distance from GTA, it serves for recreational activities to more than half of Ontario's population. The financial worth of these activities exceeds $160 Million annually (Nicholls, 2001). The lake also serves as a municipal drinking water source and is the receiving water body for treated sewage from several urban centers. The first conclusive evidence of water quality impairment was gathered during 1971-1974. To control the depleting water quality of Lake Simcoe, a comprehensive strategy was formed as "Lake Simcoe Environmental Management Strategy (LSEMS)" and an initial 5 year investigation plan was authorized in 1979 (Nicholls, 2001). The LSEMS steering committee (LSEMS 1985) identified excessive phosphorus loading to the Lake Simcoe resulting in the loss of deep water dissolved oxygen. In this report the phosphorus load entering into the Lake Simcoe was estimated at 100 ton/year and dissolved oxygen at its lowest level of 3.2 mg/l (LSEMS, 2003). LSEMS then decided to control this increased level of phosphorus and set a target of 75 tons/year to maintain a better water quality and to support a self-sustained aquatic life in Lake Simcoe.

A comprehensive campaign was launched to achieve this target, and no new point source has been allowed in Lake Simcoe since 1985. This strategy remained successful and achieved a 16.5 tons/year reduction in TP load to the Lake between 1990 to 2000 through more than 350 projects and studies (LSEMS, 2003). The TP load to Lake Simcoe was reported below 75 tons/year target during the period of 1998 to 2003. Despite the considerable reduction of TP load over the last decade, the level of DO is still below 5mg/l, which is insufficient for the survival of self-sustained cold water fisheries (Winter et. al., 2007).

Lake Simcoe Region Conservation Authority (LSRCA) has been recording the flow discharge since early 60's for most of its subwatersheds on daily basis. The water quality has become the primary concern during past few decades, hence a number of water quality monitoring stations have been installed covering all the major streams and urban point sources of load. Water flow is being recorded on daily basis, but the water quality tests (being expensive) are conducted at a frequency of 2-3 times per month. Additional samples are collected for the events of heavy rainfall (LSRCA, 2004-2007).

A major portion of the phosphorus load enters through the tributaries. LRSCA in its report on phosphorus loading for the duration of 2004 to 2007(LSRCA, 2004-2007) has reported the phosphorus load from tributaries as, 47.3, 37.2 and 44.0 tons/year for the years of 2004-2005, 2005-2006 and 2006-2007 respectively. Since rainfall is the major contributor in surface runoff, it is important to understand the relationship between rainfall and total phosphorus loading. This relationship may also support in making accurate and reliable projections of Total phosphorus load and in modeling any potential correlation with the global climatic changes.

1.3 Objective

The objective of this study is to investigate relationship between daily rainfall and daily total phosphorus load (TP Load) entering into the Lake Simcoe.

In this project a comprehensive analysis on the available data of daily flow, daily total phosphorus concentration and daily rainfall has been conducted. Different stratifications of data, including, monthly, seasonal and yearly have been examined to evaluate the relationship of flow to total phosphorus concentration (TPC) and rainfall to total phosphorus load (TPL).

In order to achieve the intended targets, relevant data was obtained from LSRCA for daily flow, rainfall and phosphorus concentration. The data for daily phosphorus concentration was not available on daily basis, thus gap filling techniques were deployed to get a continuous time series of daily TP concentration and finally to calculate the daily load as per following basic function.

$$W = C \times Q \qquad \text{(Eq-1)}$$

Where:

W= Total Phosphorus Load (kg/day),

C= Total Phosphorus concentration (µg/l)

Q= Flow (m^3/s)

Note: Units need to be converted appropriately from liters to 'm^3', 'sec' to 'day', and 'µg' to 'kg'.

CHAPTER 2

LITERATURE REVIEW

In order to better understand the morphology and water quality problems in Lake Simcoe various articles, journal papers and annual reports by LSRCA have been reviewed for; a) watershed delineations approach in Lake Simcoe, b) site description, c) Surface water quality in Lake Simcoe, d) Sources of pollution in Lake Simcoe, e) different factors affecting the water quality, and f) water quality monitoring programs in Lake Simcoe.

2.1 Watershed delineation approach

The prime focus of water management is always to improve and preserve the available water resources. This scale of watershed management has proven to be very successful because it is based on the natural watershed boundaries and deals with the complete ecosystem. Ecosystems are described as dynamic interacting, living systems; where human are parts of this system. The ecosystem approach is based on the concept that everything is connected to everything else (LSEMS, 2003).

The advantage of using a watershed boundary for planning and policy implementation is that the study area is essentially a water –based ecosystem. Therefore, the consequences of future land use in the watershed can be evaluated based on their cumulative effect relative to all natural resources contained within the ecosystem. This can help in better territorial management by the water resource planners, municipalities, town planners, and regulatory authorities with objective to minimize the damaging impacts to our ecosystem.

The watershed planning process began in the Lake Simcoe basin in the early 1990s out of public and Government concern for its protection (LSEMS, 2003). The current watershed delineation is based on the Ontario based Mapping System (OBM).

2.2 Site Description

Lake Simcoe (44°25'N 79°20'W) is located in southern Ontario, Canada, approximately 50km north of Toronto and towards the south-east side of the Georgian Bay of Lake Huron. The total watershed area is 3,557 km^2, of which 80% is terrestrial 2,899 km^2, (Evan et al., 2007). It has total water surface area of 722 km^2 and is the sixth largest lake in Ontario. Its watershed occupies a total land area of 2,900 km2 and is divided into four main physiographic units: the Oak Ridge's Moraine, the Schomberg Clay Plains, the Peterborough Drumlin Fields and the Simcoe Lowlands - each with its distinctive characteristics of topography, bedrock and soil type.

Almost 35 rivers and smaller streams drain into Lake Simcoe. The catchments of the five largest (the Holland River, the Black River, Pefferlaw Brook, the Beaver River and the Talbot River) account for about 60 % of the total land area draining to this lake. The lake drains northward through the Atherley Narrows to Lake Couchiching then through the Severn River to Georgian Bay of Lake Huron. Mean annual air temperature is 6-7°C and there are about 130 frost-free days per year. About 20-25 % of the total annual precipitation of 80-84 cm falls as snow (K.H Nicholls, 2001).

Lake Simcoe has a large surface area but relatively shallow depth with an approximate volume of 10.6 x 10^3 m^3. Land use is predominantly agricultural with areas of forest, wetland and cultural greenlands (Table 1). The term cultural greenlands is used to distinguish the areas of vegetation from agricultural, e.g., meadow or manicured open space, which is maintained but it is not agricultural. The agricultural area consists of crop and livestock production and includes the largest cultivated marsh or "polder" area in Ontario. There are seven marshes covering an area of approximately 40 km^2 in the Holland River subcatchment; the largest is the Holland Marsh (28 km^2). Water levels within the polders are maintained through a series of pumping stations and canals, this system terminates at the Art Janse Pumping Station (formerly the Bradford Pump House) located at the outflow. About 12% of the watershed comprises urban development and roads (Evan et al., 2007). The current urbanization trends across the watershed have been illustrated in Fig-1.

Land use in the sub catchments of the North Schomberg, Upper Schomberg, and Beaver rivers is predominantly agricultural, whereas the Black River and Pefferlaw Brook sub catchments have the largest proportions of forest, wetland, combined with cultural green lands (Winter et al, 2007). The East Holland River Barrie Creek and Lovers Creek subcatchments have the largest proportions of urban development and roads (Table 1 and Fig-1).

Table 1: Land-use categories (%) in the Lake Simcoe catchment and monitored sub catchments (Winter et al, 2007)

Sub Water Shed	Area (Km^2)	% Forest	% Wetland	% Cultural Greenland	% Intensive Agriculture	% Non-Intensive Agriculture	% Urban & Roads
Beaver River	325	16	16	0	26	36	4
Black River	323	37	14	1	26	13	8
East Holland River	238	25	10	3	21	11	29
Lovers Creek	58	27	11	3	29	6	24
Pefferlaw Brook	423	32	12	1	22	22	8
North Schomberg River	31	10	2	0	77	3	7
Upper Schomberg River	43	26	5	0	49	10	10

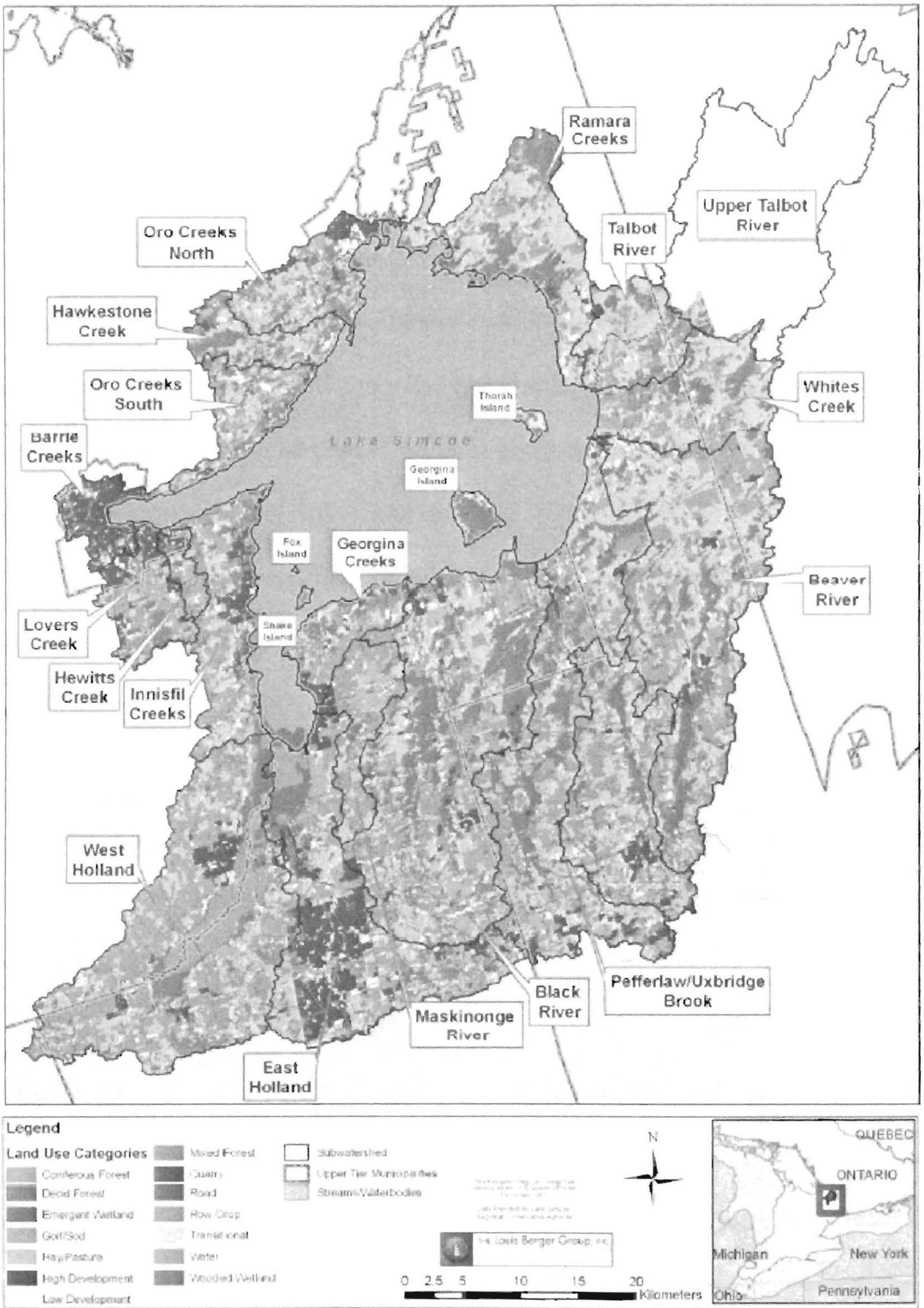


Figure 1: Lake Simcoe subwatersheds and the land use categories (Source: Louis Berger Group, 2010)

2.3 Surface water quality in Lake Simcoe

Comprehensive monitoring program, studies and reviews have enabled us to acknowledge the fact that the water quality within the Lake Simcoe has been impacted mainly by human activities. The surface water quality has shown clear variations within different watersheds. This variation is mainly because of variant land uses and the topography of each watershed.

2.4 Sources of phosphorus in Lake Simcoe

Different sources of phosphorus have been identified in Lake Simcoe, which can be categorized as;

2.4.1 Urban non-point source loads:

Lawn fertilizers, pet waste, detergents, car washing are the major urban non-point sources of phosphorus in urban runoff. The urban runoff from modernly constructed major sources is treated, but the runoff from most of the small cities and older communities enters the lake without any treatment and is termed as "uncontrolled". In 1998 the LSEMS technical report A4, reported a total of 21.9 tons of phosphorus load from selected uncontrolled urban areas of the average 102 tons of phosphorus that the Lake Simcoe received annually (LSEMS, 2003)

2.4.2 Sewage treatment plants; urban point source loads

The phosphorus concentration discharged from each sewage treatment plant (STP) and the water flow is recorded for each facility and the total phosphorus (TP) load is determined as the simple product of the two parameters. LSEMS reported 5.7 tons from STPs in 1998 (LSEMS, 2003)

2.4.3 Vegetable polder loads

Agriculture practices in marshes in the Lake Simcoe watershed (Bradford, Keswick, Colbar and Holland) rely on the management of waters in the fields. Water is either pumped onto the fields for irrigation or is pumped out from the fields to drain excess moisture. The drained water from marshes can contain significant nutrient concentration depending on the time and intensity of fertilization.

2.4.4 Atmospheric deposition

Atmospheric deposition is the second largest source of phosphorus in Lake Simcoe, the load from tributaries. It comprises of dry and wet deposition. A comprehensive monitoring system is in place at watershed as well as lake surface levels.

2.4.5 Surface water inflow

The surface runoff from the entire watershed carries the major portion of phosphorus load into Lake Simcoe. This source is the focus in this project; data has been collected for all major sub watersheds on which the detail analysis for rainfall and TP load is done.

2.5 Activities affecting surface water quality

2.5.1 Urban stormwater runoff

Urban stormwater occurs as rain or melting snow flows from surfaces such as streets, parking lots and rooftops carrying dirt and debris with it, commercial and industrial areas usually have more impervious area (paved parking lots, sidewalks, rooftops) than any other types of land use. This impervious area results in increased volume of surface runoff and subsequently more pollutants end up in the receiving bodies. Unpaved areas allow the water to percolate into the soil, which filters the pollutants prior to it becoming into the groundwater.

2.5.2 Fertilizer application

Excessive application of fertilizers (i.e., more than the required uptake of crop) can results in surface runoff or mixing with shallow groundwater flow. The discharge from this source depends on the soil condition, moisture level, rate of application, frequency and its timing.

2.5.3 Sewage effluent

Sewage effluent is one of the major sources of phosphorus nutrient. Although the sewage flows from most the modern urban sources are treated, yet a significant portion of uncontrolled effluent ends up in the lakes. Leaching septic tanks along the shorelines and rivers are also a major source of uncontrolled sewage effluent.

2.5.4 Livestock and manure handling

Manure contains nutrients such as phosphorus, nitrogen and potassium, and is therefore an excellent source of fertilizer. However if the manure is not properly stored or handled it can runoff into surface waters or infiltrate into the ground causing contamination. Well sized storage facilities for the manure can help in containing the runoff and thus preventing the contamination of surface and ground water. The spreading of manure on frozen ground should be controlled as it can quickly runoff the field during the spring rain or snow melt events.

2.5.5 Soil erosion

Soil erosion is mainly caused by wind and water. The disturbance to nature, through urbanization, farming, and removing vegetation cover increases the rate of erosion significantly. Phosphorus as nutrient attached with the soil now becomes more susceptible for transport with precipitation or winds.

2.6 Monitoring Programs in practice –LSRCA

Monitoring is essential means of developing a picture of the health of the Lake's ecosystem. In Lake Simcoe a comprehensive monitoring system has been installed and the information collected from this monitoring system is used within the Lake Simcoe Environmental Management Strategy (LSEMS) program to develop resource targets, identify current conditions, determine trends over time, and evaluate the effectiveness of remedial activities (LSEMS, 2003).

The Ontario Ministry of the Environment, Environment Canada, Parks Canada and the LSRCA operate the monitoring sites throughout the watershed. This helps in determining the guidelines to design new programs for its protection and restoration. A list of water quality monitoring stations and their geographical spread are presented in Table 2 and Figure 2, respectively.

The monitoring is done on watershed basis. A monitored subwatershed is the one for which water quality is monitored at regular intervals of time, while un-monitored watersheds do not have such monitoring installations. Similarly, the watersheds having installations for measuring the water discharge are termed as gauged or un-gauged.

As the main emphasis of this project remains on evaluation of relationship between rainfall and phosphorus loading, the gauged and monitored subwatersheds having sufficient (minimum of 5 years) long term data for daily flow, phosphorus concentration have been considered for this analysis.

Table 2: Water Quality Monitoring Stations in Lake Simcoe Region

Water Quality Monitoring Stations					
. No	St. ID	STATION NAME	MUNICIPALITY	SUBWATERSHED	PERIOD OF OPERATION
1	138	Hewitts Creek	BARRIE	Barrie Creeks	2008 - present
2	139	Bluffs Creek	ORO-MEDONTE	Oro Creeks North	2008 - present
3	82	Pefferlaw Brook	GEORGINA	Pefferlaw Brook	1993 - present
4	85	West Holland River - Hwy 11	KING	West Holland	1982 - present
5	47	West Holland River - Hwy 11	KING	West Holland	1965 - 1995 and 2002 - present
6	48	Tannery Creek - Aurora	NEWMARKET	East Holland	1964 - 1995 and 2002 - present
7	49	Mount Albert Creek	EAST GWILLIMBURY	Black River	1971 - 1995 and 2002 - present
8	101	Maskinonge Glenwoods	GEORGINA	Maskinonge River	1985 - 1995, 2000 - 2002, 2007 - present
9	52	Maskinonge River	GEORGINA	Maskinonge River	1985 - 1995 and 2002 - present
10	53	Uxbridge Brook - Davis Dr	UXBRIDGE	Uxbridge Brook	2002 - present
11	55	Black River - Sutton	GEORGINA	Black River	2002 - present
12	57	Pefferlaw Brook	GEORGINA	Pefferlaw Brook	2002 - present
13	86	Atherly Narrows		Lake Simcoe	1995, 1997 - present
14	92	Kettelby Creek	KING	West Holland	1982 - 1998, 2002 - present
15	93	Black River - Sutton	GEORGINA	Black River	1990 - present
16	94	Upper Schomberg	NEW TECUMSETH	West Holland	1990 - 1999, 2002 - present
17	137	Hotchkiss Creek	BARRIE	Barrie Creeks	2008 - present
18	140	Leonards Creek	INNISFIL	Innisfil Creeks	2008 - present
19	142	Talbot Lock 41	BROCK	Talbot River	1993 - 1996, 2006 - present
20	88	Lovers Creek	BARRIE	Lovers Creek	1996 - present
21	50	Lovers Creek	BARRIE	Lovers Creek	1974 - 1993 and 2002 - present
22	51	Upper Schomberg	NEW	West Holland	1977 - 1993 and 2002 - present
23	54	Hawkestone Creek	ORO-MEDONTE	Hawkestone Creek	2002 - present
24	56	E Holland River - Holland Landing	EAST	East Holland	2002 - present
25	58	Beaverton River	BROCK	Beaver River	2002 - present
26	87	Beaver River	BROCK	Beaver River	1994 - present
27	90	Holland River East Branch	EAST	East Holland	1993 - present
28	95	Talbot River	BROCK	Talbot River	1994 - 1999, 2006
29	84	North Schomberg River	BRADFORD-WEST	West Holland	1982 - 1998, 2002 - present
30	89	Hawkestone Creek	ORO-MEDONTE	Hawkestone Creek	1994 - present
31	91	Holland Marsh Pump House	KING	West Holland	1982 - 1996, 2001 - present
32	141	Ramara Drain	RAMARA	Ramara Creeks	2009 - present
33	83	Whites Creek	BROCK	Whites Creek	1993 - 1999, 2002 - present

Note: Sourced from the GIS data provided by the LSRCA

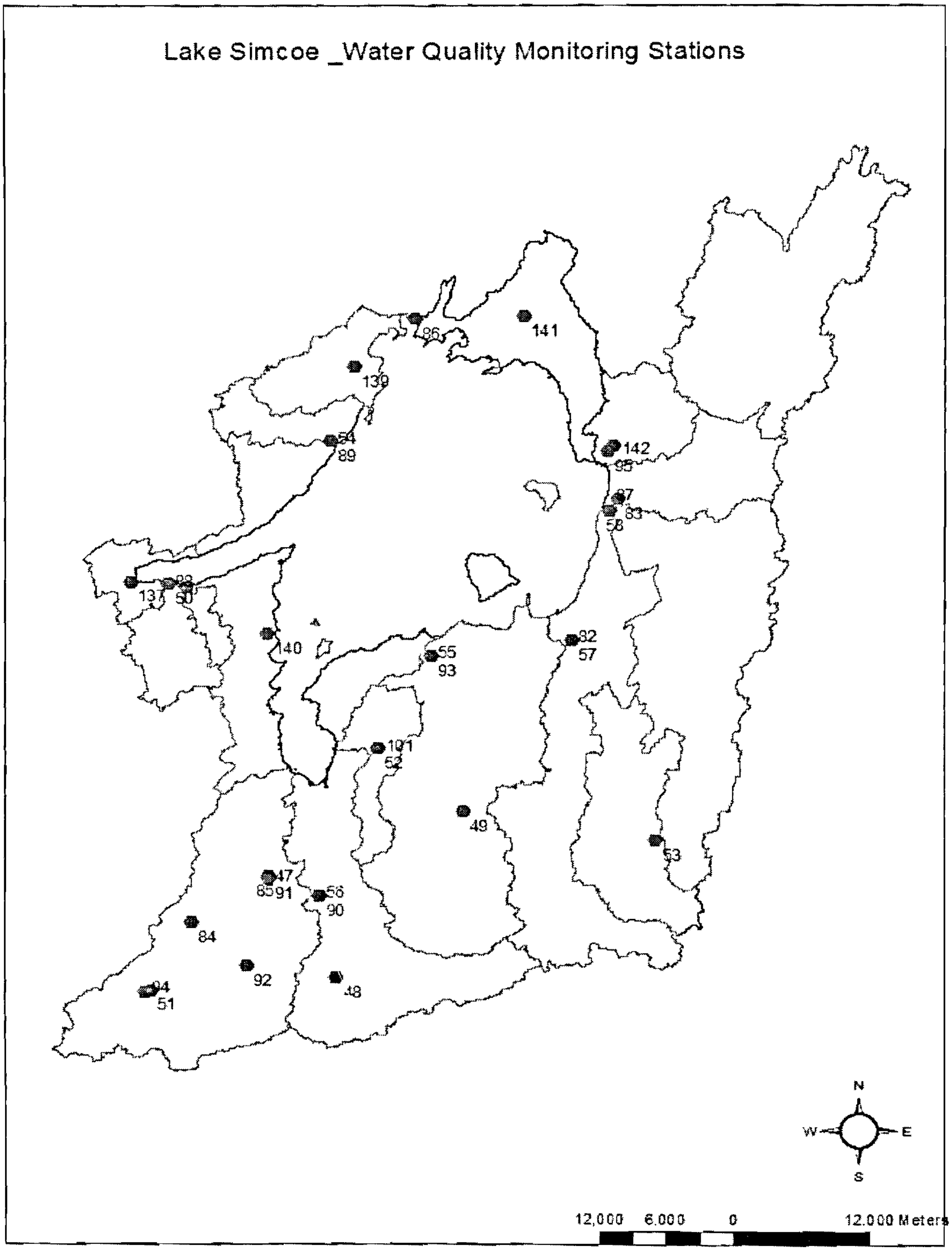


Figure 2: *Water quality monitoring stations in Lake Simcoe watershed (Source: the GIS data provided by the LSRCA*

CHAPTER 3

METHODOLOGY

3.1 Project Approach

The major part of this study is based on data analysis. Data analysis has been executed in MS Excel. A customized function as "findbestmatch" was coded in visual basic language (Appendix-1) for the execution of midpoint method. The midpoint method divides the gap in two halves and assigns the known end value to the adjacent half. A comprehensive Excel sheet was structured to perform all the functions including "findbestmatch", advance filtering through macros for various data stratification, determining the total phosphorus concentration, total phosphorus load and their mutual correlation, and plotting of graphs for such relationships.

Data analysis techniques including linear correlation, linear and polynomial regressions were used in this project. The results from this data analysis were evaluated for their statistical significance and used for interpolating the missing data. Midpoint method for filling the gaps of missing data was used where such functions were found to be insignificant. The hydrologic function of load (Eq-1) was used to determine the daily TP load. A hierarchal order of preference was assigned to choose the preferred method for gap filling the missing data for daily records of total phosphorus concentration. Two approaches; a) midpoint method, where all the gaps were filled only with conventional midpoint method and b)Function and midpoint method, where data was gap filled for the months showing functions of statistical significance from 2nd order polynomial regression and the data for the months with insignificant functions was filled with midpoint method. The results from these two approaches have also been compared to evaluate the variations in phosphorus loading calculated by the two methods.

3.2 Data Collection

For this study, the data for average daily flow (ADF) and average daily total phosphorus concentration (ADTPC) for the recorded days was obtained from Lake (LSRCA).

3.2.1 Daily flow data

The average daily flow (ADF) data was available in basic units of 'm^3/s' for most of the subwatersheds. The missing flow data had been estimated by LSRCA, based on the nearest available record (Table-3). The flow data was generally available from 1966 till 2009, yet few subwatersheds had no flow data, and were not included in this analysis. The duration of available flow data has been illustrated in (Table-4). Flow data was truncated for the duration matching with the first available record of total phosphorus concentration (TPC) for each Sub watershed.

3.2.2 Total phosphorus concentration

The average daily total phosphorus concentration (ADTPC) data was sourced from LSRCA recorded in 'µg/l'. This data was not in a continuous time series; but with wide gaps. The maximum number of sample days per hydrologic year was not more than fifty and in some cases as low as two. These gaps had to be filled in order to calculate the daily phosphorus load; different gap filling techniques were deployed to make realistic estimates of the missing data and will be discussed in later sections. The ADTPC data was available from 1993 till 2009 for most of the subwatersheds while for few subwatersheds it started from 2002 (Fig-3). The subwatersheds with lesser duration or no TPC data were not included in this analysis.

3.2.3 Rainfall/precipitation data

The rainfall data was obtained from two different sources, a) Rainfall data used provided by LSRCA and b) data compiled by Dr. H. Schroeder's. Dr. Schroeter gap filled the precipitation and air temperature data and extended the ranges from 1950-2008.

Guatam, 2010 processed report, the rainfall data for the meteorological stations with maximum available period of record, where only four stations were qualified having sufficient rainfall data. This data was available up to year 2006 only; and supplemented this data to 2009 from the data published by Environment Canada through its website (Guatam, 2010).

Thiessen polygons were plotted through GIS arc toolbox for all the rain gauges processed by Dr. H.Schroeter. The polygons within or intersecting with the watershed boundaries of LSRCA were selected and evaluated for the available rainfall data durations. Only 4 out of 17 stations were selected having rainfall data ranging from 1992 to 2008 (Fig-4). These stations were same as selected by Guatam (2010) except one station named "Orillia Brain". Dr. H.Schroeter's data was selected for this study having more number of rain gauge stations, matching with the periods of available TP concentration. TPC and flow data was available to 2009, while the selected rainfall data had records to 2008 only; hence the data for last one year has been supplemented from the data used by Gautam (2010). Thiessen polygon method was used to determine the appropriate nearest rain gauge station covering each subwatershed. Although this method has basic limitations as a) assume a consistent intensity of rainfall over the entire area within one polygon and b) the rainfall intensity and duration changes sharply over the imaginary boundary between the polygons. Despite these limitations this method is most widely used due to its simplicity. Arc GIS tool box was opted to draw the thiessen polygon for four available rain gauge stations from the available GIS data (Fig-4). Nearest rain gauge with maximum coverage has been allocated to each sub watershed for the rainfall data (Table-5).

The baseline for data selection was the available record of TPC. This data was available from 1993 to 2009; hence the data for daily flow and daily rainfall was clipped to match the respective duration of each subwatershed. A total of 13 subwatersheds having long range TPC and daily flow data were selected for this analysis (Table-5) and the rainfall data was assigned to each based subwatershed as described above.

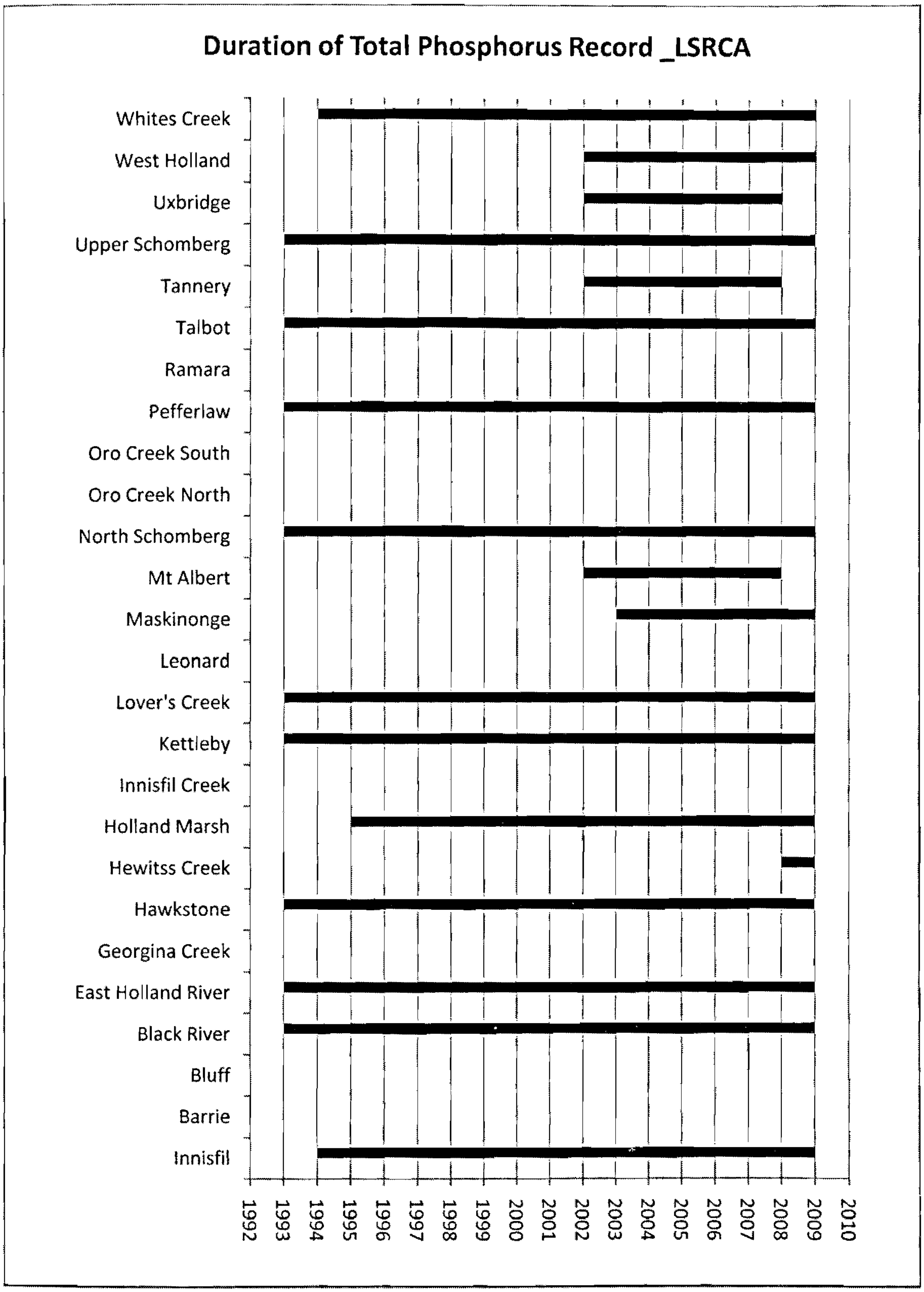


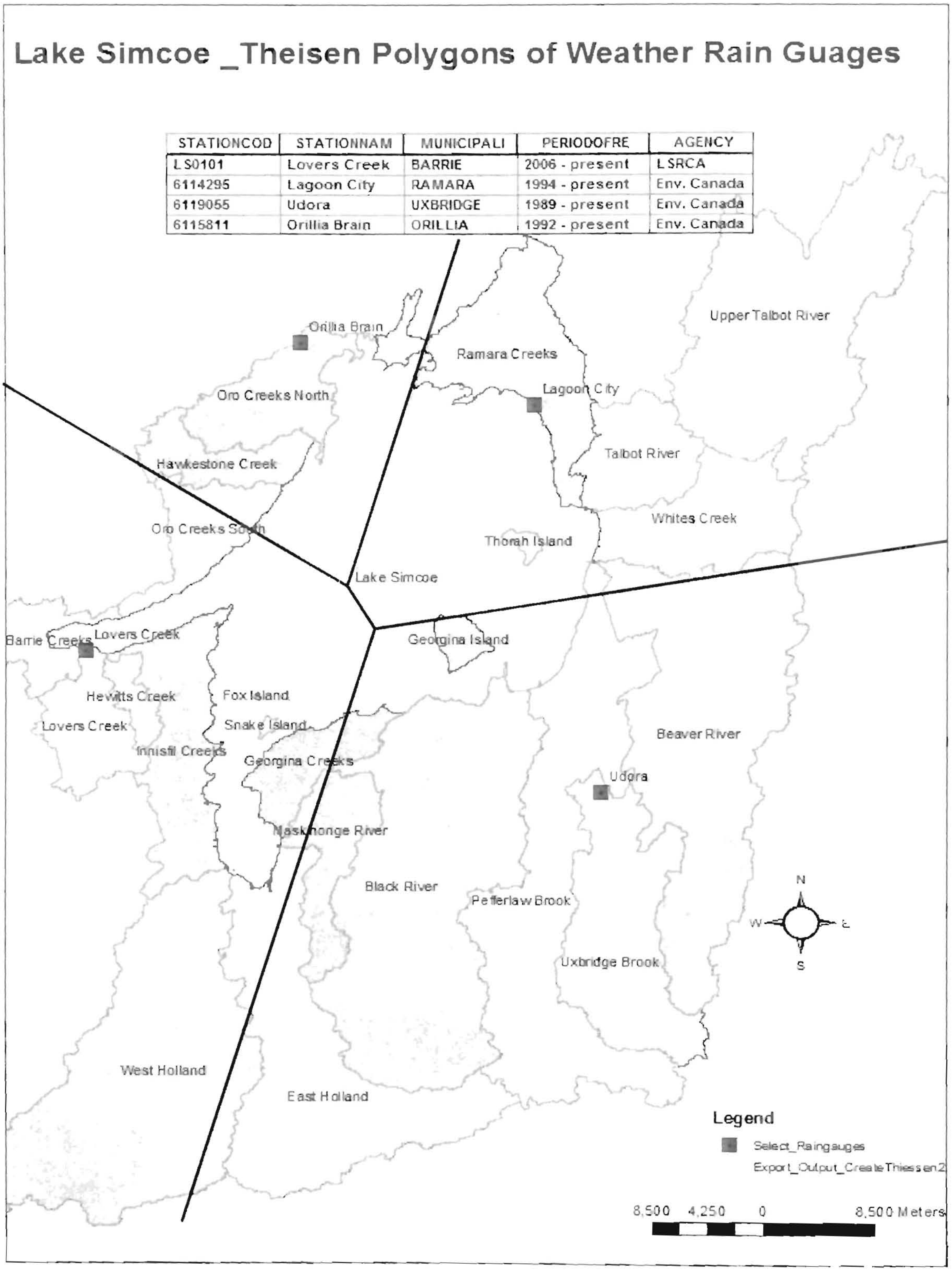
Figure 3: *Available record of total phosphorus concentration from LSRCA*

Table 3: *Lake Simcoe Subwatershed and the flow gauge stations*

Sr No	Subwatershed	Area of Subwatershed (ha)	Gauged/Ungauged	Gauge_Name	Gauge ID	Gauge Location		Duration	Estimated based on (The Estimate was made by LSRCA)
						Northing	Easting		
1	Barrie	3753.42188	Ungauged	NA	NA	NA	NA	1966-Present	pefferlaw, beaver, black, east holland, upper schomberg, lovers, hawkestone
2	Beaver	32725.4206	Gauged	Brock	02EC011	4917778	653619	1966-Present	gap-filled with Udora Environment Canada site
3	Black River	37536.0352	Gauged	Georgina	02EC008	4902187	632179	1964-2009 (with gaps)	oct 9 1969 to july 11 1983ungauged but estimated using pefferlaw, beaver, black, east holland, upper schomberg, lovers, hawkestone
4	East Holland River	24714.80809	Gauged	East Gwillumbury	02EC009	4883516	620882	1965-present	Gap-filled with Upper Schomberg Environment Canada site, but no gaps to fill
5	Georgina Creek	4933.303832	Ungauged	NA	NA	NA	1966-present	NA	pefferlaw, beaver, black, east holland, upper schomberg, lovers, hawkestone
6	Hawkstone	4784	Gauged	Oro-Medonte	02EC020	4928204	621791	2006-present	1964-2005ungauged, estimated using pefferlaw, beaver, black, east holland, upper schomberg, lovers, hawkestone
7	Hewitss Creek	1751.502626	Ungauged	NA	NA	NA	1966-present	NA	pefferlaw, beaver, black, east holland, upper schomberg, lovers, hawkestone
8	Holland Marsh	NA	Gauged	Pumphouse	LS0303	4885150	616360	NA	gap-filled using pefferlaw, beaver, black, east holland, upper schomberg, lovers, hawkestone
9	Innisfil Creek	10715.18907	Ungauged	NA	NA	NA	1966-present	NA	pefferlaw, beaver, black, east holland, upper schomberg, lovers, hawkestone
10	Kettleby	2846	Gauged	King	LS0103	4876673	614468	September 2006-2007	pre-1982-ungaugedand1982-May1999,May2002-May2004-Historic
11	Lover's Creek	5994.764283	Gauged	City of Barrie	LS0101	4914387	607553	2002-2009	1990 - 2009-Gap-filled with Upper Schomberg Environment Canada site
12	Maskinonge	6346.495831	Gauged	Georgina	NA	4897954	626082	July26 2006 to 2007	2008, 2009-ungauged, estimated using
13	North Schomberg	3213.319731	Ungauged	NA	NA	NA	1966-present	NA	pefferlaw, beaver, black, east holland, upper schomberg, lovers, hawkestone
14	Oro Creek North	7526.353199	Ungauged	NA	NA	NA	1966-present	NA	pefferlaw, beaver, black, east holland, upper schomberg, lovers, hawkestone
15	Oro Creek South	5738.706945	Ungauged	NA	NA	NA	1966-present	NA	pefferlaw, beaver, black, east holland, upper schomberg, lovers, hawkestone
16	Pefferlaw	44624	Gauged	Uxbridge	02EC018	4903162	644080.37	1987-2009	gap-filled with Beaver EC site
17	Ramara	14350.7494	Ungauged	NA	NA	NA	1966-present	NA	pefferlaw, beaver, black, east holland, upper schomberg, lovers, hawkestone
18	Talbot	36780.7989	Ungauged	NA	NA	NA	1966-present	NA	pefferlaw, beaver, black, east holland, upper schomberg, lovers, hawkestone

Table 4: *Duration of available Record for daily flow, TPC and Rainfall -LRSCA*

No	Subwatershed	Flow		TP Concentration		Rainfall	
		Start	End	Start	End	Start	End
1	Innisfil	1992	2009	1994	2009	1992	2009
2	Barrie	1992	2009				
3	Bluff						
4	Black River	1992	2009	1993	2009	1992	2009
5	East Holland River	1992	2009	1993	2009	1992	2009
6	Georgina Creek	1992	2009				
7	Hawkstone	1992	2009	1993	2009	1992	2008
8	Hewitss Creek	1992	2009	2008	2009	1992	2009
9	Holland Marsh	1992	2009	1995	2009	1992	2008
10	Innisfil Creek	1992	2009				
11	Kettleby	1992	2009	1993	2009	1992	2009
12	Lover's Creek	1992	2009	1993	2009	1992	2008
13	Leonard						
14	Maskinonge	1992	2009	2003	2009	1992	2009
15	Mt Albert			2002	2008		
16	North Schomberg	1992	2009	1993	2009	1992	2008
17	Oro Creek North	1992	2009				
18	Oro Creek South	1992	2009				
19	Pefferlaw	1992	2009	1993	2009	1992	2009
20	Ramara	1992	2009				
21	Talbot	1992	2009	1993	2009	1992	2008
22	Tannery			2002	2008		
23	Upper Schomberg			1993	2009		
24	Uxbridge			2002	2008		
25	West Holland	1992	2009	2002	2009	1992	2008
26	Whites Creek	1992	2009	1994	2009	1992	2009



STATIONCOD	STATIONNAM	MUNICIPALI	PERIODOFRE	AGENCY
LS0101	Lovers Creek	BARRIE	2006 - present	LSRCA
6114295	Lagoon City	RAMARA	1994 - present	Env. Canada
6119055	Udora	UXBRIDGE	1989 - present	Env. Canada
6115811	Orillia Brain	ORILLIA	1992 - present	Env. Canada

Figure 4: *Thiessen polygon plot for available rain gauges with rainfall data*

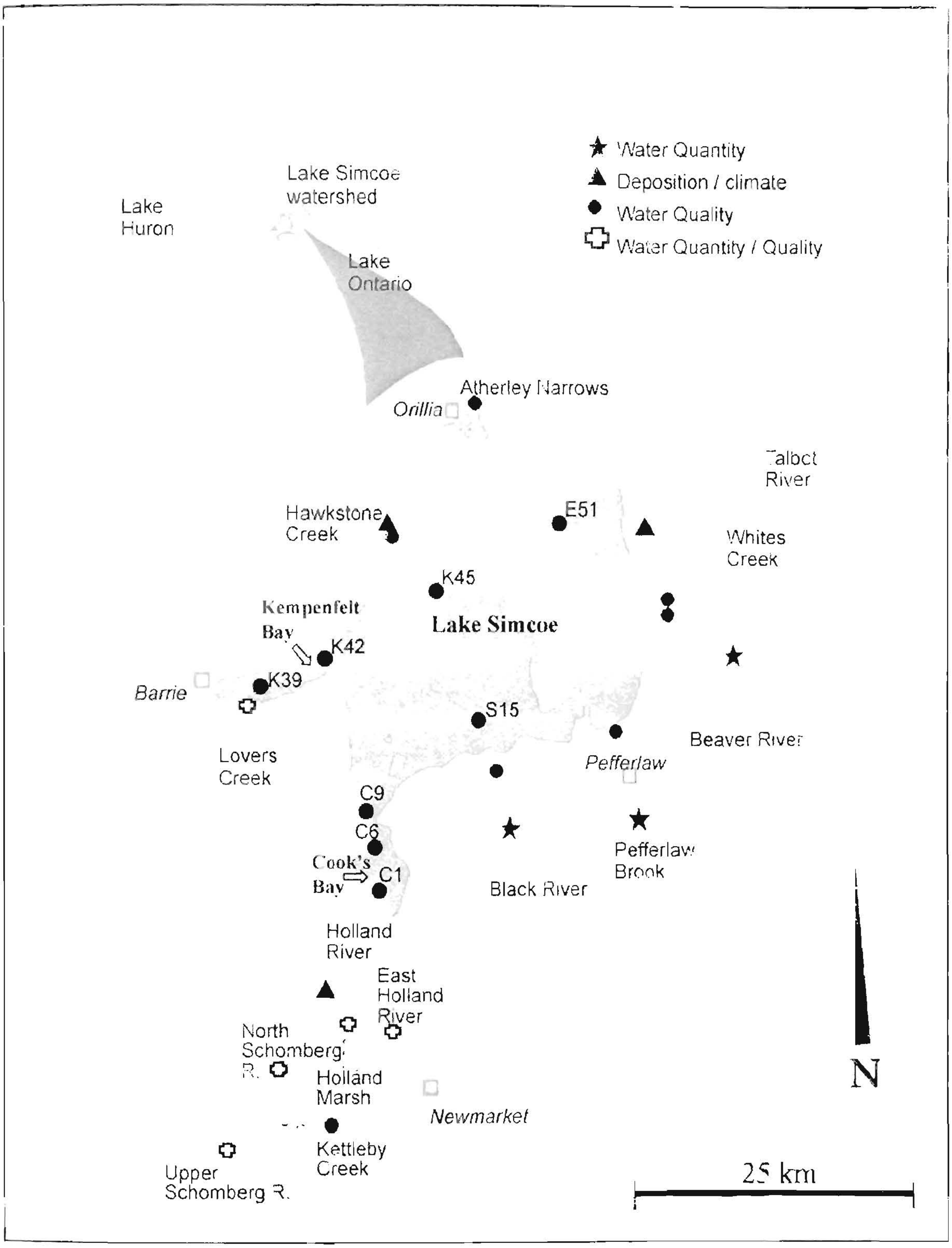


Figure 5: *Lake Simcoe and its subwatersheds (Source: Winter, 2007)*

Table 5: *Nearest Rain gauge allocated to sub watershed based on Thiessen Polygon*

	Sub watershed	Nearest Rain gauge
1	Beaver River	Udora
2	Black Creek	Udora
3	East Holland River	Udora
4	Hawkestone	Orillia Brain
5	Holland Marsh	Barrie WPCC
6	Kettleby Creek	Udora
7	Lovers Creek	Barrie WPCC
8	Maskinonge Creek	Udora
9	North Schomberg	Barrie WPCC
10	Pefferlaw	Udora
11	Talbot	Orillia Brain
12	W Holland	Barrie WPCC
13	Whites Creek	Udora

3.3 Data Stratification:

The data to be used for final analysis was stratified in three categories, a) monthly; where all the data starting from 1993 to 2009 was re grouped on monthly basis resulting in 12 subgroups for data for each calendar month, b) seasonal: a similar regrouping of data on seasonal basis, which produced 4 subgroups of data, and c) yearly; in which all the data was filtered for each hydrologic year starting from June to the end of May. These three stratifications will be referred quite frequently in upcoming analysis and discussions.

3.4 Data Processing

Data for daily flow and daily TPC was aligned and observed for any gaps. The flow data was available as a continuous time series on daily basis, but TPC data records were very limited as compare to daily flow data, which ranged between 2 days to 48 days of record against 365 days of flow record in one hydrologic year.

The data processing involved in this project was carried out in four steps: a) exploring any correlation between the average daily flow (ADF) to daily TPC concentration which could be used for the gap filling of TPC data, b) filling the gaps in TPC data c) determining the daily load from daily flow and daily TPC values, and d) evaluating the relationship between rainfall and TP load.

A first step the ADTPC data was gap filled with midpoint method, aligned with average daily flow data, and stratified on monthly, seasonal and yearly basis. The average values for each stratification (e.g., average values for flow and TPC for each stratification category) were plotted on graphs to observe the general trends for flow and TPC (Appendix 2, 3 and 4)

Historically the TPC data has been gap filled by midpoint method due to its simplicity, but as this method rounds off the variations, it is not considered good for filling wide gaps such as those encountered in this study. To overcome the limitation of the midpoint method, the correlation or regression based functions have been attempted in this project for filling the data depending on the significance of functions. In order to examine the relationship between ADF and ADTPC the recorded only data for ADTPC and its respective flow data was sorted. The correlation and R^2 values for this data were examined on yearly, seasonal and monthly basis. Stronger values of linear correlation and R^2 were observed for monthly stratification of data (Appendix 9). Therefore the monthly stratification of data has been adopted for subsequent analysis in this project.

Advancing one step further, the polynomial regression trend lines and respective R^2 values were also examined targeting for stronger functions. The 2nd, 3rd and 4th order of polynomial trend lines and their respective R^2 values were obtained from scatter plots. The R^2

values showed an increasing trend for higher order polynomial regression but in some cases the functions from 3rd and 4th order polynomial produced negative TP load for higher flow values. These results were unrealistic, despite the stronger R^2 values. A sample scatter plot for one month showing the trend lines, functions and respective R^2 values for linear, 2nd , 3rd and 4th order polynomial trend lines is illustrated in Fig-6. It is evident that the R^2 values is increasing for higher order polynomials but the trend line for 3rd and 4th order is showing a declining trend for higher flows which results in negative TPC values especially in high flood events, hence the 2nd order polynomial functions, having shown significant R^2 values, were chosen for the gap filling of ADTPC data. The R^2 values obtained from 2nd order polynomial functions for the entire data have been tabulated in Table-6.

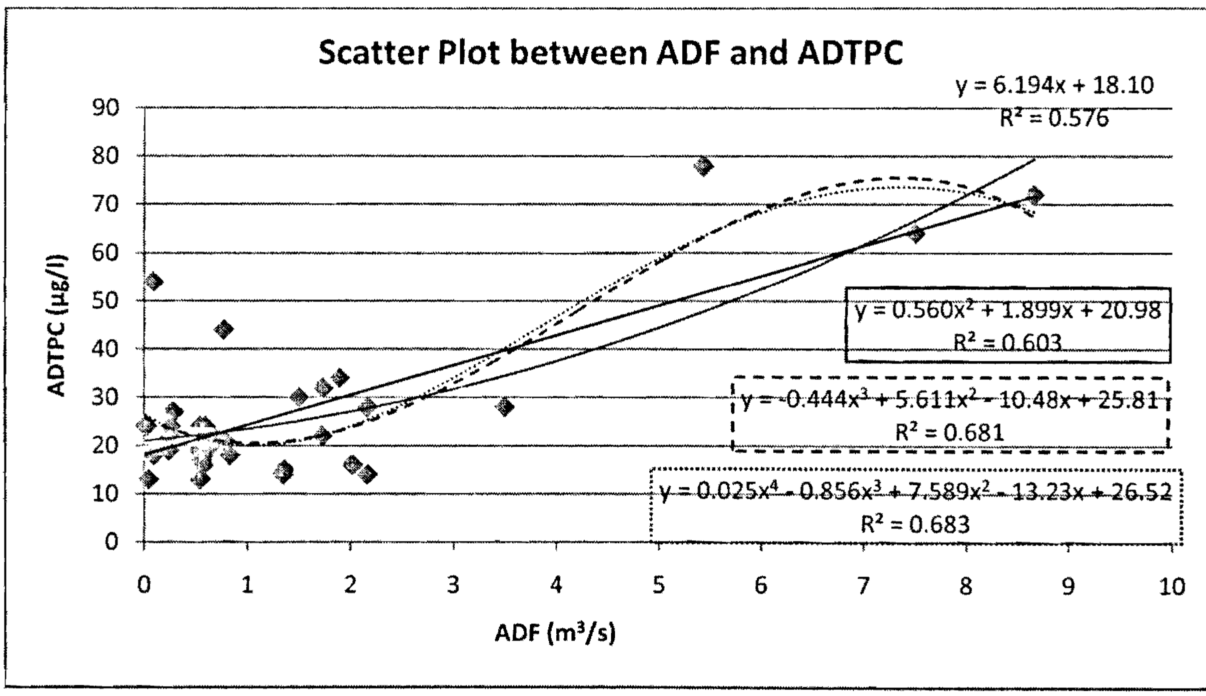


Figure 6: *Sample Scatter Plot showing general trend of polynomial functions*

The gaps of missing ADTPC data was then filled with three different approaches in the following order of preference:

1st Preference: The recorded ADTPC values must always be used as 1st priority.

2nd Preference:The missing ADTPC data within the specific months of significant R^2 values (≥ 0.5) will be calculated from these functions.

3rd Preference: The missing ADTPC data within the months of insignificant R^2 values (<0.5), will be obtained from midpoint method.

The ADTPC, ADF and the daily rainfall data was rearranged as a continuous time series and then gap filled in the hierarchal order of preference as discussed above. The daily TP load entering into the lake was determined with the function given in Eq-1. This continuous time series data was again filtered as monthly, seasonal and yearly for further analysis. TP load was then plotted against the daily rainfall on yearly, seasonal and monthly basis to evaluate any relationship between the two parameters (Appendix 13)

The ADTPC data has been filled by two methods i.e., 'Midpoint method" (MID) and "Function and midpoint method" (FUN) which will be termed as 'function method' for simplicity in this report. The daily TP load has been calculated based on both the approaches (Table 10) and plotted against daily rainfall for a comparative study (Appendix 13). Primarily the results based on function methods have been discussed in this report; however the comparison of two methods has also been illustrated at appropriate occasions.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Analysis on ADF and ADTPC

Average daily flow (ADF) and average daily TP concentration (ADTPC) plots (Appendix 2, 3, and 4) indicate that flow and concentration are almost independent of each other. This trend can be observed in all splits of data (i.e., yearly, monthly and seasonal). In the monthly analysis (Appendix 3), the ADF and ADTPC have shown higher values in the months of February, March and April, which have resulted in higher TP loads. On contrary, in summer months of June, July, August and Sep, ADTPC values are still higher, although ADF values are very low, resulting in lower TP load values in these months. In fall months, flow indicates an increasing trend again, while ADTPC shows a decreasing trend as compared with summer values. This depicts the independent behavior of flow and concentration. This behavior of ADF and ADTPC can also be observed in seasonal analysis (Appendix 4).

In yearly analysis of ADF and ADTPC (Appendix 2), an inconsistent behavior of flow and TPC has been observed in different years and different subwatersheds. In some cases the ADTPC values are high while the ADF values are quite low like in Beaver, Holland Marsh, Talbot, Lovers creek and Maskinonge for the years from 1996 to 2005(Appendix 2). On the other hand almost directly proportional trend can be seen in some other subwatersheds, e.g., Black River, East Holland River, Hawkestone, and Pefferlaw.

Results and discussion

Although the function method has been adopted for filling the gaps in ADTPC data based on the significance of 2nd order R^2 values from monthly split of data, this significance could not be observed as a general trend across the watershed. This can be observed from the number of months with significant R^2 values (≥ 0.5) (Table 6). In this analysis, overall 23% of the total duration (36 out of 156 months) has shown $R^2 \geq 0.5$. Therefore, for all the remaining duration we are still dependent on midpoint method for filling the gaps of ADTPC data.

In monthly analysis of correlation between the ADF and ADTPC, the significant correlation coefficients could only be seen in the months of high load values (January, February, March, and April) or in the East Holland River subwatershed, which has shown the maximum phosphorus load in this analysis (Table-6 and Table-7).

4.2 Analysis of total phosphorus load

TP load has been analyzed on monthly, seasonal and yearly basis, in which we can clearly see that the maximum TP load is entering into the lake in the months from January to April (Table-7 and Appendix 5), which is end of winter and start of spring. This is mainly because of the snow melt that carries the accumulated phosphorus from major sources like precipitation, agriculture, and air deposition over the entire season of winter.

Analyzing the variation of TP load from appendix 6 and comparing with the variation trends of ADF and ADTPC in appendix 3, the variation of TP load is primarily correlating with the flow variations, high flow months have shown higher TP load and low flow months have shown low TP load values. Although the months with low TP load values still have higher ADTPC values, these high values do not seem to be controlling the TP Load.

The results of TP load, based on two methods of gap filling as described in data processing section in methodology chapter of this report, have been compared (Table-10,

Appendix 4,5 and 6). Generally, both methods have generated similar results except few occasions, where the flow values have been observed to be very high. For these high flow values, 2nd order polynomial functions have resulted in very high TPC values, which may be considered as outliers. Very high phosphorus loads have been reported in the years 2008 and 2009, while East Holland River and West Holland Rivers have shown maximum phosphorus loading.

The average yearly TP load (Appendix 7) have shown increasing trend in the years 2007, 2008, and 2009. Although this phenomenon does not support the efforts being made under LSEMS to control the phosphorus loading into the Lake Simcoe, this may be attributed to the rapid growth in population and urbanization, septic tanks, and uncontrolled agricultural practices.

The annual average and cumulative phosphorus load (tons/year) per sub watershed and per hydrologic year based on by function method has been compared with similar loads reported by Lake Simcoe Region and Conservation Authority (LSRCA 2004-07) in Table-9. Similar Phosphorus loads have been reported as, 47.3, 37.2 and 44.0 tons/year for the years of 2004-05, 2005-06 and 2006-07 reported by LSRCA and 39.7, 39.3, and 42.2 tons/year for same years respectively have been resulted by the data gap filled based on function method. The variation in reported loads is primarily due to heavy loads being reported in years 2008 and 2009 which were not part of the LSRCA report and also different methods used for filling the missing data for ADTPC.

4.3 Analysis of relationship between rainfall and phosphorus load.

Phosphorus load has been examined for its relationship with daily rainfall (Appendix 13). This analysis gives us a general indicator that there is no significant correlation between the daily rainfall and TP load. Highest loads on the days with zero rainfall, and lower loads during the events of heavy rainfall have been observed. This phenomenon indicates that at zero rainfall, there is only groundwater flow carrying the major portion of phosphorus with least dilution, resulting in high TP loads. However the days with high rainfall have resulted in low TPC which reflects the dilution effect.

In order to better examine the relationship between daily rainfall and phosphorus loading, lags in rainfall have been introduced and evaluated for any significant statistical correlation (Appendix 11 and Appendix 12). Although the lag of 2 and 3 days slightly strengthen the correlation values, most of the values do not meet the threshold level of statistical significance. The values of $R^2 \geq 0.45$ from 2nd order polynomial regression between the daily rainfall and daily TP load have been highlighted in monthly (Appendix 11) and yearly (Appendix 12) split of data, which do not report more than a few occasions.

Table 6: *R^2 values from 2nd order Regression of Recorded TPC and respective flow values*

		January	Febraury	March	April	May	June	July	August	September	October	November	December
Beaver	R2	***0.775***	***0.830***	0.360	***0.732***	0.257	0.487	0.419	0.124	***0.603***	***0.500***	0.407	***0.500***
Black	R2	***0.779***	0.253	0.269	0.180	0.080	0.492	0.010	0.004	0.043	0.201	0.288	0.201
East Holland	R2	***0.920***	***0.653***	0.413	***0.696***	***0.729***	0.146	0.096	0.170	***0.510***	0.272	0.139	0.272
Hawkestone	R2	***0.947***	0.367	0.384	0.352	0.247	0.331	0.360	0.347	0.332	0.450	0.409	0.450
Holland Marsh	R2	0.194	0.286	***0.547***	0.359	0.077	0.154	0.146	0.337	0.070	0.122	0.053	0.122
Kett;eby	R2	0.128	***0.725***	0.242	0.245	0.044	0.233	0.019	***0.750***	0.101	0.461	0.001	0.461
Lovers	R2	***0.775***	***0.830***	0.360	***0.732***	0.257	0.487	0.419	0.124	**0.603**	0.456	0.407	***0.500***
Mskinonge	R2	1.000	1.000	0.374	***0.610***	0.031	***0.679***	***0.765***	0.187	0.418	***0.860***	***0.998***	1.000
North Schomberg	R2	0.083	0.081	0.043	0.031	0.138	0.284	0.167	0.053	0.319	0.083	0.014	0.085
Pefferlaw	R2	**0.772**	0.174	0.353	0.253	0.038	0.240	0.224	0.081	0.399	0.242	0.071	***0.594***
Talbot	R2	***0.852***	***0.518***	0.232	0.226	0.082	0.044	0.294	0.475	0.286	0.053	0.067	0.066
West Holland	R2	1.000	0.000	***0.574***	0.487	***0.501***	0.428	0.229	0.323	0.095	0.139	***0.643***	0.000
Whites	R2	1.000	1.000	0.374	***0.610***	0.031	***0.679***	***0.765***	0.187	0.418	***0.860***	***0.998***	1.000

Table 7: ***Average Daily TP load (Kg/day) on Monthly basis by Function Method***

Average Daily Phosphorus Load(Kg/Day)on Monthly Basis													
	Beaver	**Black**	**East Holland**	**Hawkestone**	**Holland Marsh**	**Kettleby**	**Lovers**	**Maskinonge**	**N_Schom**	**Pefferlaw**	**Talbot**	**W.Holland**	**Whites**
	TPL(FUN)	TPL(FUN)	TPL(FUN)	TPL(FUN)	TPL(FUN)	TPL(FUN)	TPL(FUN)	TPL(FUN)	TPL(FUN)	TPL(FUN)	TPL(FUN)	TPL(FUN)	TPL(FUN)
JANUARY	***12.40***	***9.90***	***39.13***	***0.86***	6.28	1.26	***1.38***	***1.67***	1.75	***12.80***	***5.27***	***10.21***	***2.52***
FEBRUARY	***20.10***	13.30	***46.55***	0.85	9.41	***6.49***	***2.26***	***18.45***	4.20	18.59	***10.35***	32.32	***5.65***
MARCH	34.49	20.84	40.19	1.89	***30.16***	4.57	4.43	12.36	3.73	26.40	12.70	***42.53***	8.86
APRIL	***22.42***	21.33	***41.15***	2.48	25.57	4.02	***3.81***	***11.85***	2.42	24.94	15.32	55.04	***6.62***
MAY	8.01	12.28	***77.54***	0.51	9.07	1.98	1.62	4.09	1.40	12.56	7.82	***21.81***	2.70
JUNE	6.98	10.21	24.69	0.55	9.86	1.30	1.54	***4.75***	1.42	12.00	5.77	17.08	***6.34***
JULY	3.12	5.58	19.22	0.30	5.43	0.83	1.96	***4.06***	1.02	8.26	3.50	14.30	***1.26***
AUGUST	2.49	4.06	14.61	0.18	11.15	***0.88***	0.72	3.37	0.86	7.92	2.64	18.62	0.93
SEPTEMBER	***3.10***	3.85	***18.63***	0.21	9.34	0.47	***0.86***	2.52	0.91	7.20	2.71	11.34	0.81
OCTOBER	***2.90***	3.63	13.23	0.22	5.07	0.42	0.75	***1.81***	0.84	6.73	3.05	13.59	***1.05***
NOVEMBER	2.90	3.63	13.23	0.22	5.07	0.42	0.75	***1.81***	0.84	6.73	3.05	***13.59***	***1.05***
DECEMBER	***5.75***	5.74	18.68	0.41	8.79	0.78	***1.00***	***1.88***	1.22	***8.33***	4.52	5.59	***1.91***

Note: The months highlighted in bold italic font have shown $R^2 > 0.5$, in 2nd Order Regression Analysis.

Table 8: *Average daily Phosphorus load (Kg/day) on yearly basis by function method.*

Average Daily Phosphorus Load(Kg/Day)on Yearly Basis

	Beaver	Black	East Holland	Hawkestone	Holland Marsh	Kettleby Creek	Lovers Creek	Maskinonge Creek	N Schomberg River	Pefferlaw Creek	Talbot	W Holland River	Whites Creek
	TPL(FUN)	TPL(FUN)	TPL(FUN)	TPL(FUN)	TPL(FUN)	TPL(FUN)	TPL(FUN)	TPL(FUN)	TPL(FUN)	TPL(FUN)	TPL(FUN)	TPL(FUN)	TPL(FUN)
1993-1994		7.600	23.258	0.808		1.726	1.810		1.384	13.198	6.750		
1994-1995	6.484	8.351	21.999	0.523		1.045	0.926		0.952	11.389	5.565		2.629
1995-1996	10.358	9.845	45.264	0.547	16.418	3.271	1.179		1.901	13.425	7.579		3.036
1996-1997	10.361	14.830	48.094	0.919	9.566	2.171	1.717		3.485	17.509	10.118		2.846
1997-1998	8.915	10.798	24.486	0.462	6.492	1.573	1.134		1.416	16.994	6.573		3.726
1998-1999	4.834	2.925	13.455	0.243	1.518	0.281	0.710		1.434	11.722	4.063		1.934
1999-2000	5.280	4.675	47.709	0.217	7.344	5.185	0.606		3.105	8.513	6.590		2.250
2000-2001	7.426	9.927	26.312	0.549	9.591	3.358	1.234		2.798	10.241	7.914		5.310
2001-2002	4.179	3.860	20.321	0.272	4.323	1.201	0.560		1.011	7.178	5.983		1.333
2002-2003	18.087	9.866	13.517	0.900	5.406	0.841	1.511		1.500	13.192	3.535	16.455	8.185
2003-2004	9.401	10.291	29.835	0.506	8.321	0.495	1.984	3.610	1.108	9.732	2.195	16.480	2.593
2004-2005	11.506	12.567	24.886	0.589	12.371	3.887	1.957	5.913	1.462	9.741	2.640	18.254	2.923
2005-2006	5.927	8.041	21.958	0.745	17.242	1.799	2.247	6.228	0.604	6.924	3.724	30.606	1.580
2006-2007	11.425	8.806	24.381	1.148	26.115	0.730	1.808	3.314	0.949	10.946	6.007	17.386	2.637
2007-2008	14.983	10.409	26.015	1.758	9.994	0.744	3.461	5.349	1.211	12.944	7.356	20.399	4.712
2008-2009	60.608	19.610	67.673	1.776	18.977	3.471	4.828	10.317	3.116	55.238	16.632	36.382	10.215

Table 9: *Total phosphorus load per year (Function method)*

	Yearly Cumulative Phosphorus Load(T/Year)													Cumulative TP Load (T/Year)	
	Beaver	Black	East Holland	Hawkestone	Holland Marsh	Kettleby Creek	Lovers Creek	Maskinonge	N Schomberg	Pefferlaw Creek	Talbot	W Holland River	Whites Creek	Total P Load Per year	reported by Lake Simcoe (2004-07)
	TPL(FUN)	TPL(FUN)	TPL(FUN)	TPL(FUN)	TPL(FUN)	TPL(FUN)	TPL(FUN)	TPL(FUN)	TPL(FUN)	TPL(FUN)	TPL(FUN)	TPL(FUN)	TPL(FUN)		
1993-1994		2.3	5.9	0.1		0.4	0.3		0.3	3.5	1.8			**14.8**	
1994-1995	2.37	3.05	8.03	0.19		0.38	[illegible]		0.35	4.16	2.03		0.96	**21.8**	
1995-1996	3.8	3.6	16.6	0.2	6.0	1.2	0.4		0.7	4.9	2.8		1.1	**41.3**	
1996-1997	3.78	5.41	17.55	0.34	3.49	0.79	0.63		1.27	6.39	3.69		1.04	**44.4**	
1997-1998	3.3	3.9	8.9	0.2	2.4	0.6	0.4		0.5	6.2	2.4		1.4	**30.1**	
1998-1999	1.8	1.1	4.9	0.1	0.6	0.1	0.3		0.5	4.3	1.5		0.7	**15.7**	
1999-2000	1.9	1.7	17.5	0.1	2.7	1.9	0.2		1.1	3.1	2.4		0.8	**33.5**	
2000-2001	2.7	3.6	9.6	0.2	3.5	1.2	0.5		1.0	3.7	2.9		1.9	**30.9**	
2001-2002	1.5	1.4	7.4	0.1	1.6	0.4	0.2		0.4	2.6	2.2		0.5	**18.3**	
2002-2003	6.6	3.6	4.9	0.3	2.0	0.3	0.6		0.5	4.8	1.3	3.7	3.0	**31.6**	
2003-2004	3.4	3.8	10.9	0.2	3.0	0.2	0.7	1.3	0.4	3.6	0.8	6.0	0.9	**35.3**	
2004-2005	4.2	4.6	9.1	0.2	4.5	1.4	0.7	2.2	0.5	3.6	1.0	6.7	1.1	**39.7**	**47.3**
2005-2006	2.2	2.9	8.0	0.3	6.3	0.7	0.8	2.3	0.2	2.5	1.4	11.2	0.6	**39.3**	**37.2**
2006-2007	4.2	3.2	8.9	0.4	9.5	0.3	0.7	1.2	0.3	4.0	2.2	6.3	1.0	**42.2**	**44**
2007-2008	5.5	3.8	9.5	0.6	3.7	0.3	1.3	2.0	0.4	4.7	2.7	7.5	1.7	**43.7**	
2008-2009	22.1	7.2	24.7	0.6	6.9	1.3	1.8	3.8	1.1	20.2	6.1	13.3	3.7	**112.7**	
Avg. TPL/SW	**4.6**	**3.5**	**10.8**	**0.3**	**4.0**	**0.7**	**0.6**	**2.1**	**0.6**	**5.1**	**2.3**	**7.8**	**1.4**		
Averga TPL/SW by LSRCA (2004-07)	**3.2**	**3.7**	**8.9**	**0.3**			**0.8**	**1.1**		**3.2**	**2.0**	**7.7**	**1.1**		

Note: TPL = Total phpsphorus load, and SW = subwatershed

Table 10: Total phosphorus load per year per subwatershed (Midpoint and function Method)

		Yearly Cumulative Phosphorus Load (Kg/Year)												
		Beaver	**Black**	**East Holland**	**Hawkestone**	**Holland Marsh**	**Kettleby Creek**	**Lovers Creek**	**Maskinonge Creek**	**N Schomberg River**	**Pefferlaw Creek**	**Talbot**	**W Holland River**	**Whites Creek**
		Cum. TP Load (Kg/Year)	Cum. TP Load (Kg/Year)	Cum. TP Load (Kg/Year)	Cum. TP Load (Kg/Year)	Cum. TP Load (Kg/Year)	Cum. TP Load (Kg/Year)	Cum. TP Load (Kg/Year)	Cum. TP Load (Kg/Year)	Cum. TP Load (Kg/Year)	Cum. TP Load (Kg/Year)	Cum. TP Load (Kg/Year)	Cum. TP Load (Kg/Year)	Cum. TP Load (Kg/Year)
1993-1994	TPL(MID)		2366	6006	147		321	304		331	3533	1943		
	TPL(FUN)		*2349*	*5884*	*147*		*412*	*329*		*331*	*3511*	*1796*		
1994-1995	TPL(MID)	2515	3108	5084	190		367	347		347	4288	1862		1021
	TPL(FUN)	*2367*	*3048*	*8030*	*191*		*382*	*338*		*347*	*4157*	*2031*		*960*
1995-1996	TPL(MID)	3686	3608	11707	203	5927	1073	522		696	4859	2480		1046
	TPL(FUN)	*3791*	*3603*	*16566*	*200*	*6009*	*1197*	*432*		*696*	*4914*	*2774*		*1111*
1996-1997	TPL(MID)	4214	5444	16554	335	2345	792	869		1272	6532	3098		1053
	TPL(FUN)	*3782*	*5413*	*17554*	*335*	*3491*	*793*	*627*		*1272*	*6391*	*3693*		*1039*
1997-1998	TPL(MID)	4795	4214	8073	168	1716	592	439		517	6785	2718		1720
	TPL(FUN)	*3254*	*3941*	*8937*	*169*	*2369*	*574*	*414*		*517*	*6203*	*2399*		*1360*
1998-1999	TPL(MID)	2538	1137	4667	90	590	105	376		523	4821	1544		806
	TPL(FUN)	*1764*	*1068*	*4911*	*89*	*554*	*103*	*259*		*523*	*4279*	*1483*		*706*
1999-2000	TPL(MID)	1618	1725	4836	78	2759	1283	156		1136	3123	2467		918
	TPL(FUN)	*1932*	*1711*	*17462*	*79*	*2688*	*1898*	*222*		*1136*	*3116*	*2412*		*823*
2000-2001	TPL(MID)	2767	3632	11327	200	3503	1150	580		1021	3782	3127		928
	TPL(FUN)	*2711*	*3623*	*9604*	*201*	*3501*	*1226*	*451*		*1021*	*3738*	*2888*		*1938*
2001-2002	TPL(MID)	1570	1421	4868	102	1503	419	160		369	2500	2404		520
	TPL(FUN)	*1525*	*1409*	*7417*	*99*	*1578*	*438*	*204*		*369*	*2620*	*2184*		*486*
2002-2003	TPL(MID)	7025	3606	5001	327	1871	306	529		548	4754	1268	3991	2182
	TPL(FUN)	*6602*	*3601*	*4934*	*329*	*1973*	*307*	*552*		*548*	*4815*	*1290*	*3653*	*2988*
2003-2004	TPL(MID)	3310	3567	9063	184	2937	178	707	995	405	3406	743	5689	915
	TPL(FUN)	*3441*	*3766*	*10920*	*185*	*3046*	*181*	*726*	*1321*	*405*	*3562*	*803*	*6032*	*949*
2004-2005	TPL(MID)	3709	4541	8170	209	4481	982	898	1819	534	3549	717	8432	1021
	TPL(FUN)	*4200*	*4587*	*9083*	*215*	*4515*	*1419*	*714*	*2158*	*534*	*3555*	*964*	*6663*	*1067*
2005-2006	TPL(MID)	2351	2867	7449	313	5693	299	668	2898	221	2359	985	16207	621
	TPL(FUN)	*2163*	*2935*	*8015*	*272*	*6293*	*657*	*820*	*2273*	*221*	*2527*	*1359*	*11171*	*577*
2006-2007	TPL(MID)	3964	2977	8443	408	9532	239	707	903	347	3604	2148	6067	749
	TPL(FUN)	*4170*	*3214*	*8899*	*419*	*9532*	*267*	*660*	*1210*	*347*	*3995*	*2193*	*6346*	*963*
2007-2008	TPL(MID)	5871	4311	10368	806	3644	266	2179	1715	443	5244	2905	10428	1965
	TPL(FUN)	*5484*	*3810*	*9522*	*643*	*3658*	*272*	*1267*	*1958*	*443*	*4738*	*2692*	*7466*	*1725*
2008-2009	TPL(MID)	10313	6797	15783	613	6891	1413	1980	3399	1137	10633	5848	13936	1915
	TPL(FUN)	*22122*	*7158*	*24701*	*648*	*6926*	*1267*	*1762*	*3766*	*1137*	*20162*	*6071*	*13280*	*3729*

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

Average daily flow (ADF) and average daily phosphorus concentration (ADTPC) have not shown any significant statistical relation which leads us to conclude the independent behavior of both these parameters. Sources of phosphorus are permanently generating phosphorus. Water flow serves only as a carrier of this nutrient from source to the receiving water bodies. The months of winter and early spring (January to April) having high flows, carry excessive phosphorus from source which results in high phosphorus loads. The months of summer and early fall (June to September), having low flows, result in low TP loads, despite the fact that higher concentration of phosphorus is generated in these months.

A significant increase in phosphorus loading in the recent years of 2008 and 2009 has been observed. During this period a phosphorus load of 24.7 tons/year has been reported from East Holland subwatershed only, whereas the average yearly phosphorus load (1993-2008) from the same subwatershed was only 9.8 which are almost 2.5 times higher in magnitude. Upon detail exploration of flow and rainfall data in this year, three events of exceptional runoff were observed, the details of runoff and rainfall is tabulated in Table 11.

These flow values are exceptionally high when compared with the average daily flow from same subwatershed from 1993 to 2009 which is just 1.85 m^3/s.

Table 11: *Events of Exceptional runoff in East Holland River (2008-2009)*

1st Event			2nd Event			3rd Event		
Date	ADF (m^3/s)	Rainfall (mm)	Date	ADF (m^3/s)	Rainfall (mm)	Date	ADF (m^3/s)	Rainfall (mm)
26/12/08		14	2/10/09		4.0	4/2/09		4.2
27/12/08	11.81	12	2/11/09	11.538	31.8	4/3/09	15.4	44.2
28/12/08	36.423		2/12/09	61.75	0	4/4/09	33.1	
29/12/08	13.30		2/13/09	20.27		4/5/09	11.11	

Although no significant relation could be observed between flow and rainfall from the statistical analysis done in this project, a direct relation of flow has been observed towards the total phosphorus load.

We could not observe any strong relationship between daily rainfall and daily TP load, this may be because of the fact that TPC behaves almost independent of flow. A statistical significance has been observed on high TP load events, which indicates that heavy flush of runoff carries higher TP loads. High flows have greater capacity of carrying the pollutants and nutrients like phosphorus

5.2 Recommendations

Already a lot of effort is being made to control the phosphorus loading through surface runoff. Equivalent efforts are required to control the TP load through groundwater flow as well. In order to have better results, more samples should be recorded for average daily total phosphorus values to minimize the width of gaps and to capture the events of high loadings during the high flows.

Despite showing high TPC values the months of summer and early fall did not exhibit very high TP loads, yet this duration should not be ignored for the efforts in controlling the generation of phosphorus from its sources.

High flows have resulted in high TP loads, hence the multiphase strategy in controlling the TP load should be adopted, a) reducing the generation of phosphorus form its sources and b) preventing the direct entry of heavy flushes of runoff into the Lake through the treatment provided by flood protection and detention storage facilities.

Although the relation between rainfall and flow could not be strongly supported by the basic statistical operations conducted in this project, hence a higher level of study to explore this relationship must be conducted based on more advance statistical functions.

The rainfall is not the only source of flow, snow melt and groundwater flow are also equally important in the transportation of phosphorus, hence these data sets should also be included for a more comprehensive study in this regard.

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APPENDICES

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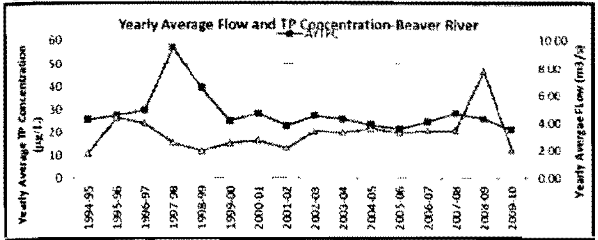
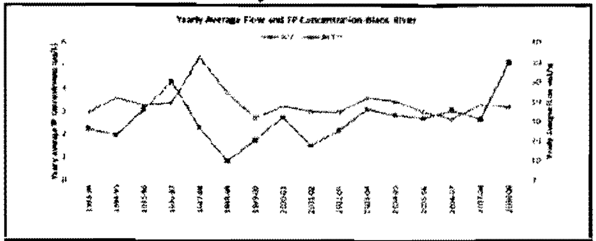
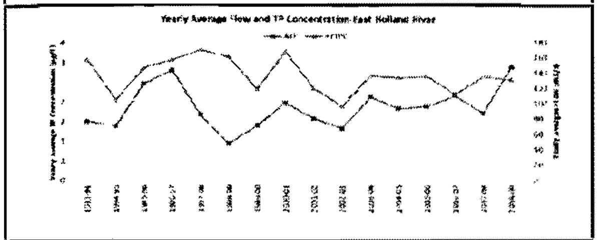
Appendix-1: Visual Basic code for the custom function in MS Excel, "findbestmatch".

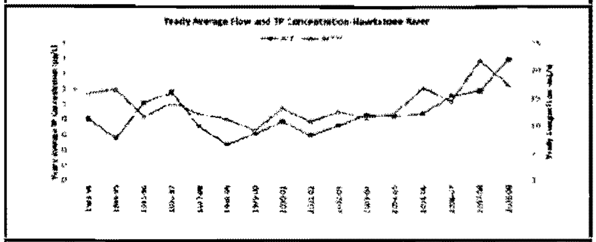
```
////
Function FindBestMatch(Table As Range, dateToFind As Date, colNum As Integer)

Dim last As Integer
For i = 1 To Table.Rows.Count
    If IsEmpty(Table.Cells(i, 1).Value) Then
        Exit For
    End If
Next i
last = i - 1

For i = 1 To last
    If Table.Cells(i, 1) >= dateToFind Then
        Exit For
    End If
Next i

If Table.Cells(i, 1) = dateToFind Or i = 1 Then
    FindBestMatch = Table.Cells(i, colNum)
    Exit Function
End If
If i = last + 1 Then
    FindBestMatch = Table.Cells(i - 1, colNum)
    Exit Function
End If

' date at i is definitely bigger than request date...
' it is possibel that i is first element...
' it is possibel that i is last element...

Dim prevValue As Double
prevValue = Table.Cells(i - 1, colNum)
Dim prevDate As Date
prevDate = Table.Cells(i - 1, 1)

Dim nextValue As Double
nextValue = Table.Cells(i, colNum)
Dim nextDate As Date
nextDate = Table.Cells(i, 1)

If dateToFind - prevDate <= nextDate - dateToFind Then
   FindBestMatch = prevValue
Else
   FindBestMatch = nextValue
End If
End Function

////
```

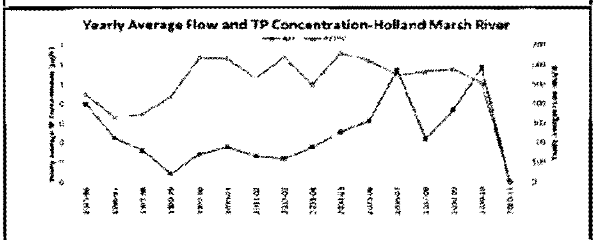
Appendix-2: Phosphorus concentration and water flow on Yearly basis

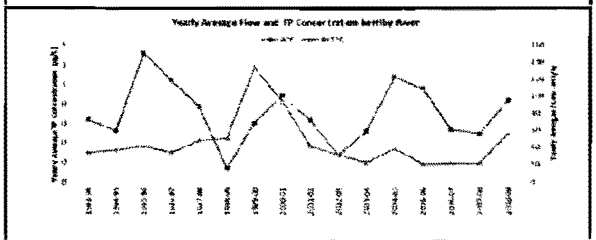


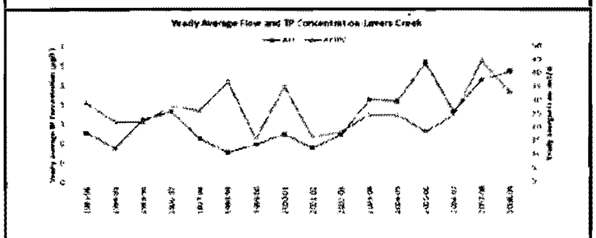


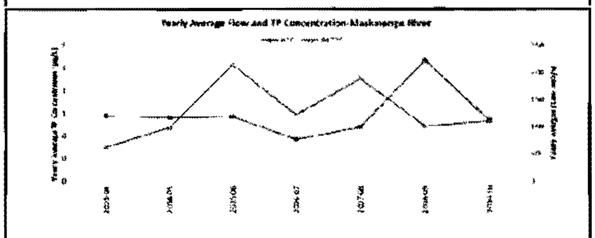


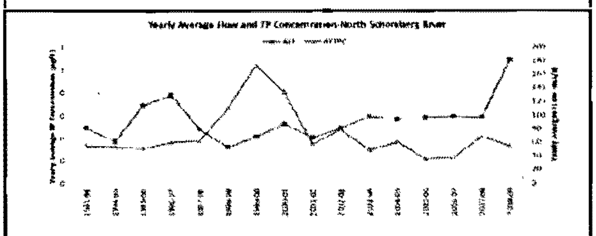


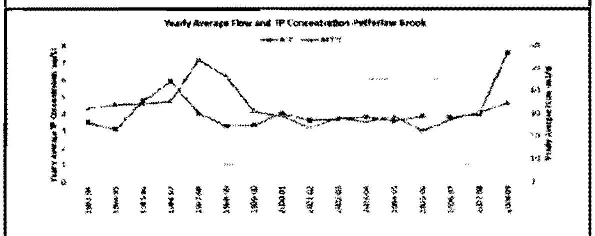


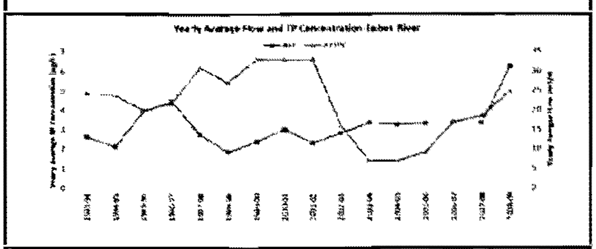


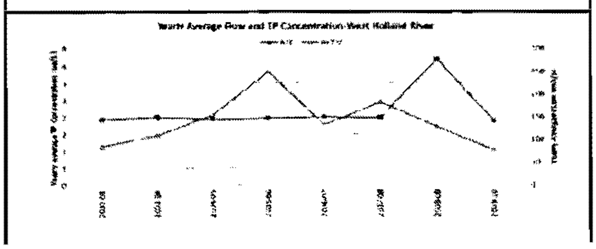


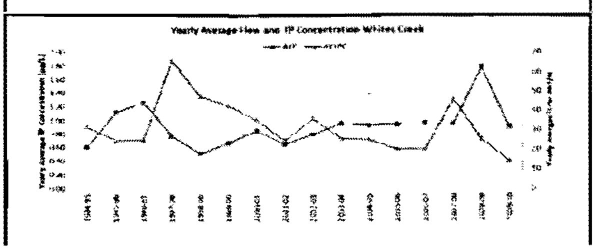




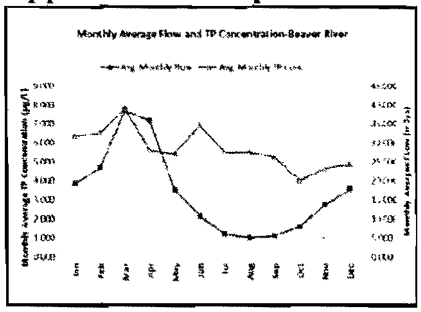


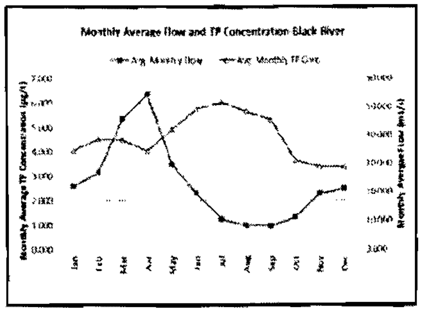


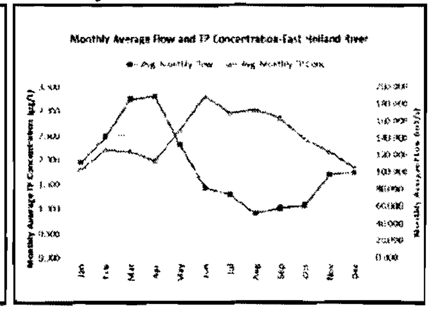


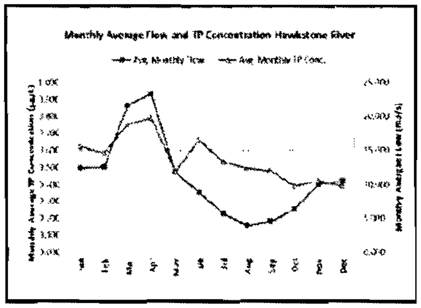


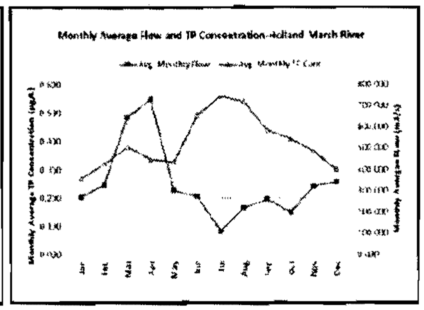
Appendix-3: Phosphorus concentration and water flow on Monthly basis

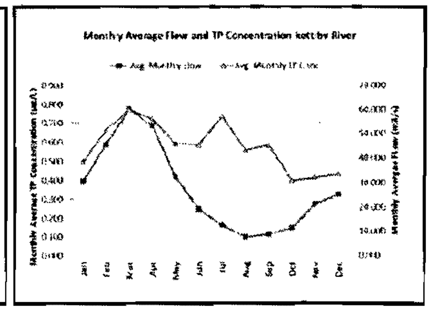


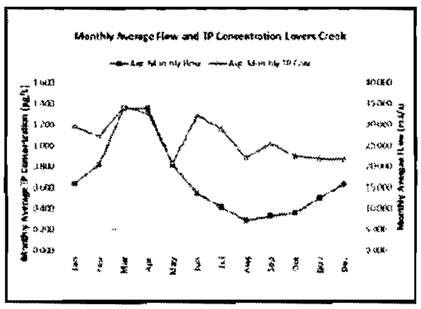


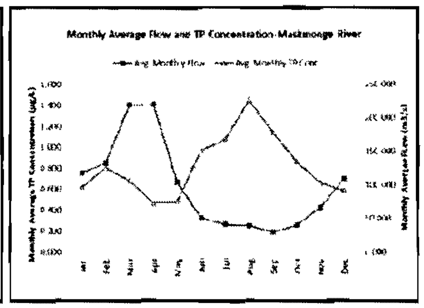


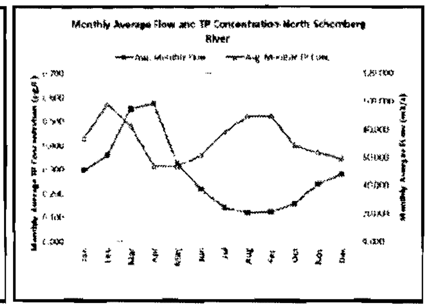


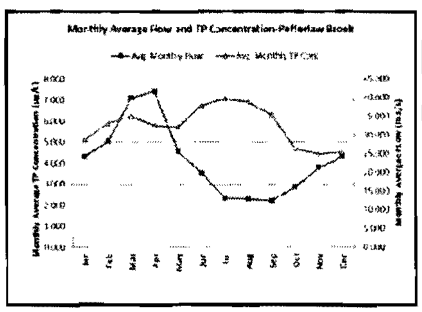


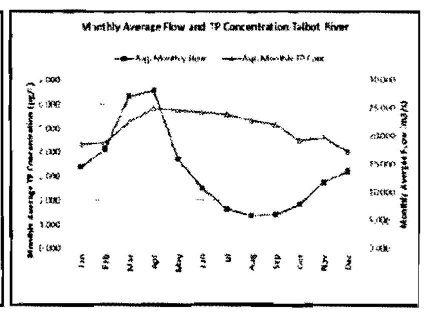


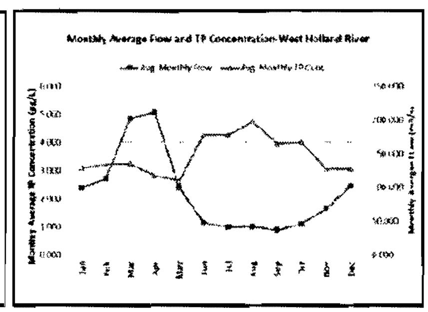


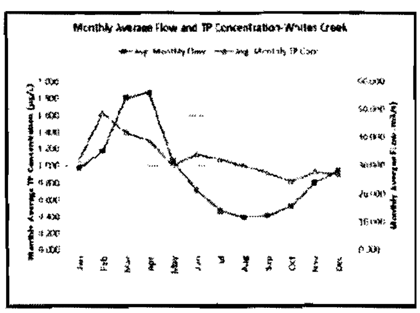




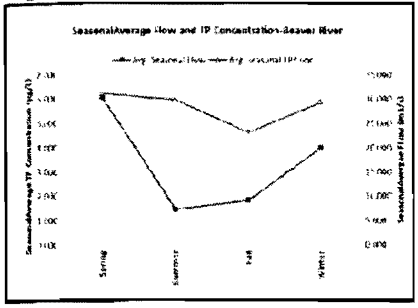


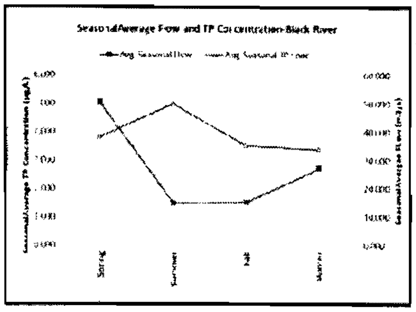


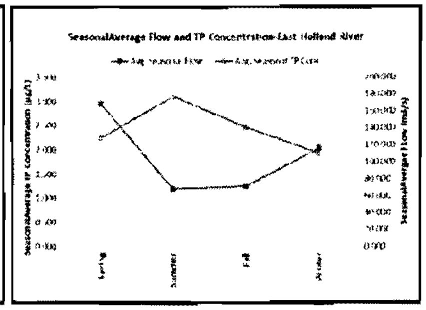


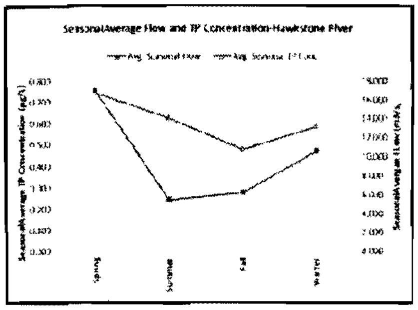


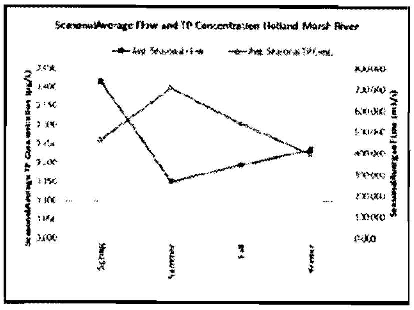
Appendix-4: Phosphorus concentration and water flow on Seasonal basis

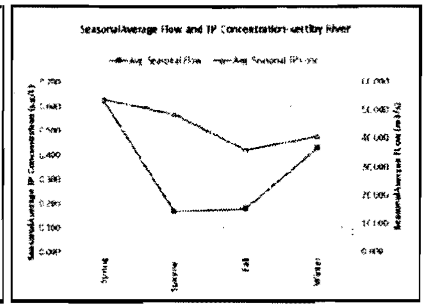


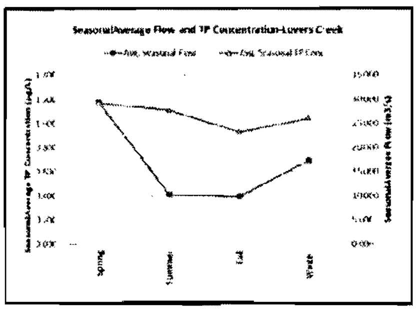


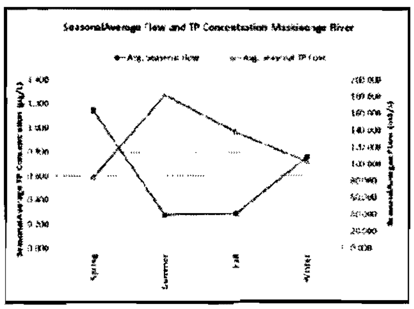


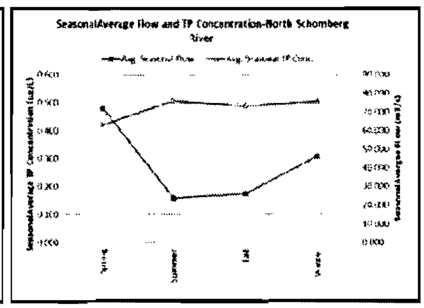


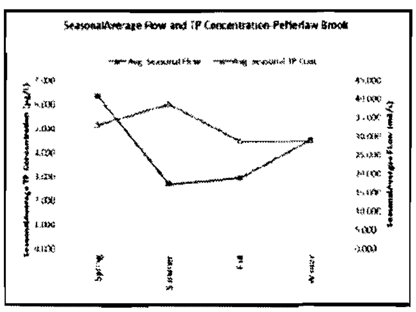


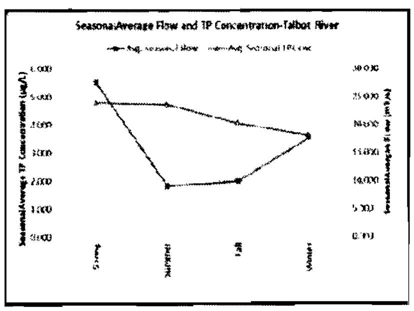


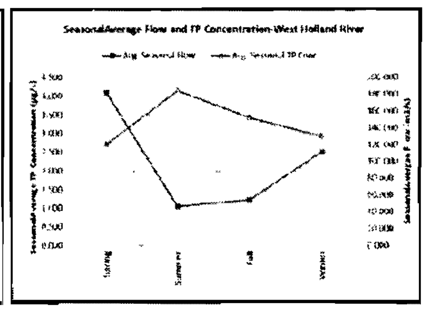


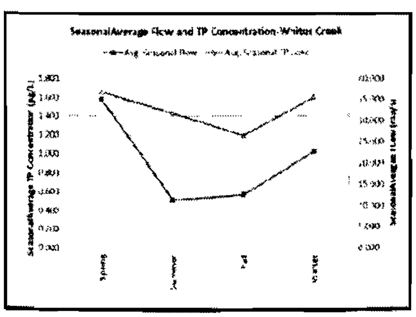




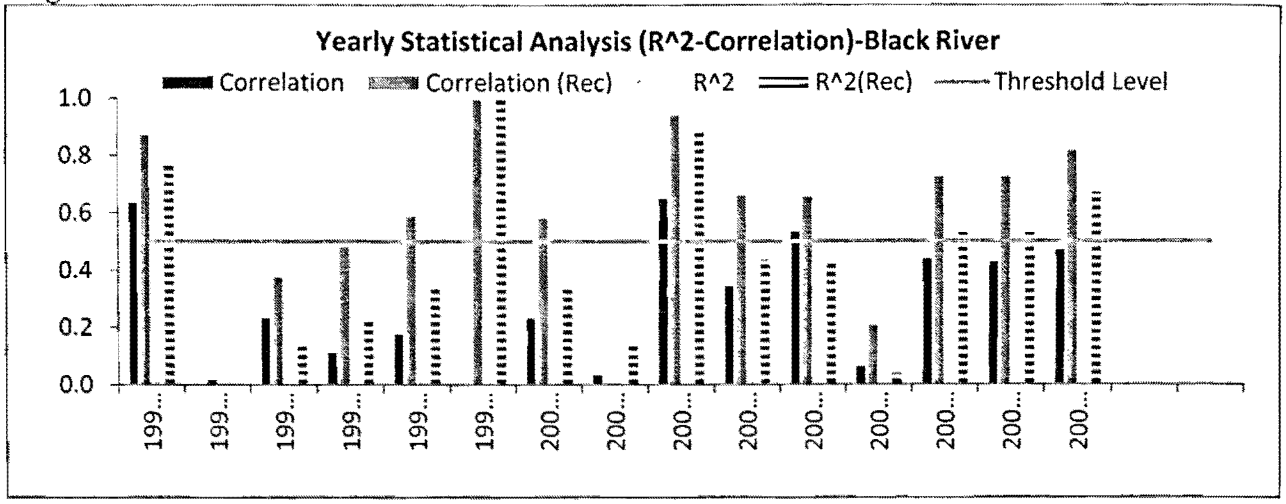


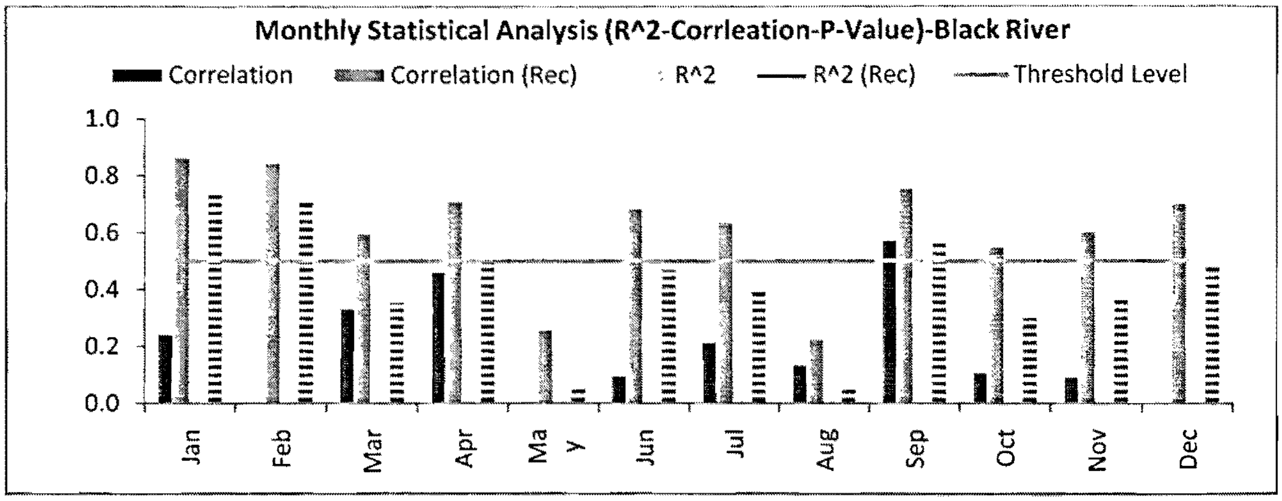


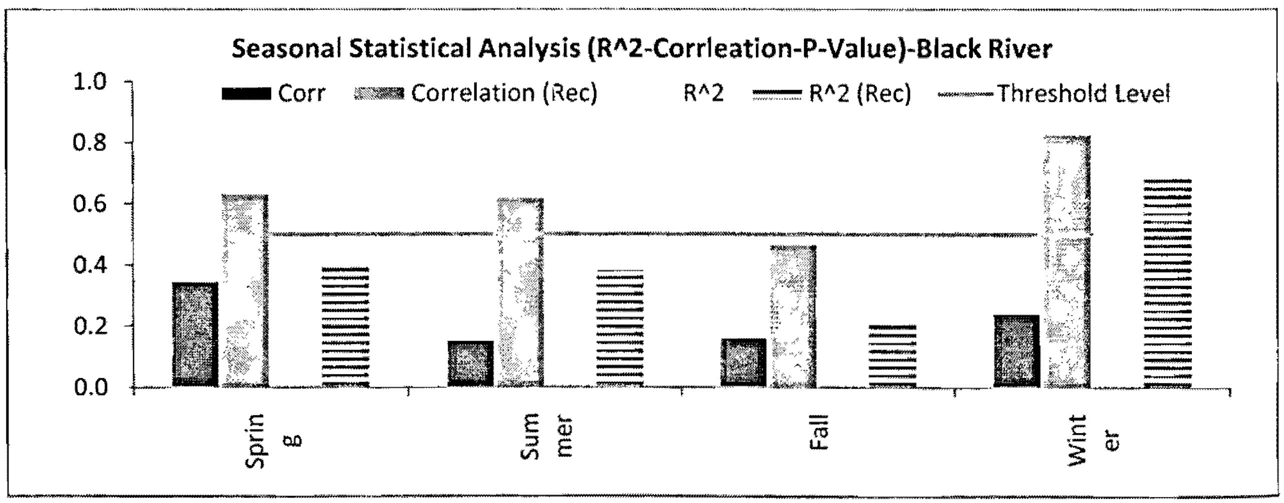




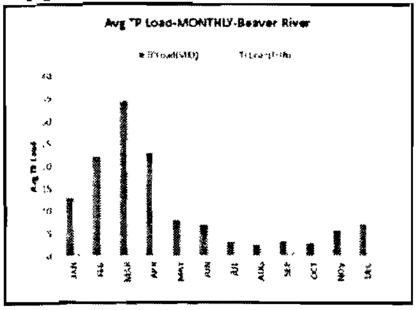
Appendix-5: Variation in correlation between gap filled data with midpoint method and original recorded data for TP concentration

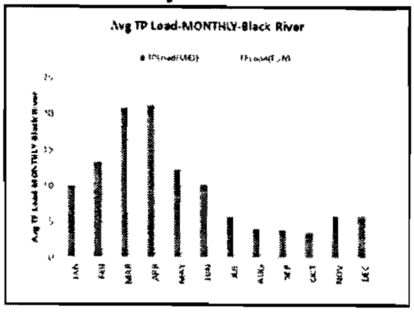


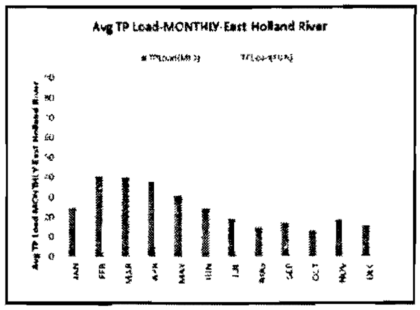


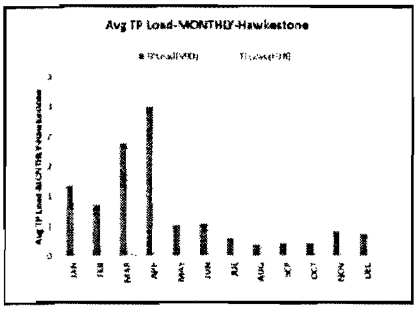


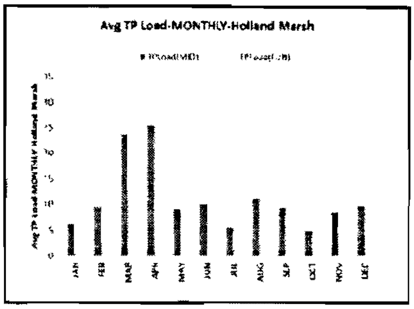
Appendix-6: Average TP Load on Monthly basis

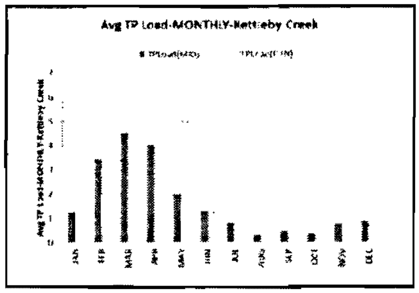


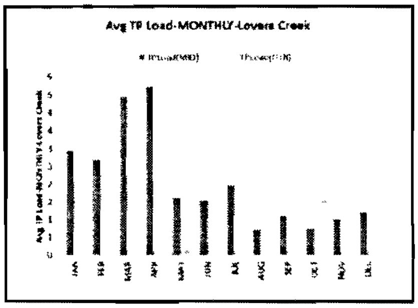


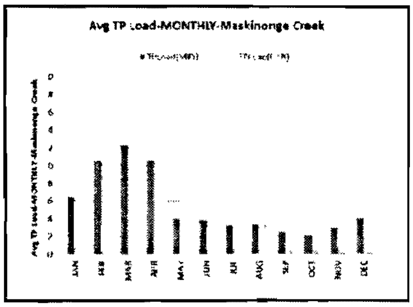


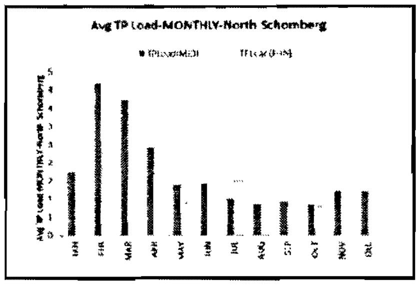


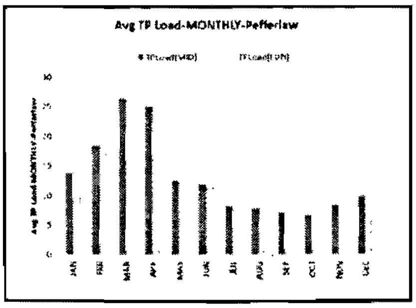


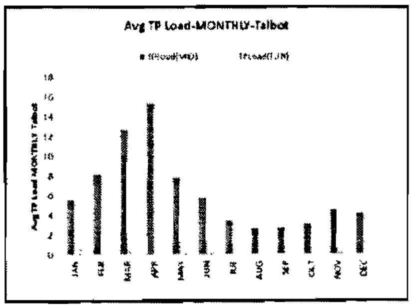


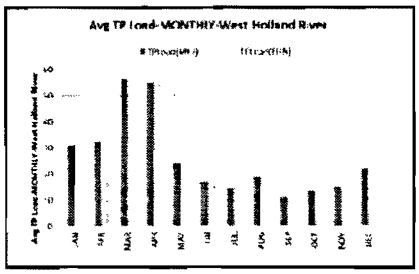


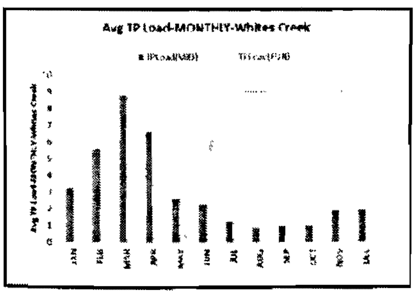




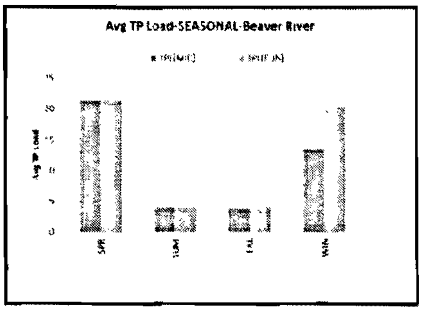


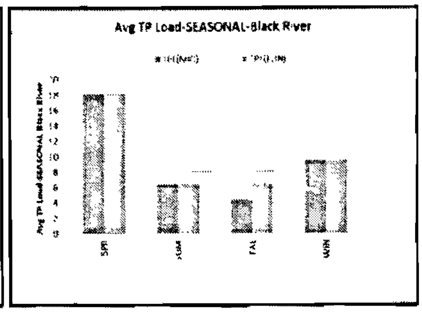


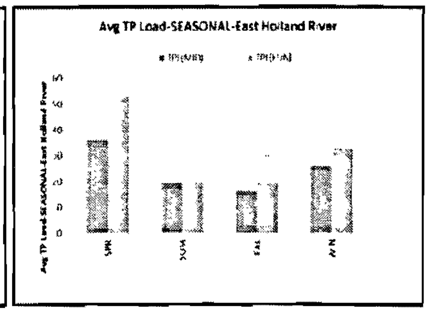


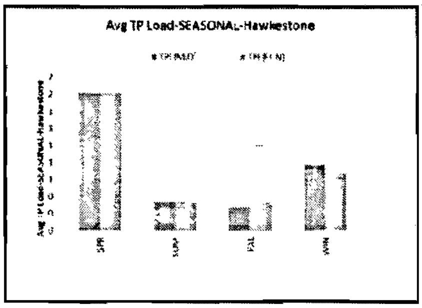


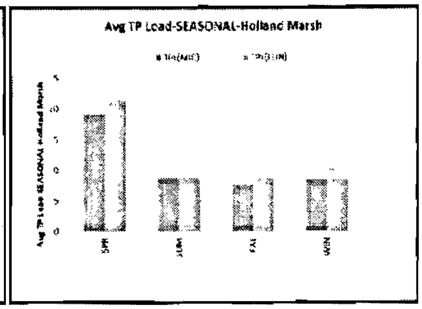
Appendix-7: Average TP Load on Seasonal basis

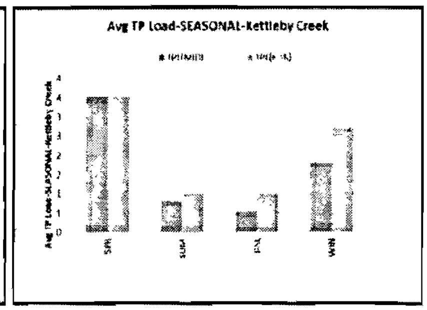


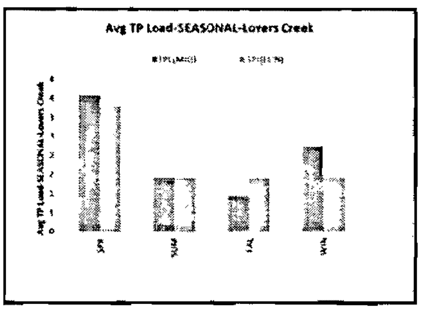


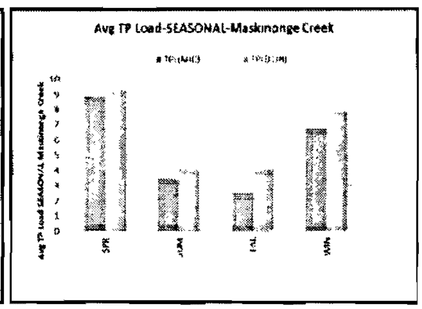


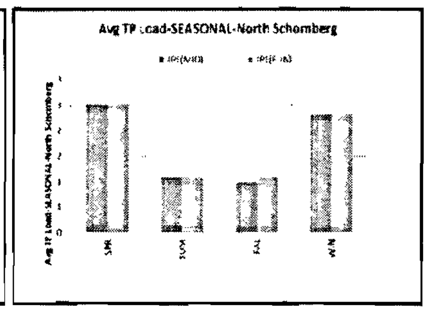


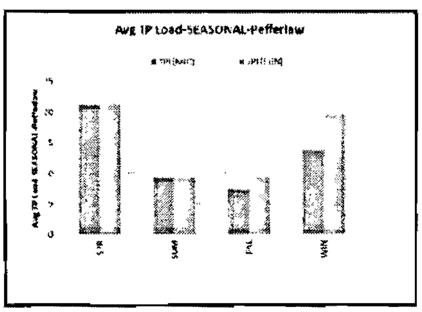


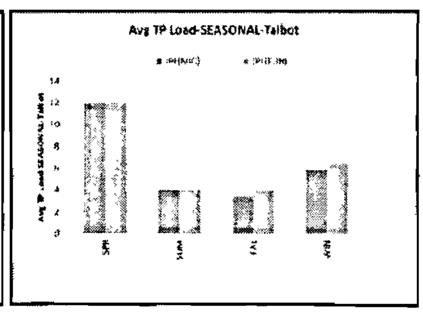


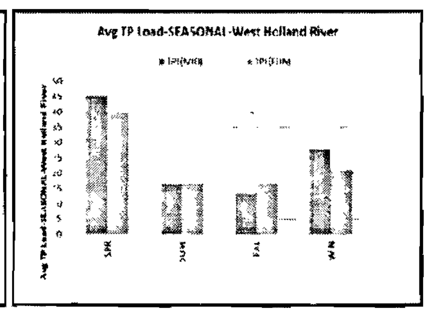


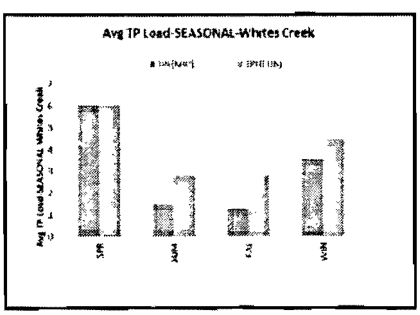




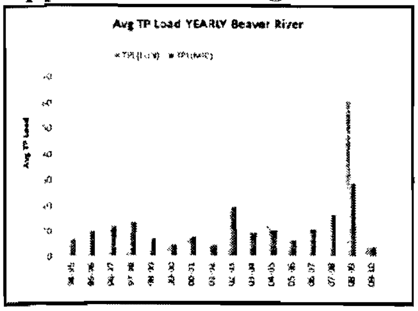


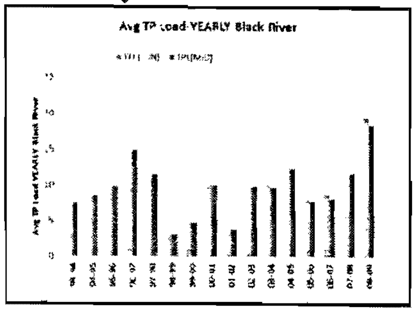


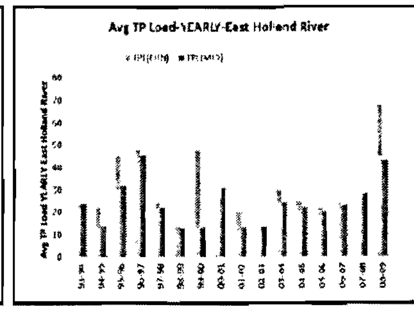


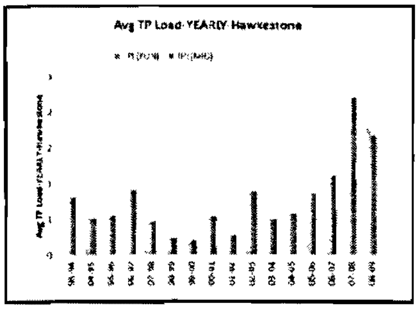


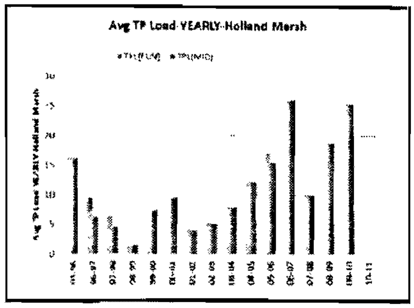
Appendix-8: Average TP Load on Yearly basis

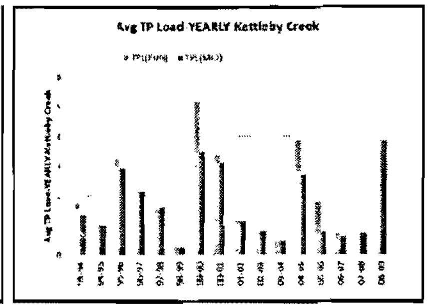


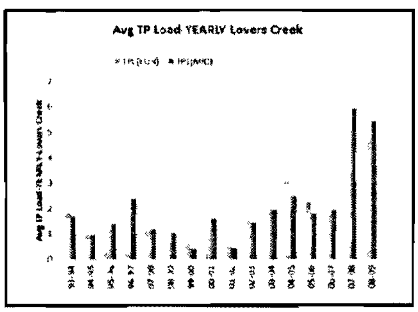


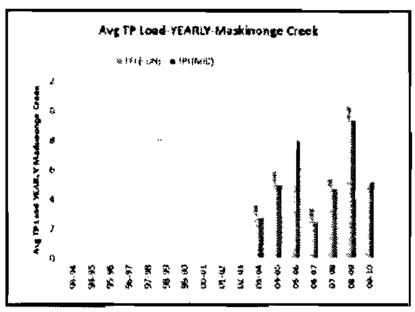


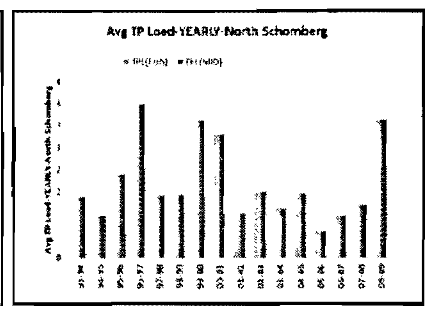


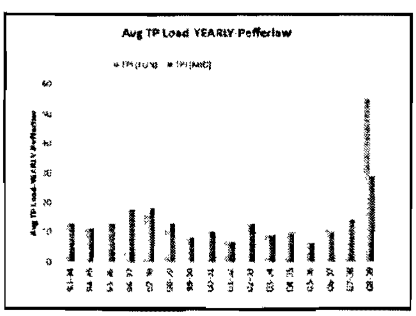


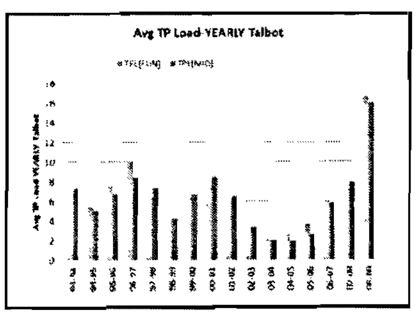


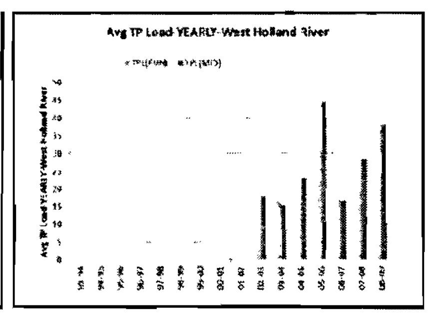


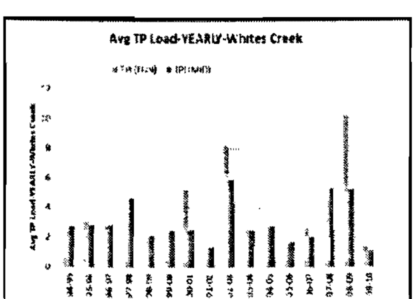




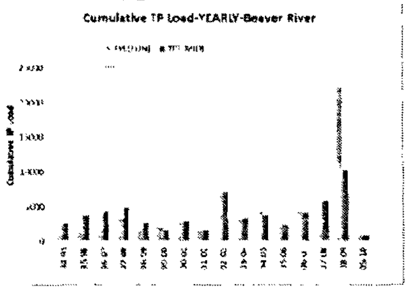


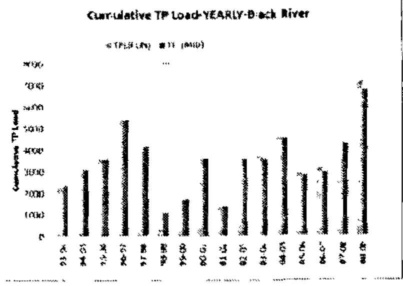


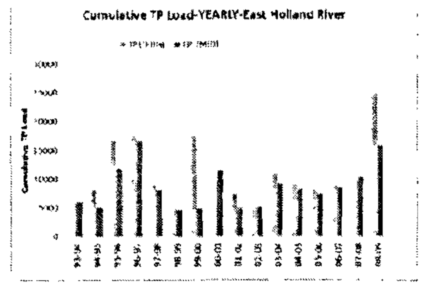


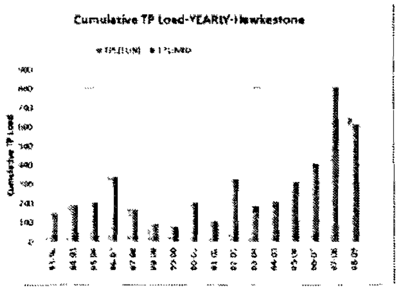


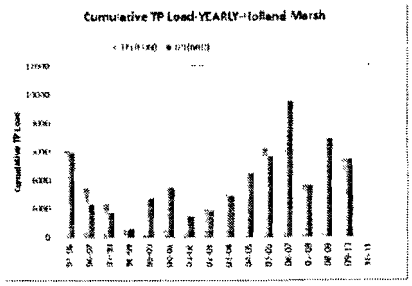
Appendix-9: Cumulative TP Load on Yearly basis

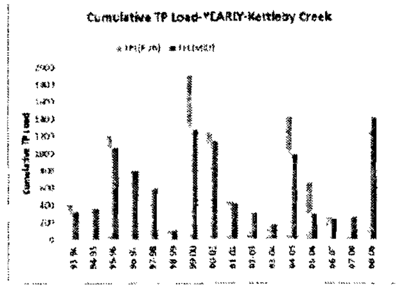


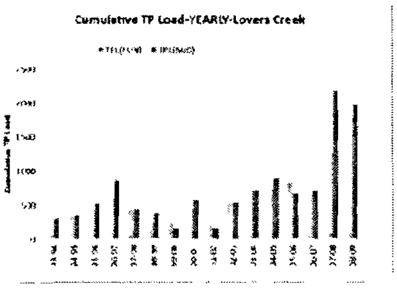


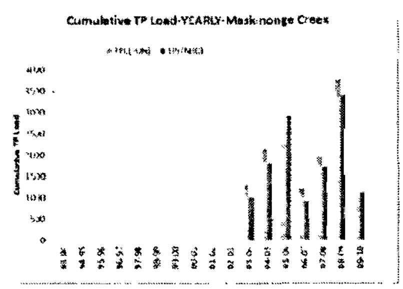


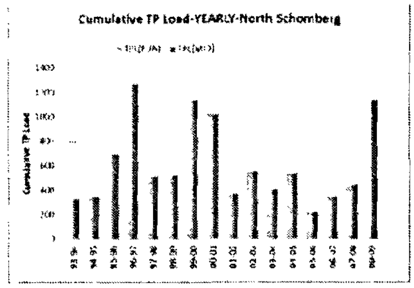


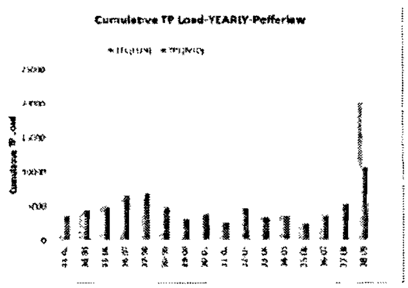


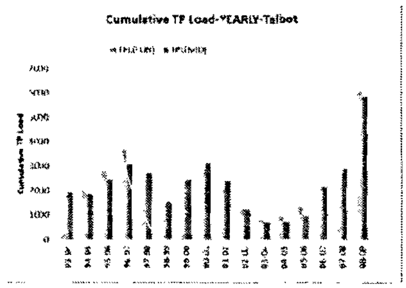


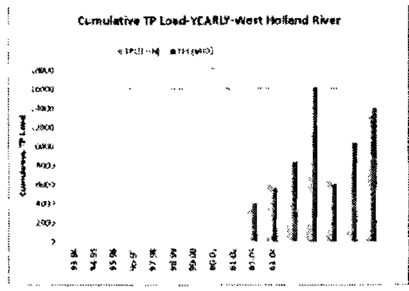


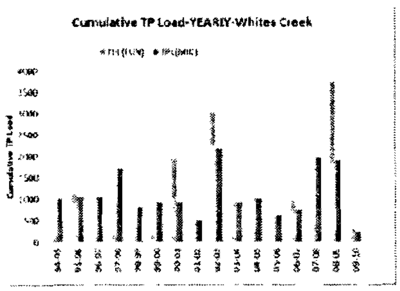












Appendix-10: Average TP Load on Yearly basis by two methods used for gap filling

		Beaver	Black	East Holland	Hawkestone	Holland Marsh	Kettleby Creek	Lovers Creek	Maskinonge Creek	N Schomberg River	Pefferlaw Creek	Talbot	W Holland River	Whites Creek
		Avg TP Load	Avg TP Load	Avg TP Load	Avg TP Load	Avg TP Load	Avg TP Load	Avg TP Load	Avg TP Load	Avg TP Load	Avg TP Load	Avg TP Load	Avg TP Load	Avg TP Load
1993-1994	(MID)		7.66	23.74	0.81		1.34	1.67		1.38	13.28	7.31		
	(FUN)		7.60	23.26	0.81		1.73	1.81		1.38	13.20	6.75		
1994-1995	(MID)	6.89	8.51	***13.93***	0.52		1.01	0.95		0.95	11.75	5.10		2.80
	(FUN)	6.48	8.35	***22.00***	0.52		1.05	0.93		0.95	11.39	5.56		2.63
1995-1996	(MID)	10.07	9.86	31.99	0.55	16.19	2.93	1.43		1.90	13.28	6.78		2.86
	(FUN)	10.36	9.85	45.26	0.55	16.42	3.27	1.18		1.90	13.42	7.58		3.04
1996-1997	(MID)	11.55	14.92	45.35	0.92	6.42	2.17	2.38		3.48	17.90	8.49		2.88
	(FUN)	10.36	14.83	48.09	0.92	9.57	2.17	1.72		3.48	17.51	10.12		2.85
1997-1998	(MID)	13.14	11.55	22.12	0.46	4.70	1.62	1.20		1.42	18.59	7.45		4.71
	(FUN)	8.92	10.80	24.49	0.46	6.49	1.57	1.13		1.42	16.99	6.57		3.73
1998-1999	(MID)	6.95	3.11	12.79	0.25	1.62	0.29	1.03		1.43	13.21	4.23		2.21
	(FUN)	4.83	2.93	13.46	0.24	1.52	0.28	0.71		1.43	11.72	4.06		1.93
1999-2000	(MID)	4.42	4.71	***13.21***	0.21	7.54	3.50	0.43		3.10	8.53	6.74		2.51
	(FUN)	5.28	4.67	***47.71***	0.22	7.34	5.18	0.61		3.10	8.51	6.59		2.25
2000-2001	(MID)	7.58	9.95	31.03	0.55	9.60	3.15	1.59		2.80	10.36	8.57		2.54
	(FUN)	7.43	9.93	26.31	0.55	9.59	3.36	1.23		2.80	10.24	7.91		5.31
2001-2002	(MID)	4.30	3.89	13.34	0.28	4.12	1.15	0.44		1.01	6.85	6.59		1.42
	(FUN)	4.18	3.86	20.32	0.27	4.32	1.20	0.56		1.01	7.18	5.98		1.33
2002-2003	(MID)	19.25	9.88	13.70	0.90	5.13	0.84	1.45		1.50	13.03	3.47	17.98	5.98
	(FUN)	18.09	9.87	13.52	0.90	5.41	0.84	1.51		1.50	13.19	3.54	16.46	8.19
2003-2004	(MID)	9.04	9.75	24.76	0.50	8.02	0.49	1.93	2.72	1.11	9.31	2.03	15.54	2.50
	(FUN)	9.40	10.29	29.84	0.51	8.32	0.49	1.98	3.61	1.11	9.73	2.19	16.48	2.59
2004-2005	(MID)	10.16	12.44	22.38	0.57	12.28	2.69	2.46	4.98	1.46	9.72	1.96	23.10	2.80
	(FUN)	11.51	12.57	24.89	0.59	12.37	3.89	1.96	5.91	1.46	9.74	2.64	18.25	2.92
2005-2006	(MID)	6.44	7.85	20.41	0.86	15.60	0.82	1.83	7.94	0.60	6.46	2.70	44.40	1.70
	(FUN)	5.93	8.04	21.96	0.75	17.24	1.80	2.25	6.23	0.60	6.92	3.72	30.61	1.58
2006-2007	(MID)	10.86	8.16	23.13	1.12	26.12	0.65	1.94	2.47	0.95	9.87	5.89	16.62	2.05
	(FUN)	11.43	8.81	24.38	1.15	26.12	0.73	1.81	3.31	0.95	10.95	6.01	17.39	2.64
2007-2008	(MID)	16.04	11.78	28.33	2.20	9.96	0.73	5.95	4.69	1.21	14.33	7.94	28.49	5.37
	(FUN)	14.98	10.41	26.02	1.76	9.99	0.74	3.46	5.35	1.21	12.94	7.36	20.40	4.71
2008-2009	(MID)	***28.26***	18.62	***43.24***	1.68	18.88	3.87	5.42	9.31	3.12	***29.13***	16.02	38.18	5.25
	(FUN)	***60.61***	19.61	***67.67***	1.78	18.98	3.47	4.83	10.32	3.12	***55.24***	16.63	36.38	10.22

Appendix-11: Coefficients of correlation - phosphorus load and rainfall lagged for 0, 1, 2 and 3 days (Monthly)

Co-effecients of Correlation between daily Rainfall (mm) with '0, 1, 2, and 3 day lag versus Phsphorus Loading (kg/day) -

		Beaver River				Black River				East Holland River				Hawkestone				Holland Marsh			
		Coeffecient of Corr with Lag (Days)				Coeffecient of Corr with Lag (Days)				Coeffecient of Corr with Lag (Days)				Coeffecient of Corr with Lag (Days)				Coeffecient of Corr with Lag (Days)			
		0	1	2	3	0	1	2	3	0	1	2	3	0	1	2	3	0	1	2	3
	(MID)	0.23	0.37	0.41	0.37	0.14	0.26	0.44	***0.50***	0.16	0.44	0.28	0.12	0.22	0.49	0.41	0.21	0.01	0.09	0.15	0.25
JAN	(FUN)	0.09	0.20	0.25	0.19	0.07	0.23	0.43	***0.52***	0.16	***0.58***	0.32	0.08	0.17	***0.53***	0.43	0.12	0.01	0.09	0.15	0.25
	(MID)	0.00	0.35	0.35	0.33	0.07	0.20	0.45	***0.57***	0.16	***0.78***	0.27	0.08	0.04	0.14	0.17	0.15	0.00	0.09	0.17	0.10
FEB	(FUN)	0.00	0.40	0.30	0.25	0.07	0.20	0.45	***0.57***	0.15	***0.83***	0.28	0.05	0.04	0.14	0.17	0.15	0.00	0.09	0.17	0.10
	(MID)	0.07	0.13	0.17	0.19	0.07	0.14	0.23	0.26	0.23	0.38	0.25	0.11	0.14	0.17	0.19	0.15	0.01	0.11	0.24	0.28
MAR	(FUN)	0.07	0.13	0.17	0.19	0.07	0.14	0.23	0.26	0.23	0.38	0.25	0.11	0.14	0.17	0.19	0.15	0.02	0.22	0.35	0.22
	(MID)	-0.01	0.12	0.10	0.03	-0.01	0.10	0.15	0.15	0.05	0.31	0.13	0.03	0.00	0.17	0.12	-0.01	-0.01	0.19	0.23	0.14
APR	(FUN)	-0.02	0.23	0.11	0.03	-0.01	0.10	0.15	0.15	0.05	***0.51***	0.10	0.02	0.00	0.17	0.12	-0.01	-0.01	0.19	0.23	0.14
	(MID)	0.07	0.30	0.37	0.24	0.00	0.18	0.40	0.45	0.15	0.45	0.24	0.07	0.08	0.29	0.34	0.26	0.01	0.30	0.27	0.24
MAY	(FUN)	0.07	0.30	0.37	0.24	0.00	0.18	0.40	0.45	0.11	0.34	0.11	0.05	0.08	0.29	0.34	0.26	0.01	0.30	0.27	0.24
	(MID)	0.08	0.31	0.32	0.29	0.06	0.23	0.35	0.36	0.14	0.41	0.18	0.09	0.11	0.27	0.25	0.19	0.01	0.17	0.08	0.08
JUN	(FUN)	0.08	0.31	0.32	0.29	0.06	0.23	0.35	0.36	0.14	0.41	0.18	0.09	0.11	0.27	0.25	0.19	0.01	0.17	0.08	0.08
	(MID)	-0.01	0.22	0.34	0.20	-0.02	0.04	0.15	0.15	0.12	0.36	0.13	0.06	0.06	0.22	0.17	0.14	0.05	0.14	0.13	0.13
JUL	(FUN)	-0.01	0.22	0.34	0.20	-0.02	0.04	0.15	0.15	0.12	0.36	0.13	0.06	0.06	0.22	0.17	0.14	0.05	0.14	0.13	0.13
	(MID)	0.01	0.14	0.21	0.20	0.12	0.17	0.21	0.24	0.15	0.47	0.15	0.07	0.06	0.15	0.18	0.15	-0.10	-0.09	-0.08	-0.03
AUG	(FUN)	0.01	0.14	0.21	0.20	0.12	0.17	0.21	0.24	0.15	0.47	0.15	0.07	0.06	0.15	0.18	0.15	-0.10	-0.09	-0.08	-0.03
	(MID)	0.11	0.18	0.23	0.21	0.05	0.11	0.21	0.28	0.30	***0.57***	0.14	0.04	0.13	0.30	0.27	0.23	-0.10	-0.06	-0.05	-0.07
SEP	(FUN)	0.06	0.18	0.25	0.24	0.05	0.11	0.21	0.28	0.30	***0.60***	0.10	0.02	0.13	0.30	0.27	0.23	-0.10	-0.06	-0.05	-0.07
	(MID)	-0.02	0.12	0.18	0.17	-0.05	0.04	0.12	0.18	0.16	***0.60***	0.18	0.08	0.06	0.28	0.22	0.14	0.00	0.07	0.21	0.11
OCT	(FUN)	-0.02	0.12	0.18	0.17	-0.05	0.04	0.12	0.18	0.16	***0.60***	0.18	0.08	0.06	0.28	0.22	0.14	0.00	0.07	0.21	0.11
	(MID)	-0.01	0.15	0.20	0.21	-0.03	0.11	0.22	0.28	0.18	***0.59***	0.27	0.11	0.09	0.23	0.21	0.16	0.04	0.14	0.36	0.28
NOV	(FUN)	-0.01	0.15	0.20	0.21	-0.03	0.11	0.22	0.28	0.18	***0.59***	0.27	0.11	0.09	0.23	0.21	0.16	0.04	0.14	0.36	0.28
	(MID)	0.07	0.18	0.24	0.16	0.01	0.11	0.23	0.29	0.17	***0.65***	0.34	0.12	0.09	0.19	0.14	0.07	0.00	0.15	0.21	0.23
DEC	(FUN)	-0.01	0.16	0.23	0.09	0.01	0.11	0.23	0.29	0.17	***0.65***	0.34	0.12	0.09	0.19	0.14	0.07	0.00	0.15	0.21	0.23

Appendix-11: Continued

Coefficients of Correlation between daily Rainfall (mm) with '0, 1, 2, and 3 day lag versus Phosphorus Loading (kg/day) - Monthly

		Kettleby Creek Coefficient of Corr with Lag (Days)				Lovers Creek Coefficient of Corr with Lag (Days)				Maskinonge Creek Coefficient of Corr with Lag (Days)				North Schomberg Coefficient of Corr with Lag (Days)				Pefferlaw Coefficient of Corr with Lag (Days)			
		0	1	2	3	0	1	2	3	0	1	2	3	0	1	2	3	0	1	2	3
	(MID)	0.23	0.35	0.25	0.16	0.07	0.22	0.27	0.20	0.27	0.48	0.41	0.22	0.11	0.33	0.27	0.27	0.15	0.27	0.47	***0.53***
JAN	(FUN)	0.23	0.35	0.25	0.16	0.03	0.14	0.22	0.19	0.22	0.45	0.40	0.24	0.11	0.33	0.27	0.27	0.07	0.24	0.46	***0.56***
	(MID)	0.20	0.37	0.11	0.04	0.06	0.19	0.23	0.20	0.17	0.50	0.45	0.39	0.14	0.28	0.38	0.36	0.04	0.18	0.38	0.46
FEB	(FUN)	0.06	0.23	0.08	0.01	0.02	0.12	0.12	0.08	0.17	***0.53***	0.34	0.27	0.14	0.28	0.38	0.36	0.04	0.18	0.38	0.46
	(MID)	0.13	0.20	0.17	0.09	0.18	0.20	0.13	0.06	0.17	0.34	0.38	0.26	0.07	0.14	0.16	0.19	0.08	0.15	0.26	0.26
MAR	(FUN)	0.13	0.20	0.17	0.09	0.18	0.20	0.13	0.06	0.17	0.34	0.38	0.26	0.07	0.14	0.16	0.19	0.08	0.15	0.26	0.26
	(MID)	0.14	0.24	0.11	0.09	-0.03	0.14	0.20	0.02	0.04	0.29	0.26	0.19	-0.02	0.17	0.16	0.14	0.02	0.15	0.23	0.21
APR	(FUN)	0.14	0.24	0.11	0.09	-0.01	0.34	0.06	0.07	0.03	0.29	0.27	0.19	-0.02	0.17	0.16	0.14	0.02	0.15	0.23	0.21
	(MID)	0.03	0.36	0.14	0.07	0.10	0.42	0.27	0.09	0.12	0.44	0.48	0.38	0.06	0.29	0.32	0.27	0.05	0.37	***0.53***	0.43
MAY	(FUN)	0.03	0.36	0.14	0.07	0.10	0.42	0.27	0.09	0.12	0.44	0.48	0.38	0.06	0.29	0.32	0.27	0.05	0.37	***0.53***	0.43
	(MID)	0.13	0.22	0.06	0.05	0.12	0.32	0.25	0.18	0.17	0.32	0.48	0.42	0.03	0.23	0.24	0.25	0.07	0.48	***0.52***	0.43
JUN	(FUN)	0.13	0.22	0.06	0.05	0.12	0.32	0.25	0.18	0.04	0.27	0.19	0.13	0.03	0.23	0.24	0.25	0.07	0.48	***0.52***	0.43
	(MID)	0.08	0.09	0.07	0.08	0.05	0.15	0.12	0.16	0.06	0.24	0.19	0.20	0.00	0.16	0.12	0.09	0.01	0.20	0.32	0.29
JUL	(FUN)	0.08	0.09	0.07	0.08	0.05	0.15	0.12	0.16	0.05	0.32	0.24	0.24	0.00	0.16	0.12	0.09	0.01	0.20	0.32	0.29
	(MID)	0.02	0.17	0.14	0.07	0.04	0.18	0.06	0.01	0.21	0.40	0.26	0.24	0.02	0.21	0.16	0.14	0.08	0.26	0.35	0.39
AUG	(FUN)	0.02	0.08	0.11	0.00	0.04	0.18	0.06	0.01	0.21	0.40	0.26	0.24	0.02	0.21	0.16	0.14	0.08	0.26	0.35	0.39
	(MID)	0.08	0.43	0.20	0.11	0.11	0.27	0.20	0.07	0.02	0.16	0.17	0.12	0.16	0.37	0.26	0.15	0.06	0.19	0.31	0.32
SEP	(FUN)	0.08	0.43	0.20	0.11	0.05	0.28	0.15	0.04	0.02	0.16	0.17	0.12	0.16	0.37	0.26	0.15	0.06	0.19	0.31	0.32
	(MID)	0.03	0.24	0.22	0.07	0.04	0.19	0.07	0.01	-0.01	0.09	0.07	0.13	-0.03	0.18	0.16	0.08	-0.04	0.08	0.23	0.29
OCT	(FUN)	0.05	0.47	0.04	0.05	0.04	0.19	0.07	0.01	-0.03	0.14	0.06	0.07	-0.03	0.18	0.16	0.08	-0.04	0.08	0.23	0.29
	(MID)	0.06	0.50	0.22	0.13	0.08	0.32	0.21	0.12	0.01	0.35	0.27	0.21	-0.01	0.23	0.23	0.21	-0.02	0.18	0.32	0.34
NOV	(FUN)	0.06	0.50	0.22	0.13	0.08	0.32	0.21	0.12	0.02	0.38	0.35	0.29	-0.01	0.23	0.23	0.21	-0.02	0.18	0.32	0.34
	(MID)	0.12	0.35	0.21	0.09	-0.01	0.11	0.09	0.04	0.01	0.33	0.44	0.37	0.02	0.22	0.22	0.18	0.01	0.13	0.26	0.33
DEC	(FUN)	0.12	0.35	0.21	0.09	0.03	0.26	0.27	0.11	0.02	0.28	0.42	0.31	0.02	0.22	0.22	0.18	-0.02	0.00	0.11	0.24

Appendix-11: Continued

Coefficients of Correlation between daily Rainfall (mm) with '0, 1, 2, and 3 day lag versus Phosphorus Loading (kg/day) - Monthly

		Talbot				West Holland River				Whites Creek			
		Coefficient of Corr with Lag (Days)				coefficient of Corr with Lag (Days)				coefficient of Corr with Lag (Days)			
		0	1	2	3	0	1	2	3	0	1	2	3
	(MID)	0.23	0.46	0.48	0.43	0.19	0.45	***0.50***	0.34	0.23	0.41	0.46	0.42
JAN	(FUN)	0.14	0.48	***0.52***	0.40	0.08	0.36	0.45	0.34	0.11	0.42	0.49	0.37
	(MID)	0.01	0.06	0.08	0.07	0.01	0.17	0.16	0.19	0.08	0.38	0.22	0.18
FEB	(FUN)	0.03	0.19	0.26	0.26	0.01	0.17	0.16	0.19	0.08	0.38	0.22	0.18
	(MID)	0.08	0.12	0.14	0.12	0.17	0.34	0.38	0.32	0.08	0.14	0.16	0.16
MAR	(FUN)	0.08	0.12	0.14	0.12	0.16	0.42	0.44	0.33	0.08	0.14	0.16	0.16
	(MID)	-0.02	0.16	0.12	0.02	-0.05	0.17	0.17	0.17	0.03	0.21	0.17	0.12
APR	(FUN)	-0.02	0.16	0.12	0.02	-0.05	0.17	0.17	0.17	0.03	0.21	0.17	0.12
	(MID)	-0.01	0.18	0.19	0.13	-0.06	0.09	0.10	0.05	0.10	0.40	0.42	0.33
MAY	(FUN)	-0.01	0.18	0.19	0.13	-0.04	0.36	0.37	0.19	0.10	0.40	0.42	0.33
	(MID)	0.03	0.24	0.27	0.27	0.19	0.32	0.26	0.20	0.11	0.44	0.45	0.39
JUN	(FUN)	0.03	0.24	0.27	0.27	0.19	0.32	0.26	0.20	0.08	0.30	0.35	0.25
	(MID)	0.00	0.17	0.16	0.11	0.13	0.36	0.28	0.19	0.01	0.23	0.24	0.16
JUL	(FUN)	0.00	0.17	0.16	0.11	0.13	0.36	0.28	0.19	0.01	0.23	0.24	0.16
	(MID)	0.04	0.16	0.14	0.13	0.09	0.24	0.24	0.25	0.12	0.40	0.35	0.30
AUG	(FUN)	0.04	0.16	0.14	0.13	0.09	0.24	0.24	0.25	0.12	0.40	0.35	0.30
	(MID)	0.04	0.23	0.20	0.21	0.08	0.33	0.20	0.15	0.11	0.29	0.25	0.24
SEP	(FUN)	0.04	0.23	0.20	0.21	0.08	0.33	0.20	0.15	0.10	0.34	0.27	0.25
	(MID)	-0.01	0.19	0.16	0.12	-0.02	0.08	0.07	0.03	0.04	0.28	0.29	0.24
OCT	(FUN)	-0.01	0.19	0.16	0.12	-0.02	0.08	0.07	0.03	0.04	0.28	0.29	0.24
	(MID)	0.03	0.29	0.32	0.32	0.08	0.36	0.32	0.18	0.06	0.35	0.33	0.31
NOV	(FUN)	0.03	0.29	0.32	0.32	0.08	0.31	0.28	0.22	0.06	0.35	0.33	0.31
	(MID)	0.12	0.30	0.26	0.19	0.01	0.27	0.28	0.28	0.05	0.23	0.25	0.20
DEC	(FUN)	0.12	0.30	0.26	0.19	0.01	0.27	0.28	0.28	-0.01	0.17	0.25	0.14

Appendix-12: Coefficients of correlation - phosphorus load and rainfall lagged for 0, 1, 2 and 3 days (Yearly)

Coefficients of Correlation between daily Rainfall (mm) with '0, 1, 2, and 3 day lag versus Phosphorus Loading (kg/day) - Yearly																					
		Beaver River				Black River				East Holland River				Hawkestone				Holland Marsh			
		coefficient of Corr with Lag (Days)				coefficient of Corr with Lag (Days)				coefficient of Corr with Lag (Days)				coefficient of Corr with Lag (Days)				coefficient of Corr with Lag (Days)			
		0	1	2	3	0	1	2	3	0	1	2	3	0	1	2	3	0	1	2	3
	(MID)					-0.04	0.04	0.13	0.13	0.07	0.22	0.06	0.00	0.06	0.13	0.24	0.23				
1993-94	(FUN)					-0.04	0.04	0.13	0.14	0.21	0.28	0.07	0.00	0.06	0.13	0.24	0.23				
	(MID)	0.11	0.28	0.30	0.29	0.03	0.17	0.33	0.39	0.21	***0.53***	0.28	0.13	-0.01	0.10	0.11	0.11				
1994-95	(FUN)	0.04	0.26	0.35	0.29	-0.01	0.14	0.34	0.41	0.23	***0.55***	0.30	0.07	-0.02	0.10	0.14	0.13				
	(MID)	-0.04	0.09	0.12	0.11	-0.04	0.02	0.11	0.16	0.04	0.29	0.08	0.01	-0.02	0.15	0.13	0.15	-0.02	0.09	0.12	0.05
1995-96	(FUN)	-0.07	0.08	0.09	0.10	-0.05	0.03	0.11	0.16	0.00	0.23	0.04	-0.01	-0.02	0.16	0.13	0.14	-0.02	0.08	0.11	0.04
	(MID)	0.03	0.18	0.24	0.23	-0.01	0.08	0.22	0.27	0.11	0.35	0.13	0.02	-0.03	0.06	0.07	0.07	-0.06	0.03	0.08	0.02
1996-97	(FUN)	0.00	0.15	0.25	0.27	-0.01	0.08	0.22	0.27	0.08	0.37	0.12	0.00	-0.03	0.06	0.07	0.07	-0.03	0.02	0.04	0.00
	(MID)	0.07	0.24	0.24	0.29	0.07	0.22	0.25	0.29	0.17	***0.63***	0.25	0.19	0.14	0.24	0.24	0.21	-0.03	0.07	0.25	0.23
1997-98	(FUN)	0.06	0.23	0.23	0.28	0.05	0.21	0.24	0.29	0.14	***0.68***	0.23	0.19	0.14	0.25	0.26	0.23	-0.02	0.07	0.20	0.15
	(MID)	-0.08	0.10	0.18	0.15	-0.08	0.03	0.22	0.24	0.00	0.22	0.10	-0.02	-0.06	0.12	0.14	0.09	-0.06	-0.06	0.09	-0.01
1998-99	(FUN)	-0.07	0.19	0.29	0.22	-0.06	0.04	0.22	0.24	-0.01	0.11	0.10	-0.01	-0.06	0.12	0.15	0.09	-0.05	-0.06	0.10	0.00
	(MID)	-0.02	0.26	0.26	0.19	-0.01	0.01	0.13	0.26	0.11	***0.58***	0.22	0.11	0.01	0.28	0.28	0.25	-0.03	0.18	0.28	0.18
1999-00	(FUN)	-0.03	0.10	0.12	0.09	-0.01	0.01	0.13	0.26	0.00	0.28	0.07	0.05	0.00	0.28	0.28	0.25	-0.03	0.18	0.28	0.18
	(MID)	0.22	0.35	0.35	0.30	0.12	0.28	0.42	0.42	0.18	0.44	0.24	0.10	0.03	0.18	0.16	0.14	0.03	0.26	0.15	0.21
2000-01	(FUN)	0.23	0.37	0.37	0.33	0.12	0.28	0.42	0.43	0.14	0.48	0.22	0.08	0.03	0.18	0.16	0.14	0.03	0.23	0.13	0.19
	(MID)	0.08	0.27	0.19	0.14	0.12	0.30	0.30	0.24	0.17	***0.59***	0.31	0.12	0.01	0.24	0.19	0.11	0.06	0.17	0.19	0.17
2001-02	(FUN)	0.08	0.26	0.19	0.14	0.12	0.30	0.30	0.24	0.05	0.33	0.15	0.06	0.02	0.25	0.20	0.12	0.05	0.16	0.19	0.17
	(MID)	0.00	0.02	0.04	0.04	0.01	0.09	0.12	0.12	0.08	0.23	0.10	0.03	0.01	0.03	0.04	0.03	0.05	0.08	0.01	0.03
2002-03	(FUN)	0.00	0.02	0.05	0.04	0.01	0.09	0.12	0.12	0.08	0.23	0.09	0.03	0.01	0.03	0.04	0.03	0.08	0.14	0.03	0.05
	(MID)	-0.01	0.12	0.19	0.12	-0.03	0.06	0.16	0.19	0.25	***0.56***	0.26	0.11	0.07	0.27	0.31	0.23	-0.01	0.08	0.13	0.09
2003-04	(FUN)	-0.02	0.12	0.19	0.12	-0.04	0.05	0.15	0.20	0.18	0.40	0.25	0.03	0.07	0.27	0.31	0.23	-0.01	0.12	0.12	0.07
	(MID)	-0.04	-0.01	0.00	-0.03	0.01	0.03	0.04	0.05	0.13	0.35	0.20	0.11	0.03	0.11	0.13	0.07	0.02	0.10	0.13	0.10
2004-05	(FUN)	-0.04	-0.01	0.00	-0.01	0.01	0.03	0.04	0.05	0.08	0.27	0.18	0.07	0.03	0.12	0.15	0.08	0.02	0.10	0.13	0.10
	(MID)	-0.01	0.06	0.09	0.04	0.11	0.28	0.43	0.39	0.16	0.49	0.29	0.08	0.00	0.07	0.07	0.02	0.01	0.06	0.12	0.15
2005-06	(FUN)	-0.01	0.09	0.11	0.06	0.11	0.28	0.43	0.39	0.12	0.46	0.23	0.05	0.01	0.07	0.07	0.04	0.00	0.08	0.16	0.11
	(MID)	-0.04	0.01	0.01	-0.01	-0.06	-0.02	0.03	0.09	0.33	***0.55***	0.11	0.03	0.12	0.28	0.15	0.08	-0.02	0.11	0.11	0.21
2006-07	(FUN)	-0.05	0.06	0.04	0.00	-0.07	-0.03	0.03	0.08	0.34	***0.55***	0.07	0.00	0.12	0.28	0.15	0.08	-0.02	0.11	0.11	0.21
	(MID)	0.00	0.09	0.10	0.01	-0.02	0.03	0.09	0.08	0.04	0.17	0.10	-0.01	0.05	0.20	0.16	0.03	-0.05	0.08	0.08	0.05
2007-08	(FUN)	0.01	0.11	0.10	0.01	-0.01	0.04	0.10	0.09	0.05	0.23	0.10	-0.01	0.04	0.21	0.16	0.00	-0.06	0.08	0.08	0.05
	(MID)	-0.04	0.17	0.16	0.13	0.00	0.11	0.25	0.27	0.05	0.41	0.13	0.02	-0.02	-0.01	-0.03	-0.04	-0.11	-0.05	-0.05	-0.07
2008-09	(FUN)	-0.05	0.14	0.15	0.05	-0.02	0.09	0.23	0.25	0.21	0.30	0.06	0.03	-0.03	-0.02	-0.03	-0.04	-0.11	-0.05	-0.05	-0.07

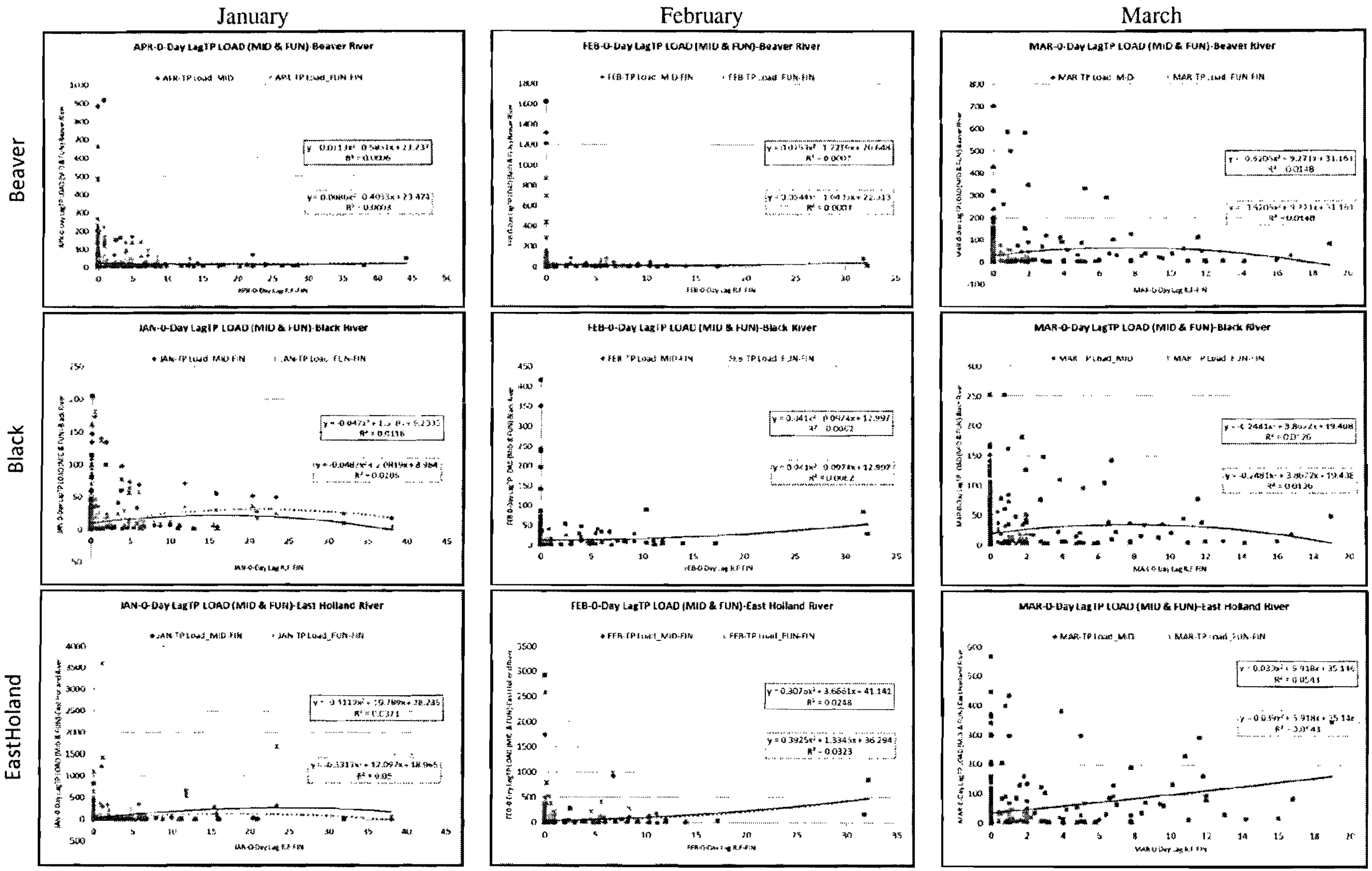
		Coefficients of Correlation between daily Rainfall (mm) with '0, 1, 2, and 3 day lag versus Phosphorus Loading (kg/day) - Yearly																			
		Kettleby Creek				Lovers Creek				Maskinonge Creek				North Schomberg				Pefferlaw			
		coefficient of Corr with Lag				coefficient of Corr with Lag				coefficient of Corr with Lag				coefficient of Corr with Lag				coefficient of Corr with Lag			
		0	1	2	3	0	1	2	3	0	1	2	3	0	1	2	3	0	1	2	3
1993-	(MID	0.00	0.03	-0.01	-0.03	0.02	0.09	0.12	0.10					0.01	0.08	0.12	0.10	-0.03	0.03	0.06	0.06
94	(FU	-0.01	0.00	-0.01	-0.02	0.02	0.08	0.12	0.10					0.01	0.08	0.12	0.10	-0.03	0.03	0.06	0.06
1994-	(MID	0.07	0.22	0.10	0.03	0.00	0.10	0.09	0.07					0.07	0.24	0.20	0.18	0.04	0.16	0.33	0.39
95	(FU	0.06	0.21	0.09	0.02	-0.01	0.07	0.06	0.07					0.07	0.24	0.20	0.18	-0.01	0.13	0.33	0.41
1995-	(MID	-0.02	0.06	-0.02	-0.04	-0.03	0.06	0.06	0.06					-0.02	0.07	0.03	0.03	-0.04	0.07	0.20	0.22
96	(FU	-0.03	0.18	-0.02	0.01	0.02	0.07	0.11	0.11					-0.02	0.07	0.03	0.03	-0.05	0.07	0.19	0.21
1996-	(MID	0.00	0.04	0.03	0.01	0.02	0.13	0.17	0.17					0.03	0.11	0.15	0.15	-0.04	0.10	0.26	0.28
97	(FU	0.00	0.08	0.03	0.00	-0.02	0.09	0.13	0.12					0.03	0.11	0.15	0.15	-0.04	0.10	0.26	0.29
1997-	(MID	0.00	0.09	0.04	0.04	0.12	0.28	0.26	0.23					0.09	0.26	0.22	0.22	0.09	0.24	0.30	0.32
98	(FU	0.01	0.11	0.04	0.05	0.11	0.26	0.25	0.23					0.09	0.26	0.22	0.22	0.09	0.25	0.31	0.33
1998-	(MID	0.14	0.07	-0.01	0.01	-0.03	0.06	0.06	0.04					-0.08	0.22	0.19	0.12	-0.05	0.45	0.40	0.29
99	(FU	0.14	0.06	-0.02	0.01	-0.05	0.15	0.12	0.06					-0.08	0.22	0.19	0.12	-0.03	0.48	0.42	0.31
1999-	(MID	0.01	0.34	0.11	0.05	0.01	0.31	0.27	0.25					-0.01	0.22	0.20	0.18	0.05	0.28	0.40	0.38
00	(FU	0.00	0.14	0.03	0.00	-0.01	0.15	0.14	0.13					-0.01	0.22	0.20	0.18	0.05	0.28	0.40	0.38
2000-	(MID	0.27	0.47	0.18	0.13	0.02	0.16	0.17	0.18					0.07	0.35	0.36	0.38	0.16	0.35	0.42	0.38
01	(FU	0.22	0.46	0.19	0.12	0.08	0.31	0.35	0.36					0.07	0.35	0.36	0.38	0.16	0.35	0.42	0.38
2001-	(MID	0.08	0.33	0.24	0.10	0.11	0.39	0.30	0.08					0.05	0.25	0.25	0.13	0.13	0.47	0.37	0.21
02	(FU	0.07	0.27	0.18	0.04	0.07	0.30	0.24	0.04					0.05	0.25	0.25	0.13	0.12	0.45	0.38	0.23
2002-	(MID	0.03	0.04	0.01	0.01	0.07	0.14	0.08	0.01					0.02	0.09	0.12	0.12	0.00	0.08	0.12	0.12
03	(FU	0.03	0.04	0.01	0.01	0.06	0.14	0.08	0.01					0.02	0.09	0.12	0.12	0.00	0.07	0.12	0.11
2003-	(MID	0.06	0.16	0.08	0.00	0.19	*0.50*	0.24	0.05	0.05	0.25	0.25	0.20	0.01	0.21	0.19	0.14	0.00	0.12	0.22	0.21
04	(FU	0.05	0.15	0.07	-0.01	0.18	0.48	0.23	0.05	-0.02	0.29	0.16	0.11	0.01	0.21	0.19	0.14	-0.01	0.12	0.23	0.23
2004-	(MID	0.03	0.06	0.07	0.06	-0.01	0.16	0.07	-0.01	-0.03	0.03	0.03	0.01	-0.01	0.07	0.06	0.04	0.04	0.09	0.11	0.11
05	(FU	0.00	0.11	0.17	0.02	0.01	0.21	0.11	0.01	-0.02	0.08	0.08	0.03	-0.01	0.07	0.06	0.04	0.03	0.09	0.11	0.11
2005-	(MID	0.03	0.18	0.12	0.04	0.14	0.37	0.27	0.14	0.09	0.31	0.32	0.25	0.05	0.25	0.20	0.13	0.09	0.23	0.34	0.33
06	(FU	0.00	0.12	0.07	-0.01	0.10	0.33	0.18	0.12	0.04	0.17	0.22	0.14	0.05	0.25	0.20	0.13	0.08	0.23	0.35	0.32
2006-	(MID	0.00	0.06	0.00	-0.02	0.12	0.37	0.13	0.04	0.00	0.07	0.07	0.05	-0.01	0.06	0.05	0.02	-0.01	0.08	0.12	0.12
07	(FU	0.02	0.07	-0.01	-0.03	0.12	0.43	0.07	0.03	0.02	0.17	0.08	0.07	-0.01	0.06	0.05	0.02	-0.03	0.08	0.17	0.18
2007-	(MID	0.02	0.09	0.02	-0.03	0.00	0.12	0.23	0.07	-0.03	0.07	0.08	0.05	-0.05	0.08	0.12	0.10	-0.01	0.02	0.09	0.09
08	(FU	0.01	0.09	0.02	-0.03	0.00	0.16	0.11	0.10	-0.05	0.03	0.05	0.04	-0.05	0.08	0.12	0.10	-0.01	0.03	0.10	0.11
2008-	(MID	0.16	0.25	0.04	-0.01	0.09	0.28	0.22	0.21	0.06	0.31	0.28	0.21	-0.08	-0.04	-0.04	-0.06	0.00	0.15	0.28	0.27
09	(FU	0.14	0.28	0.06	0.01	0.08	0.29	0.21	0.21	0.03	0.32	0.27	0.17	-0.08	-0.04	-0.04	-0.06	-0.04	0.00	0.09	0.16

Appendix-12: Continued

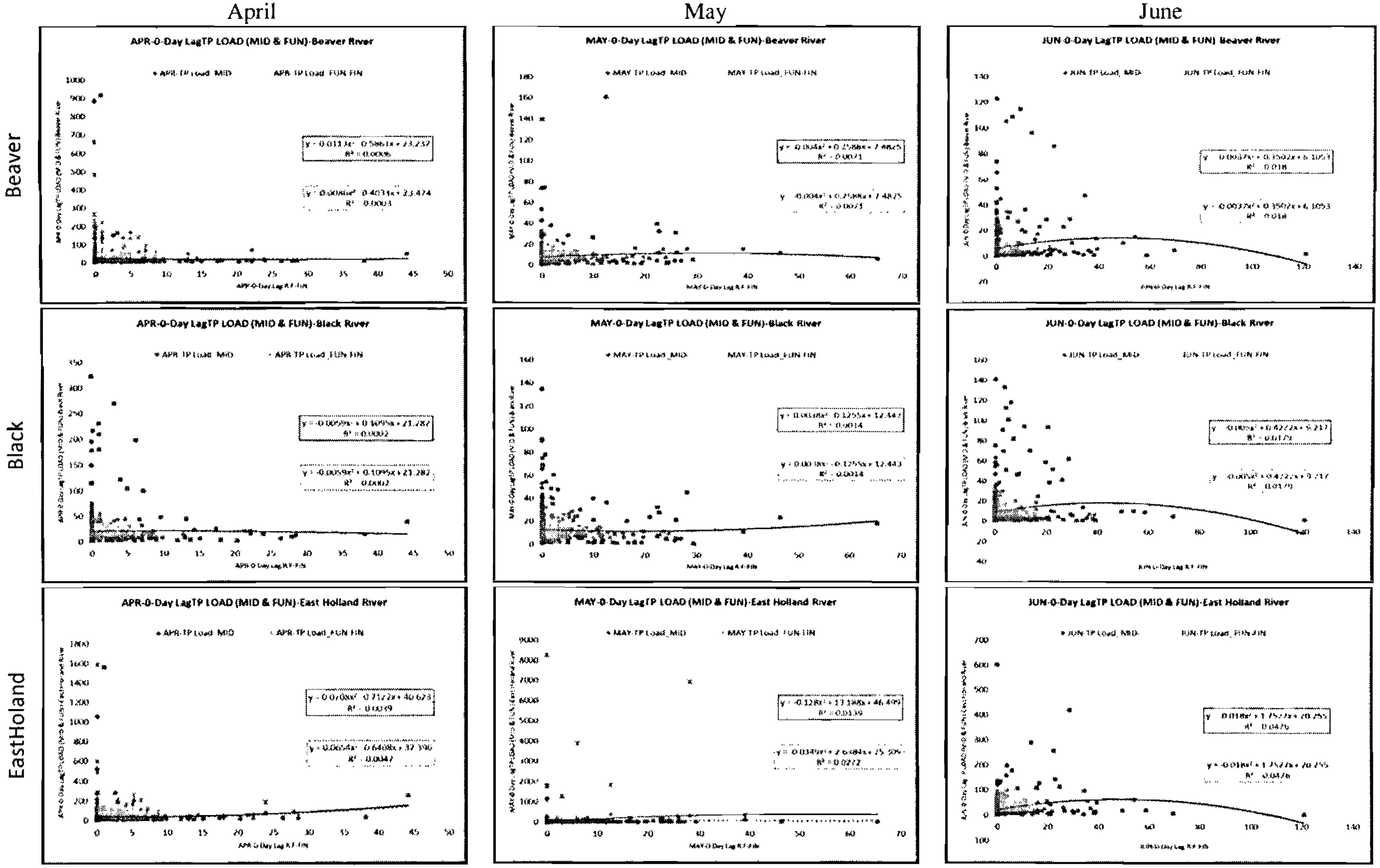
Coefficients of Correlation between daily Rainfall (mm) with '0, 1, 2, and 3 day lag versus Phosphorus Loading (kg/day) - Yearly

		Talbot				West Holland River				Whites Creek			
		coefficient of Corr with Lag				coefficient of Corr with Lag				coefficient of Corr with Lag			
		0	1	2	3	0	1	2	3	0	1	2	3
	(MID)	-0.01	0.08	0.09	0.08								
1993-94	(FUN)	0.01	0.11	0.11	0.11								
	(MID)	-0.01	0.14	0.13	0.16					0.09	0.22	0.27	0.26
1994-95	(FUN)	0.01	0.19	0.23	0.22					0.02	0.20	0.30	0.25
	(MID)	0.05	0.23	0.24	0.26					0.03	0.17	0.15	0.14
1995-96	(FUN)	0.02	0.24	0.20	0.23					0.01	0.18	0.14	0.13
	(MID)	-0.01	0.16	0.17	0.15					0.00	0.16	0.18	0.16
1996-97	(FUN)	0.00	0.18	0.24	0.24					-0.02	0.23	0.17	0.14
	(MID)	0.12	0.27	0.27	0.25					0.08	0.33	0.28	0.29
1997-98	(FUN)	0.11	0.25	0.24	0.22					0.05	0.28	0.20	0.23
	(MID)	-0.06	0.25	0.29	0.21					-0.02	0.40	0.39	0.29
1998-99	(FUN)	-0.06	0.24	0.29	0.20					-0.03	***0.59***	0.48	0.24
	(MID)	0.00	0.21	0.21	0.19					-0.01	0.26	0.23	0.21
1999-00	(FUN)	0.00	0.18	0.19	0.18					0.00	0.28	0.26	0.22
	(MID)	-0.02	0.21	0.18	0.17					0.21	0.43	0.43	0.38
2000-01	(FUN)	-0.01	0.21	0.18	0.17					0.24	0.43	0.36	0.31
	(MID)	0.00	0.20	0.17	0.08					0.11	0.40	0.31	0.19
2001-02	(FUN)	0.03	0.22	0.19	0.10					0.13	0.41	0.32	0.20
	(MID)	0.06	0.18	0.23	0.23	0.07	0.10	0.12	0.13	0.00	0.03	0.03	0.03
2002-03	(FUN)	0.06	0.17	0.23	0.23	0.05	0.07	0.12	0.16	0.04	0.22	0.35	0.23
	(MID)	0.06	0.30	0.32	0.24	0.02	0.30	0.26	0.19	0.06	0.22	0.24	0.17
2003-04	(FUN)	0.04	0.26	0.28	0.23	0.00	0.35	0.33	0.19	0.05	0.24	0.26	0.18
	(MID)	0.03	0.13	0.16	0.11	0.03	0.17	0.15	0.10	-0.01	0.04	0.04	0.02
2004-05	(FUN)	-0.01	0.13	0.25	0.12	0.03	0.17	0.14	0.10	-0.01	0.05	0.05	0.02
	(MID)	0.07	0.24	0.19	0.12	0.02	0.17	0.14	0.09	0.14	0.32	0.38	0.28
2005-06	(FUN)	0.01	0.17	0.13	0.07	0.04	0.17	0.13	0.10	0.05	0.27	0.37	0.16
	(MID)	0.05	0.14	0.04	0.03	0.13	0.36	0.27	0.23	-0.01	0.06	0.01	-0.01
2006-07	(FUN)	0.04	0.14	0.04	0.03	0.08	0.28	0.20	0.17	0.03	0.19	0.12	0.05
	(MID)	0.02	0.12	0.12	0.04	-0.07	0.05	0.09	0.09	-0.04	0.04	0.04	-0.01
2007-08	(FUN)	0.01	0.12	0.13	0.03	-0.06	0.07	0.12	0.12	-0.03	0.06	0.05	0.00
	(MID)	-0.08	-0.07	-0.07	-0.07	-0.01	0.11	0.11	0.10	0.01	0.24	0.13	0.08
2008-09	(FUN)	-0.08	-0.07	-0.07	-0.07	0.00	0.12	0.12	0.11	-0.03	0.11	0.14	0.07

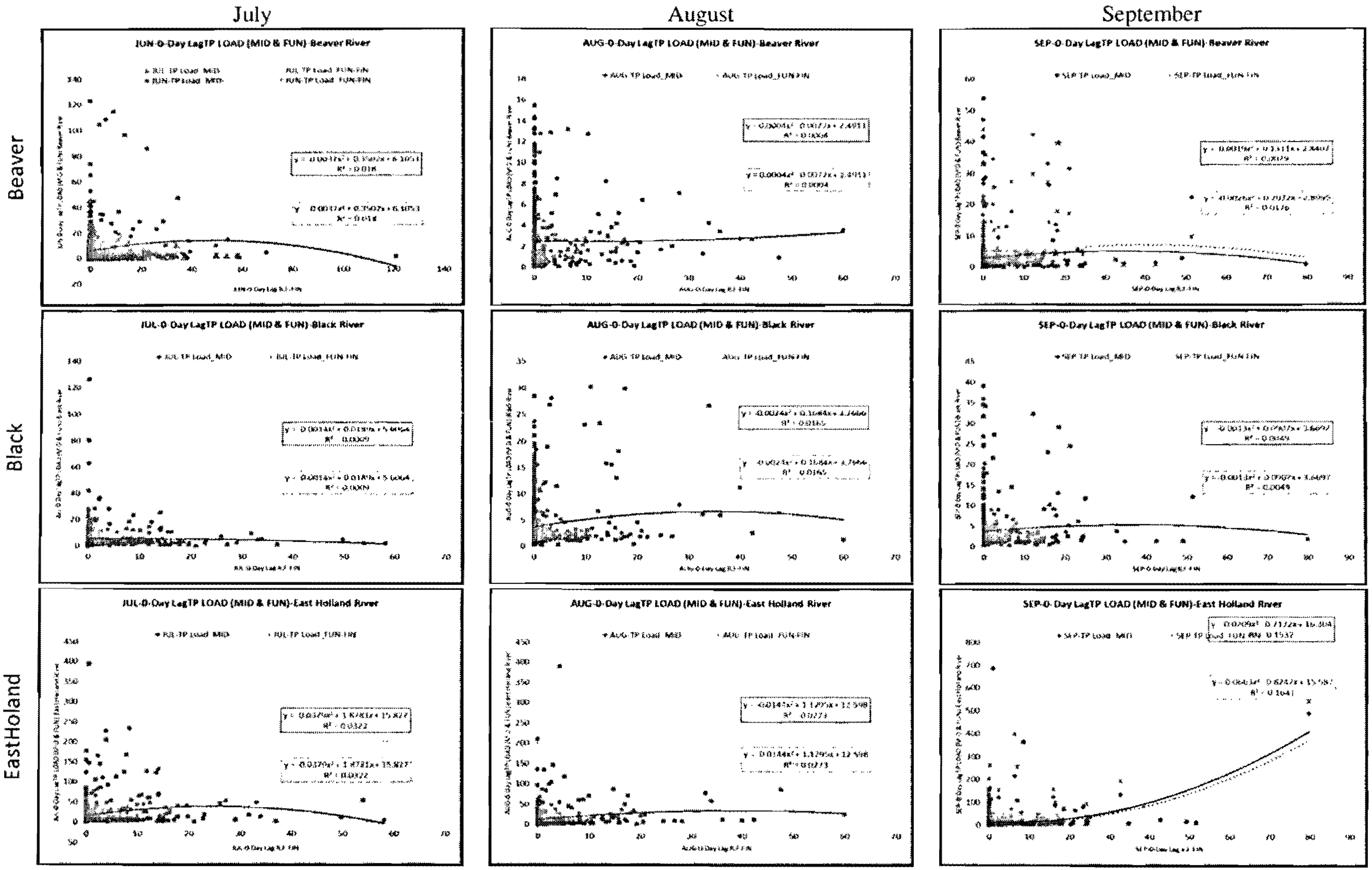
Appendix-13: Correlation charts between daily rainfall and daily TP load in monthly stratification



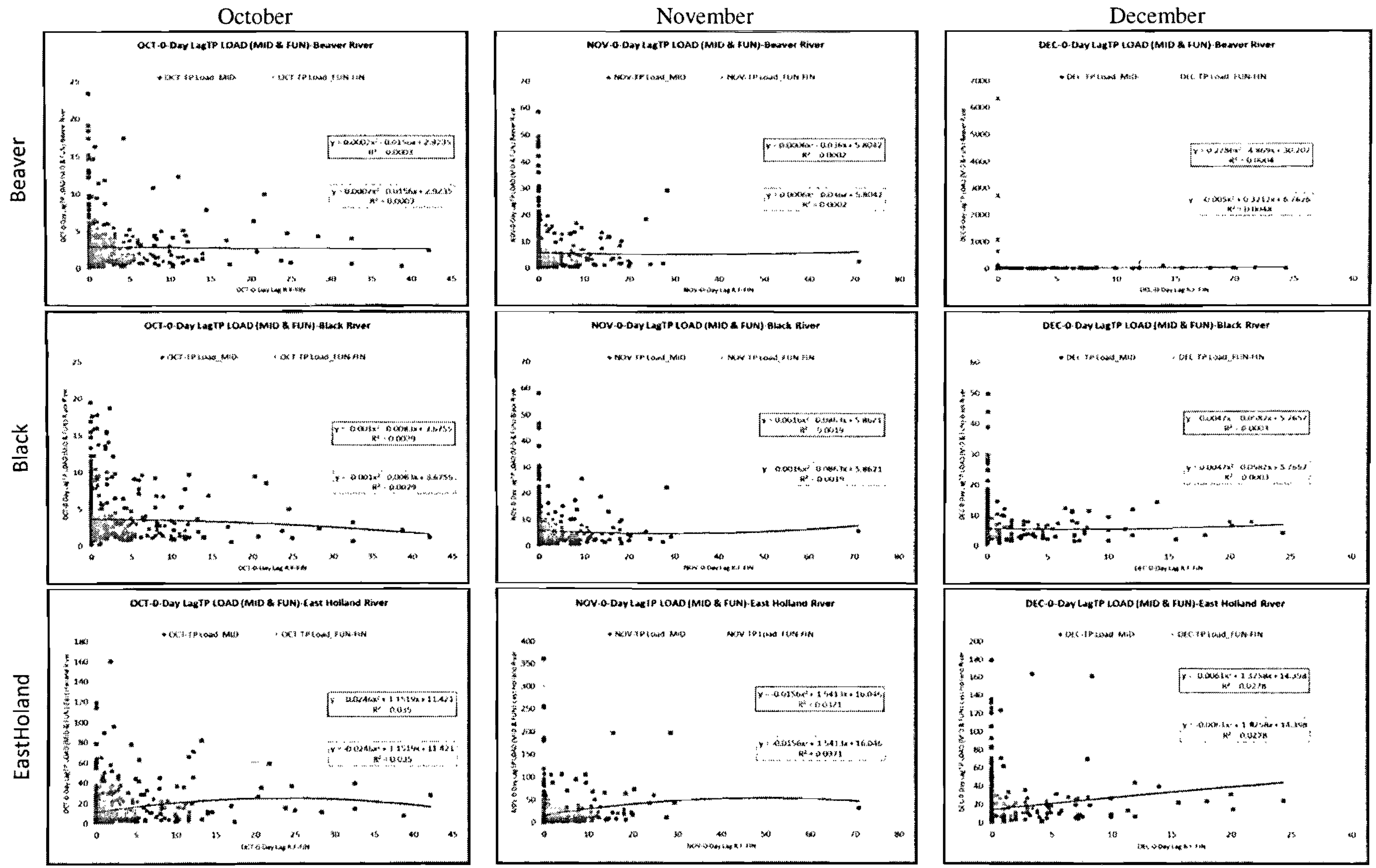
Appendix-13: Continued



Appendix-13: Continued



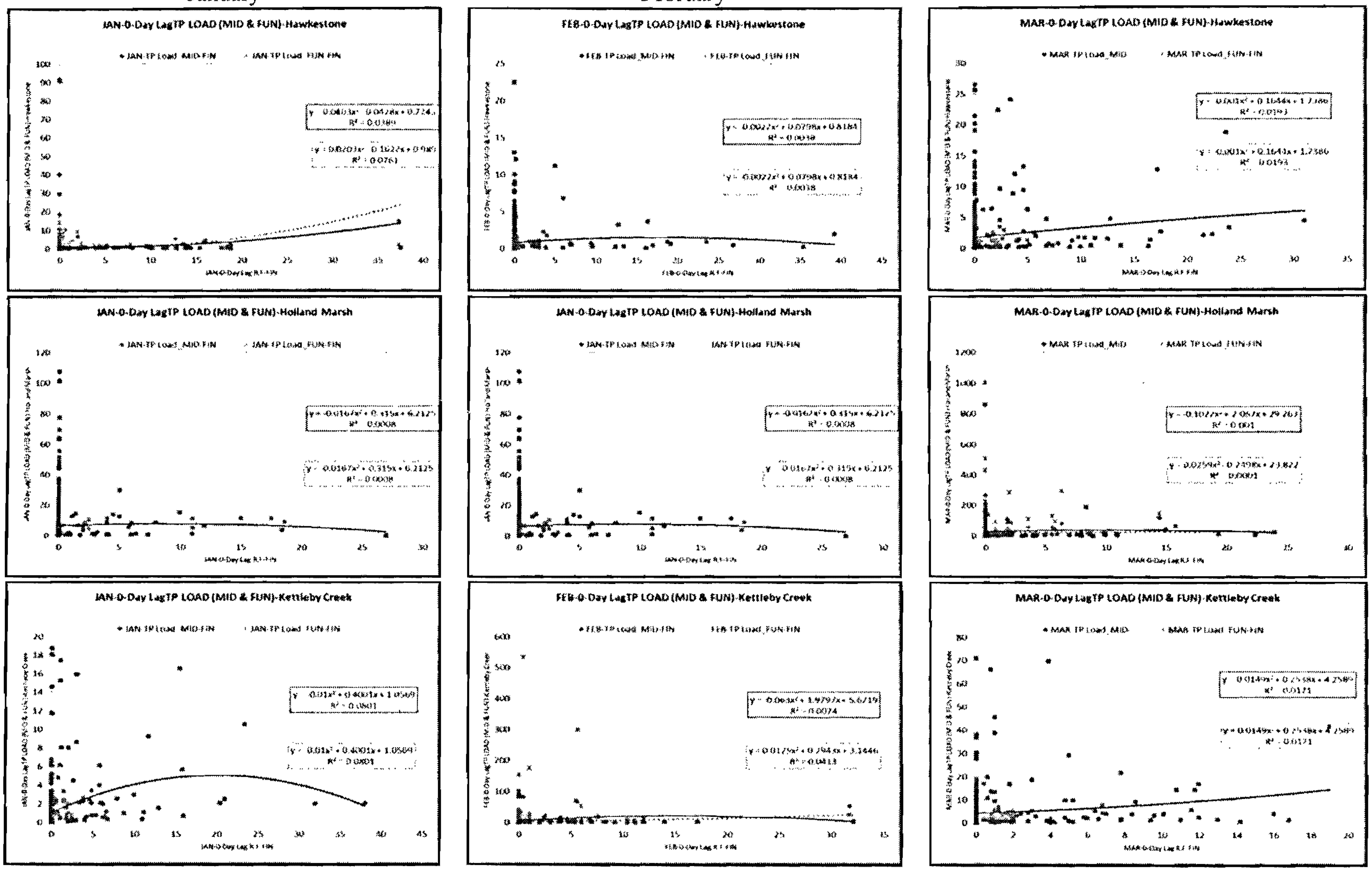
Appendix-13: Continued



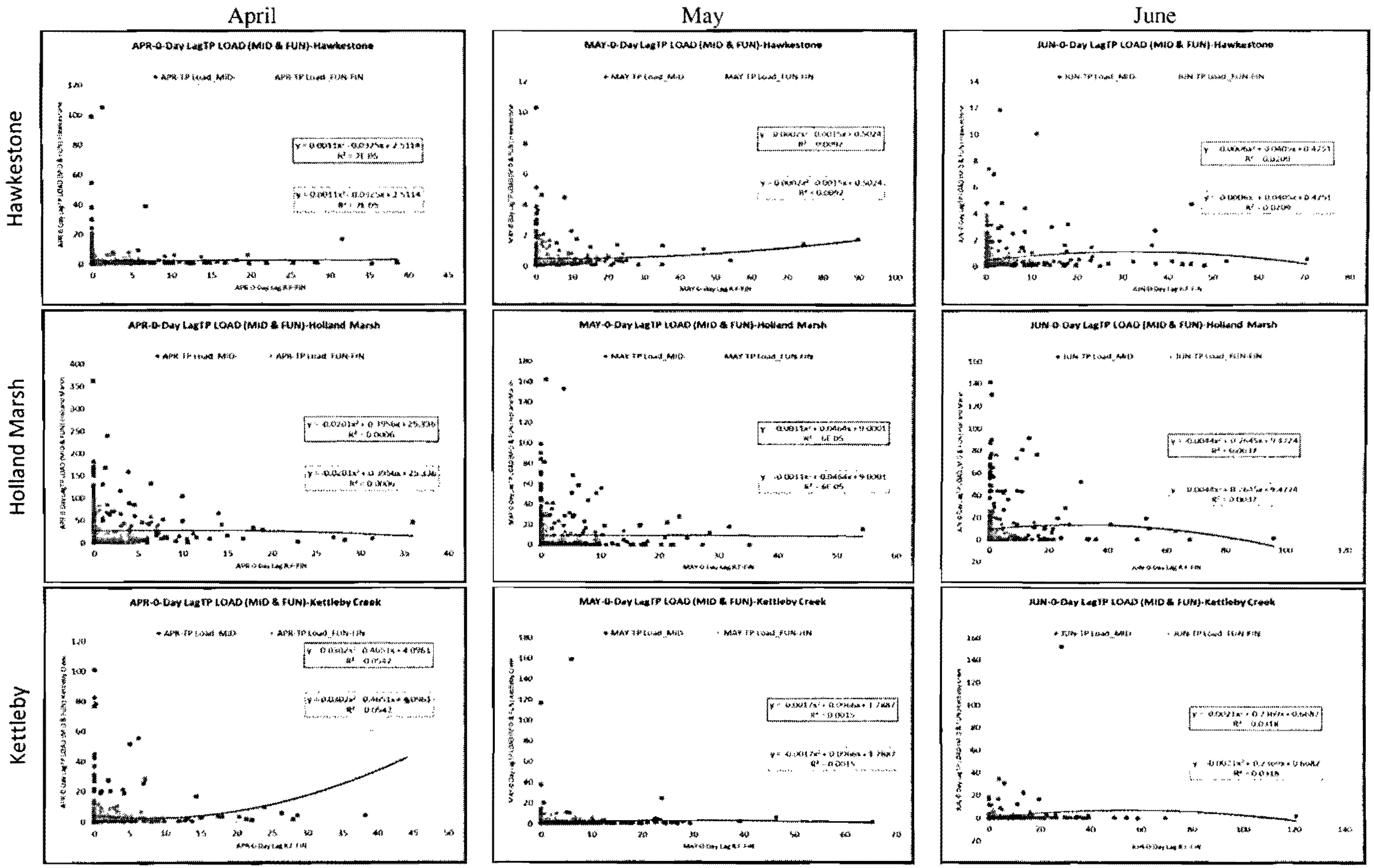
Appendix-13: Continued

January | February | March

Hawkestone | Holland Marsh | Kettleby



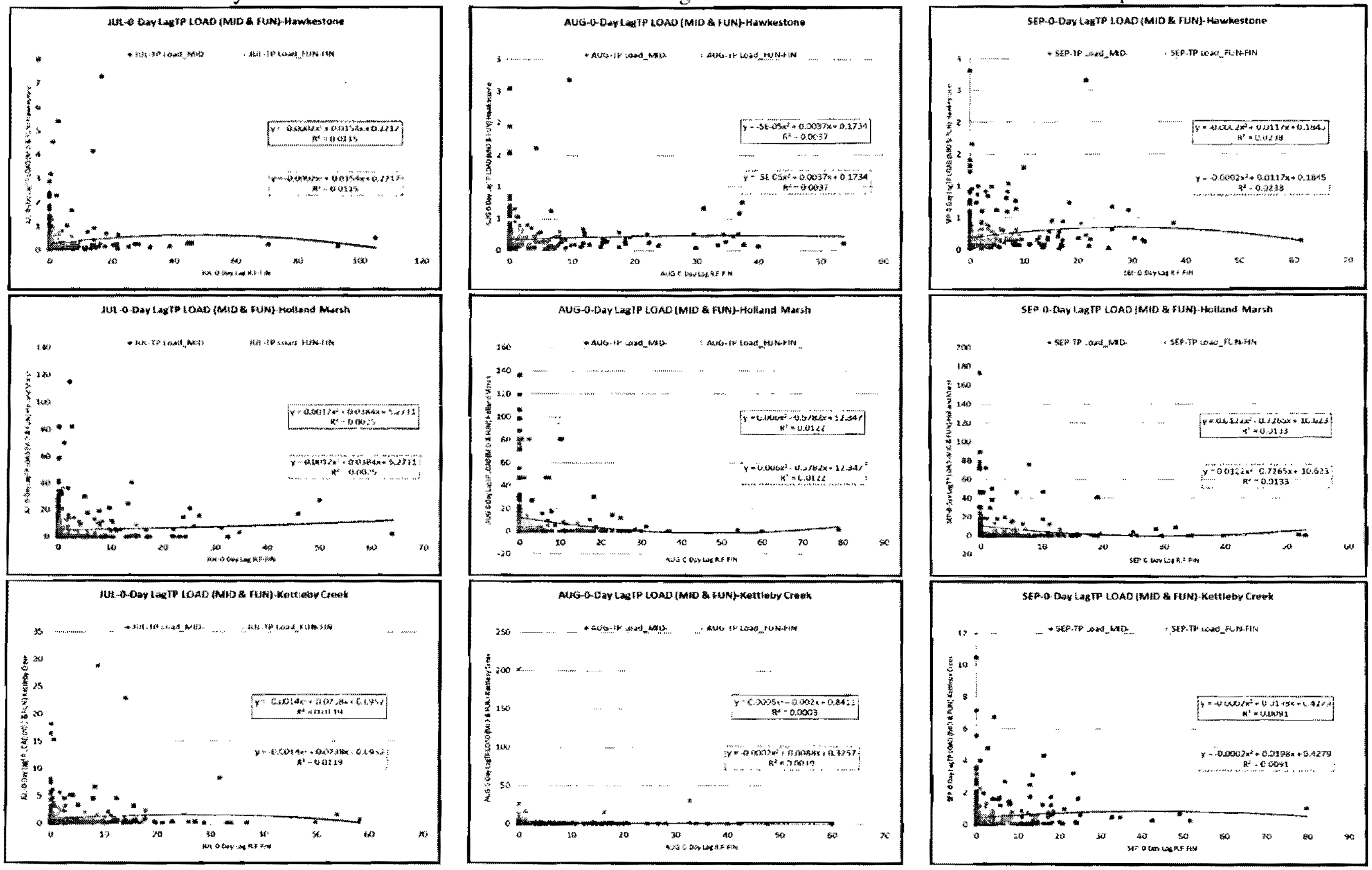
Appendix-13: Continued



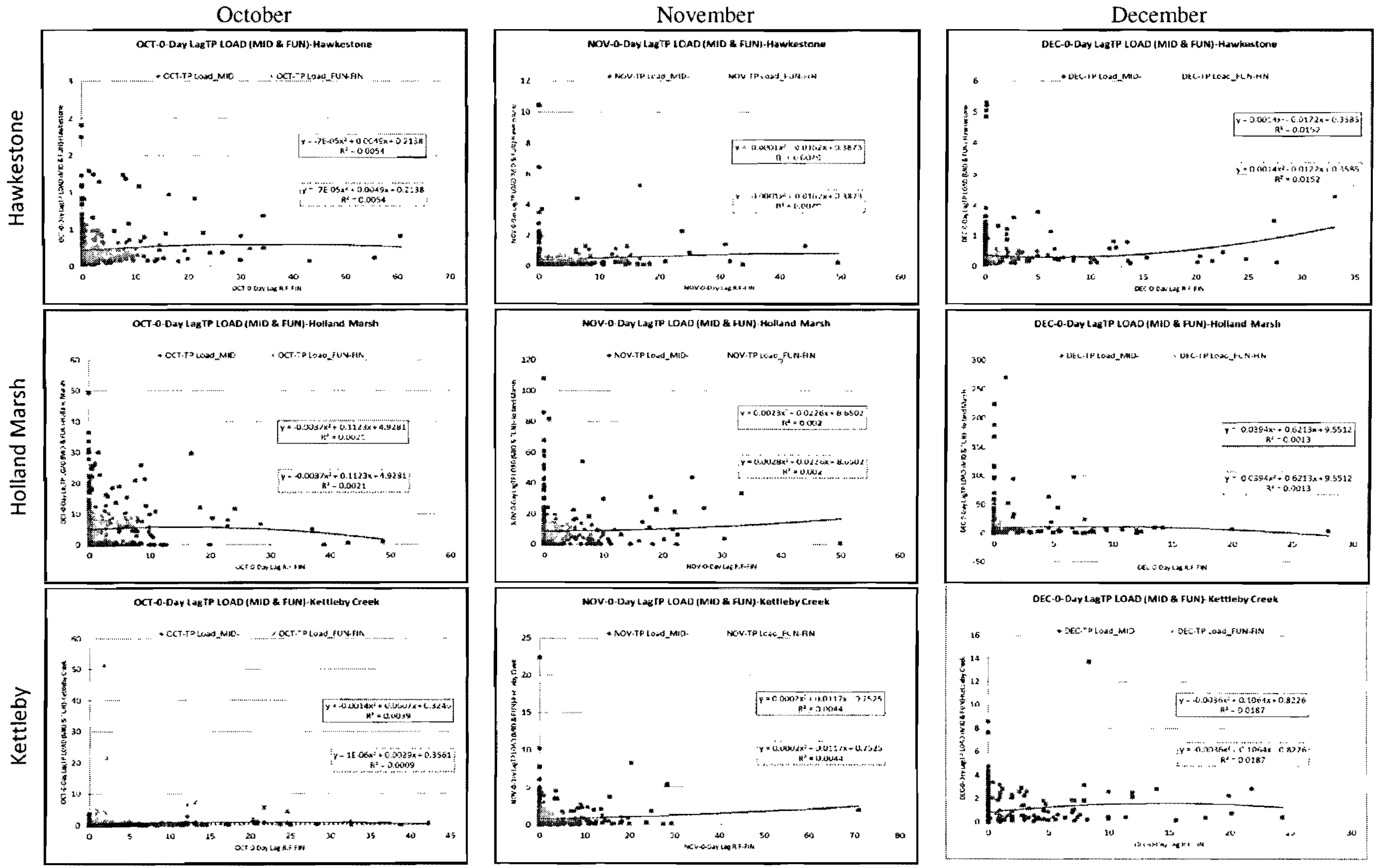
Appendix-13: Continued

July | August | September

Hawkestone | Holland Marsh | Kettleby



Appendix-13: Continued



Appendices

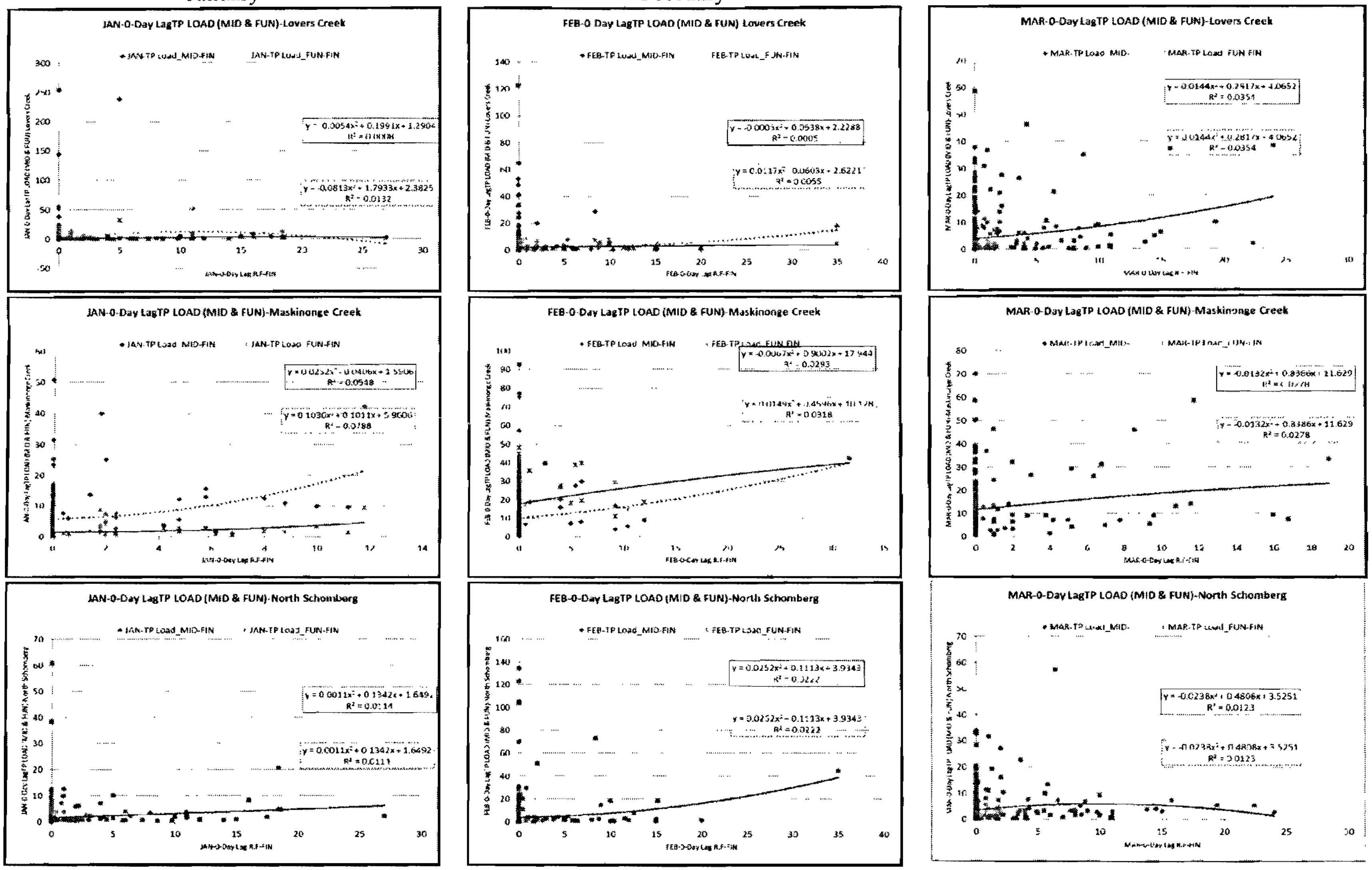
Appendix-13: Continued

January February March

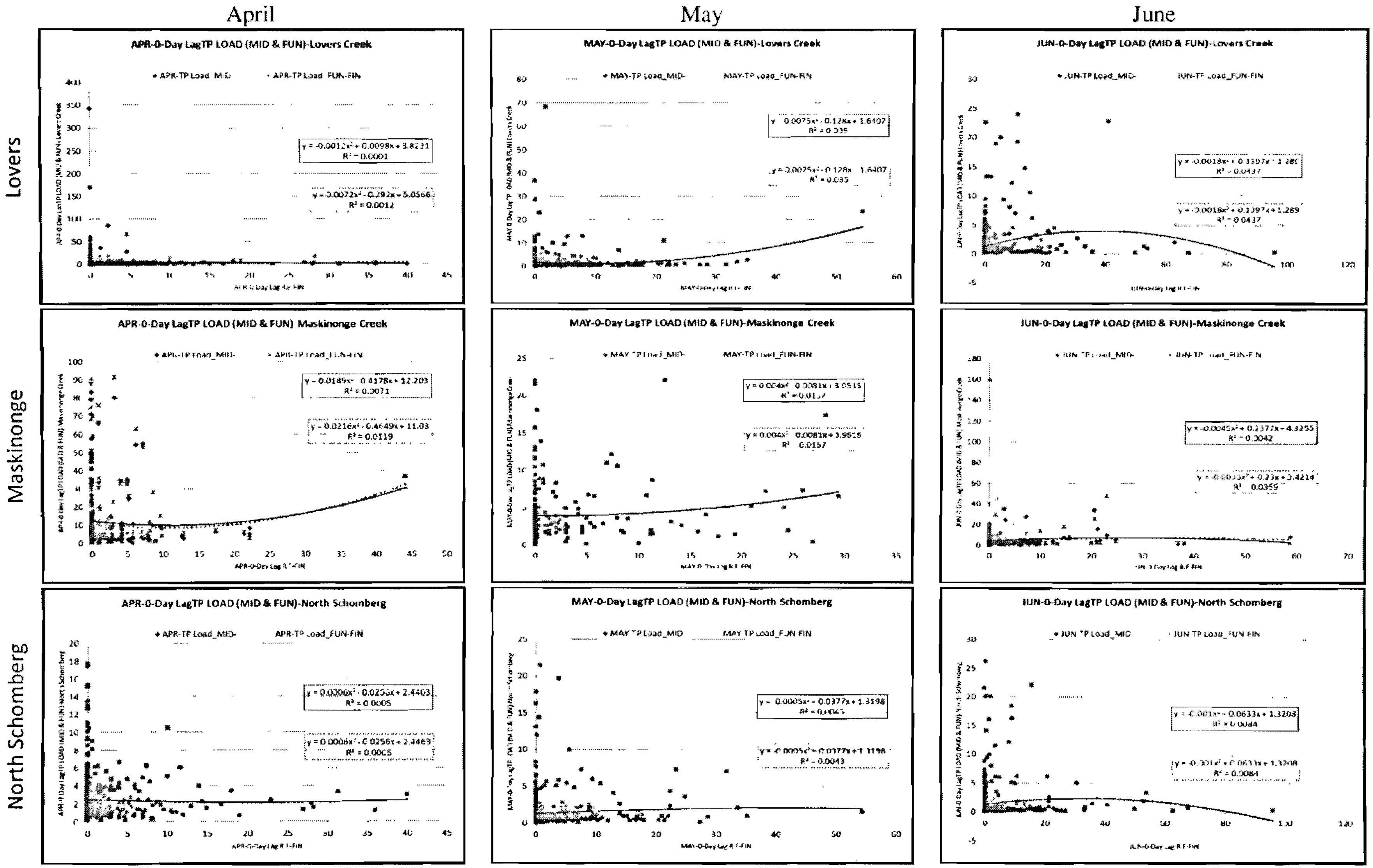
Lovers

Maskinonge

North Schomberg

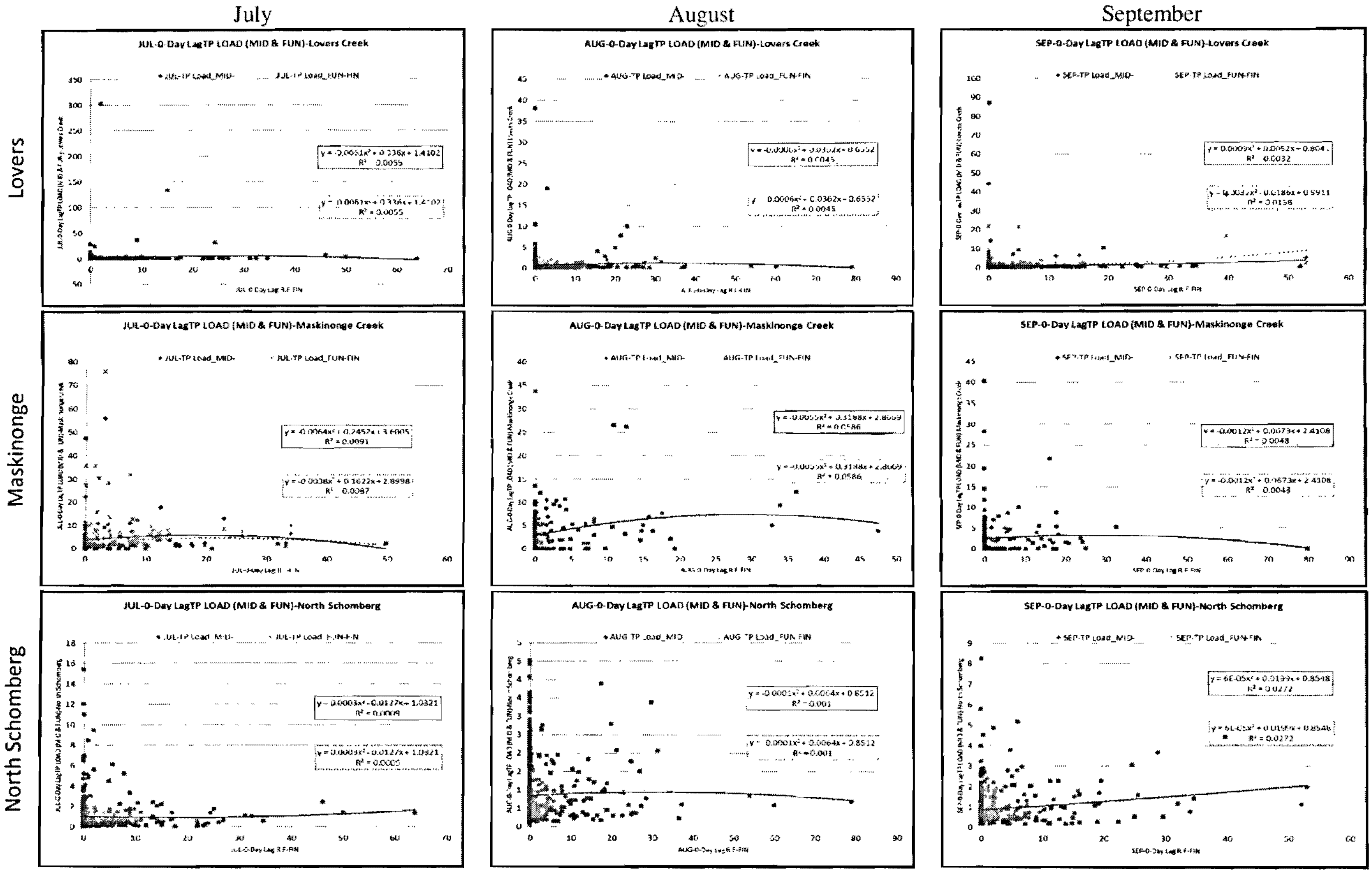


Appendix-13: Continued



Appendices

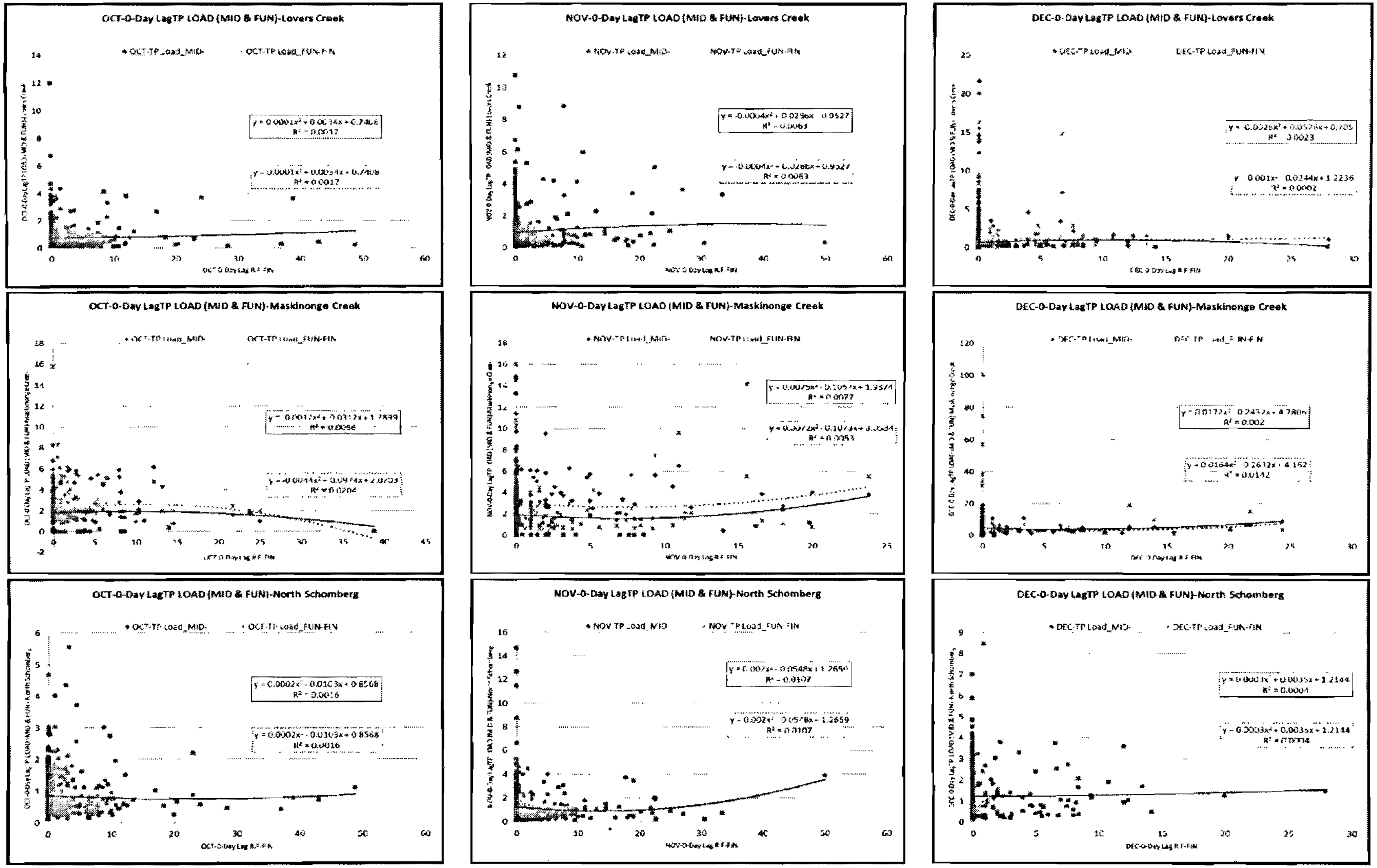
Appendix-13: Continued



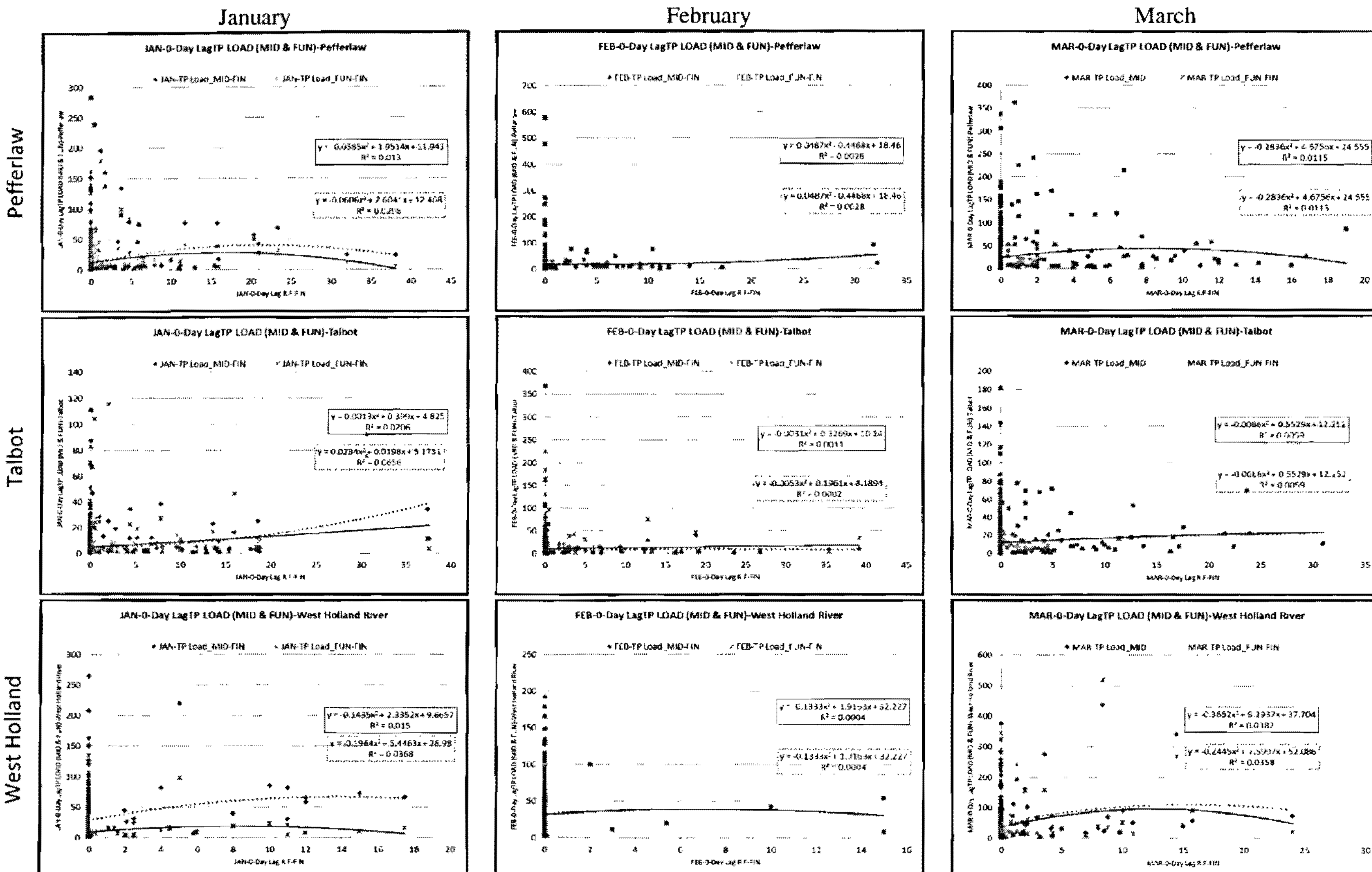
Appendix-13: Continued

October | November | December

Lovers | Maskinonge | North Schomberg



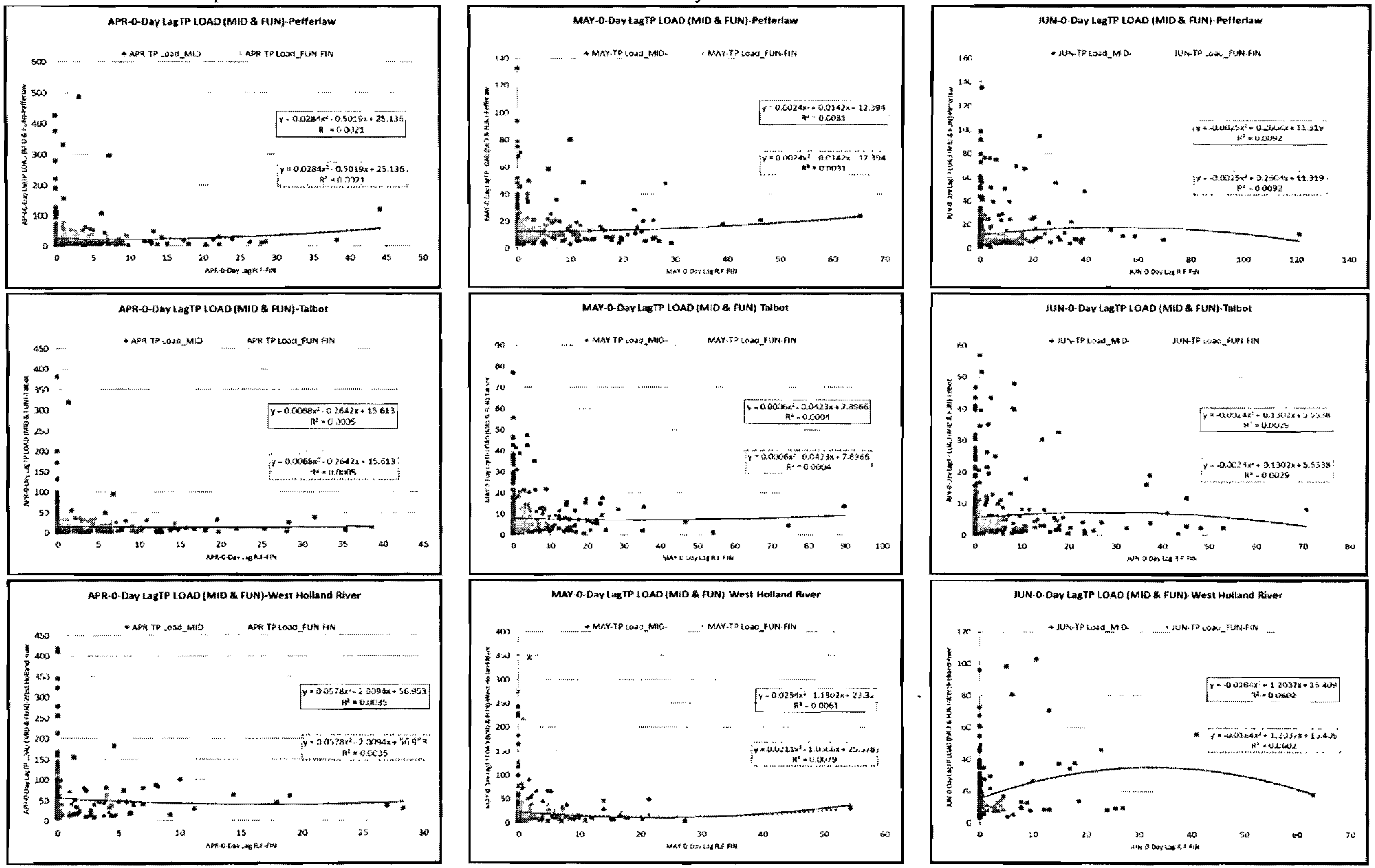
Appendix-13: Continued



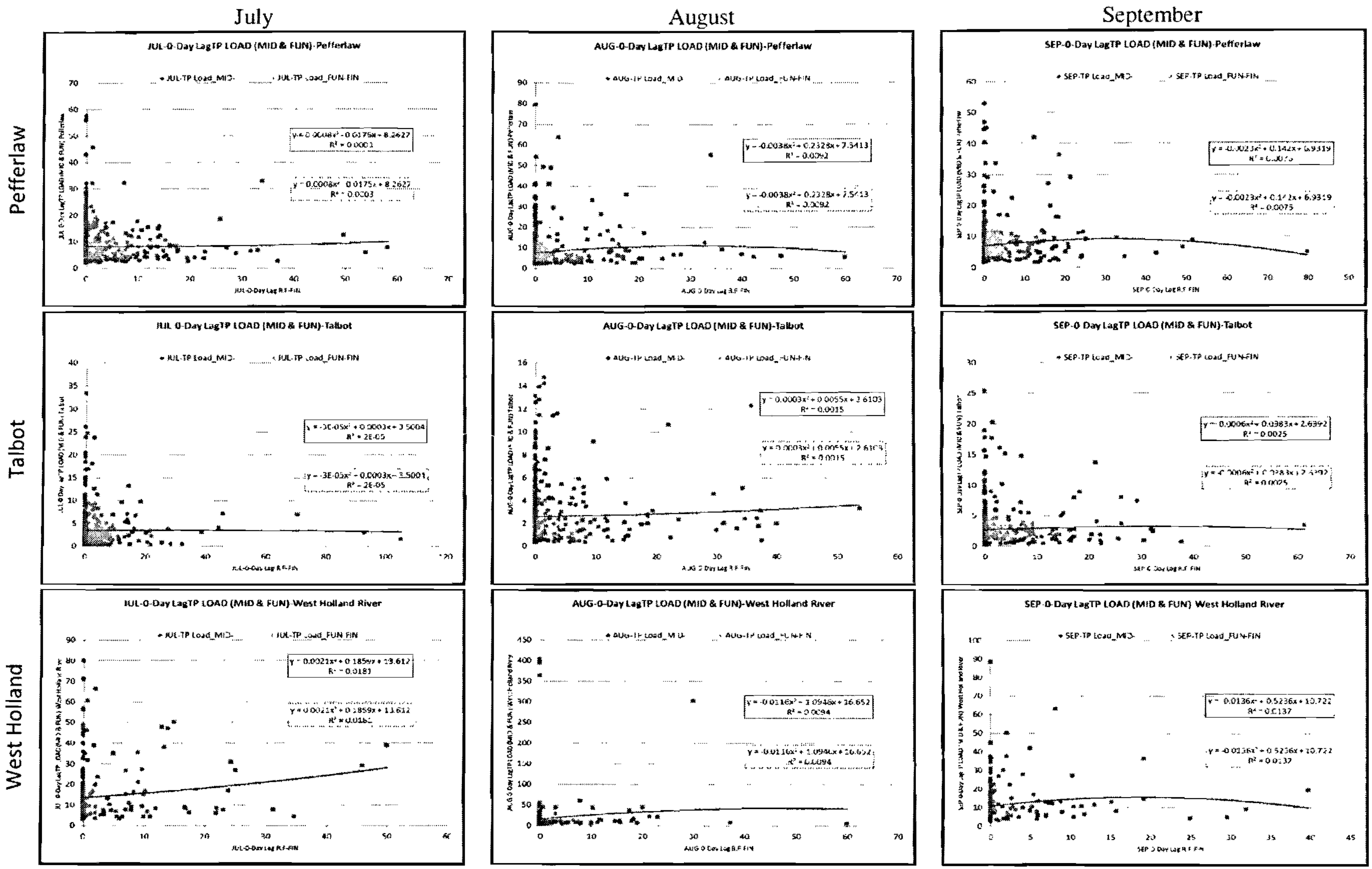
Appendix-13: Continued

April | May | June

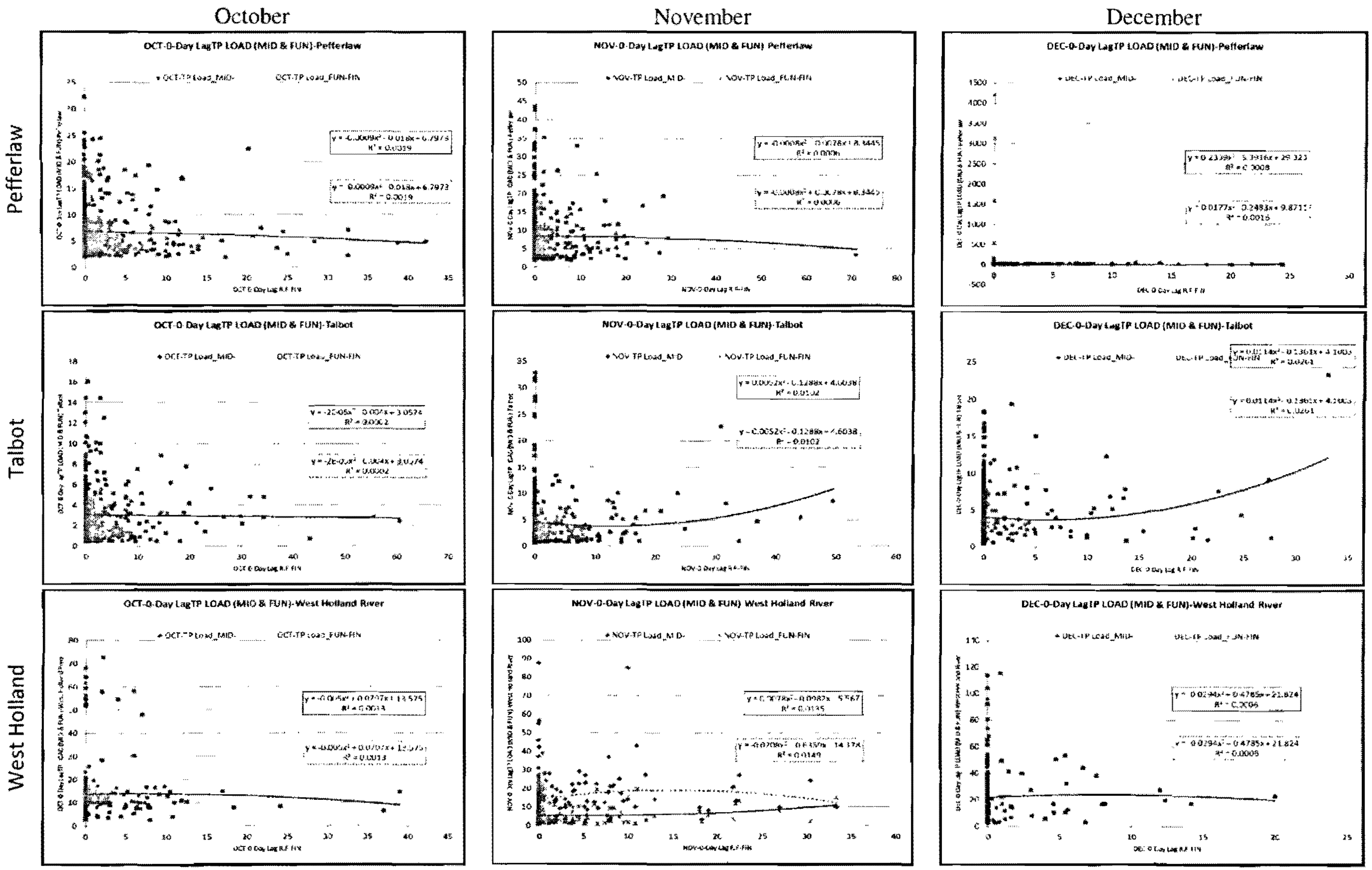
Pefferlaw | Talbot | West Holland



Appendix-13: Continued



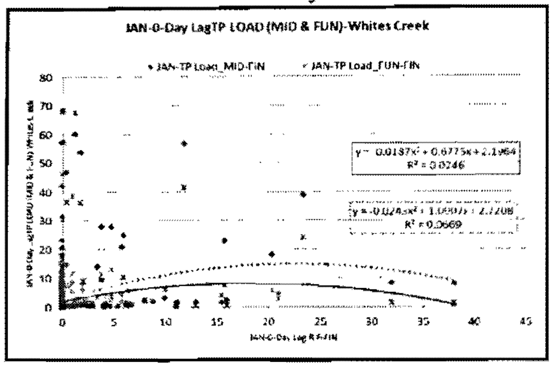
Appendix-13: Continued



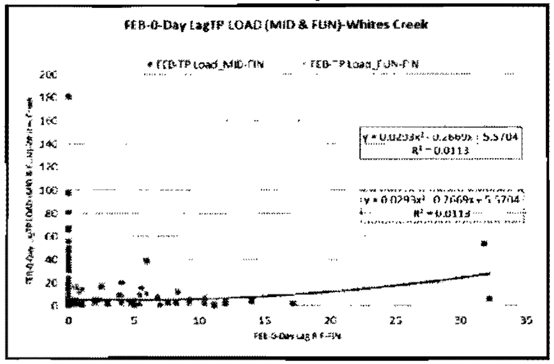
Appendix-13: Continued

Whites

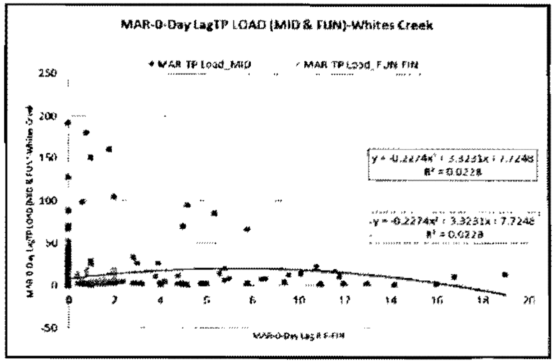
January



February

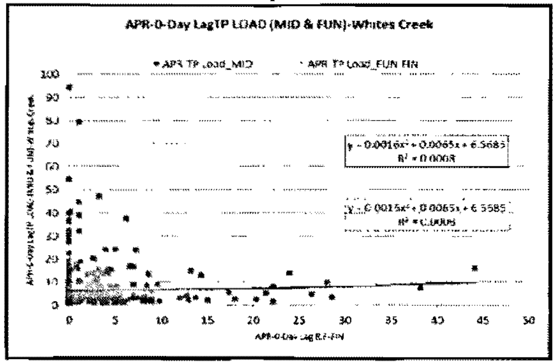


March

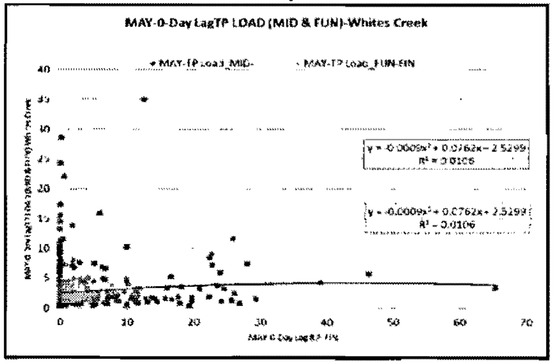


Whites

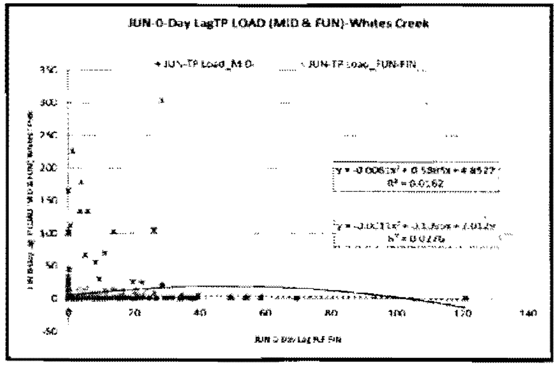
April



May



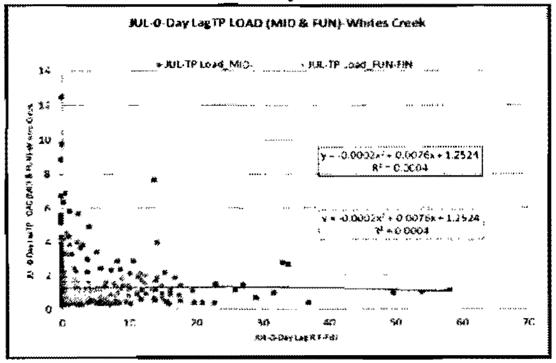
June



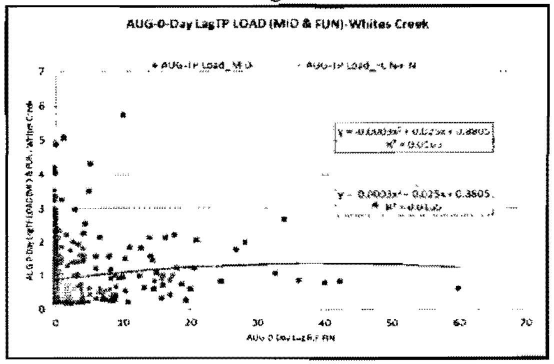
Appendix-13: Continued

Whites

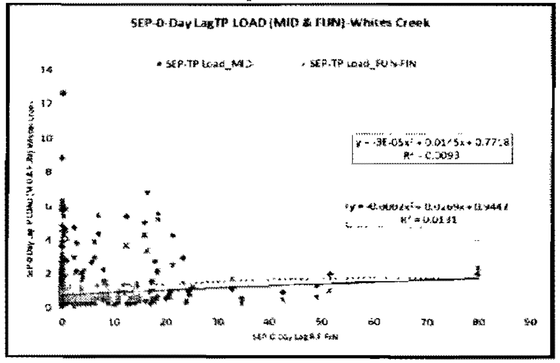
July



August

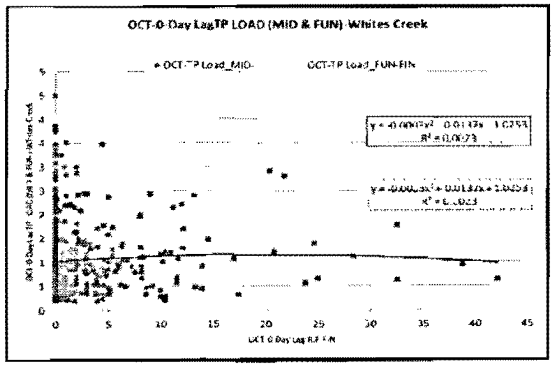


September

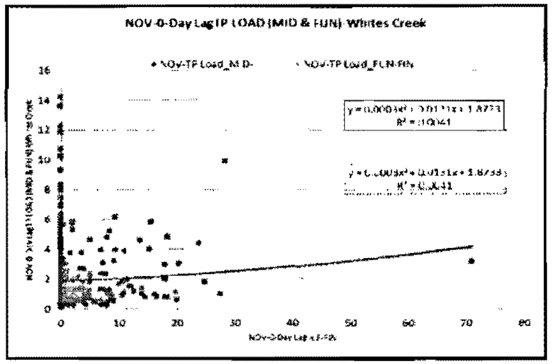


Whites

October



November



December