SWMM PROJECT-2 REPORT

ENGG*6610 Urban Stormwater Management

Submitted to

Dr. Narayan Shrestha

Submitted by

Pardeep Kaur
1076663
Gurkaranbir Singh
1074664

Abstract

This project report is based on the simulation results from the SWMM(Stormwater management model). SWMM is an Urban Stormwater management tool, it can be used for both runoff quantity and quality purpose. This project is focused on the water quality, a sewer system is used to assess the impact on the receiving water quality. A river is considered a point of analysis where the quality of the water needs to be analyzed. Both Dry weather flow(DWF) and combined sewer overflows(CSO) are considered to analyze the impact of the Wastewater treatment plant(WWTP) on the river water. Total Suspended Solids (TSS) is assumed as a pollutant entering the river water. During dry weather flow, 7 days simulation period is used and then loads are reported. TSS loads sent to the river during dry weather flow are reduced by adding storage units with treatment facilities. After adding treatment facilities loads are reduced by 31% during dry weather flow. 2-year rainfall data is used for long-term simulation and 3 month period is used for this simulation by considering less time required to run the simulation for 3-months as compared to 2 years. To reduce the loads for combined sewer flow 2 storage units are added and loads reduced by 41% at the end of the outlets. It is observed that rainfall events have a very high impact on the TSS loads sent to the river as compared to the dry weather flow.

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Introduction

Stormwater Management Model (SWMM) is a tool to simulate rainfall-runoff quality and quantity from Urban areas. SWMM was first developed in 1971 and since then it has been the widely used urban stormwater management tool. It can be used for a single- event and for the long-term simulation period. SWMM works on the distribution of the sub-catchments that receive rainfall and pollutant loads(Rossman, 2015). It has many applications in planning., analysis and designs related to stormwater runoff, sanitary sewers, combined sewers and other urban drainage systems.

This project includes the combined sewer system of a town which has a WWTP wastewater treatment plant having treatment facilities at storage unit 381 and settling basin 412. The treatment facility has the ability to reduce the TSS loads by 91%. After the treatment of the wastewater, water is discharged to the river at outlet 414.

The Combined Sewer System of the Town

Both dry weather flow and combined sewer overflows are considered to analyze the behavior of WWTP with respect to the loads sent to the river. For dry weather flow, 7 days period is selected for simulation and during rainfall periods 3-month simulation period is selected. 2-year rainfall data is used for long-term simulation.

Total suspended solids (TSS) are assumed to be the cause of concern for river pollutants, during dry weather flow and combined sewer flow.

Table 1: Average concentrations (in mg/l) of some pollutants at the inlet and at the outlet of the WWTP during dry weather flow conditions.

TSS			BOD			NH_4		
In	Out	% removal	In	Out	% removal	In	Out	% removal
158	15	91	104	9	91	19	11	42

Project Objectives

The purpose of this project is to analyze the impact of dry weather flow and combined sewer overflow on the pollutant loads sent to the river. After analysis, it is also required to reduce the pollutant loads sent to the river by 30%. This can be done by changing treatment facilities in the Wastewater Treatment Plant (WWTP) during dry weather flow and by adding more storage units and changing pump controls during combined sewer flow.

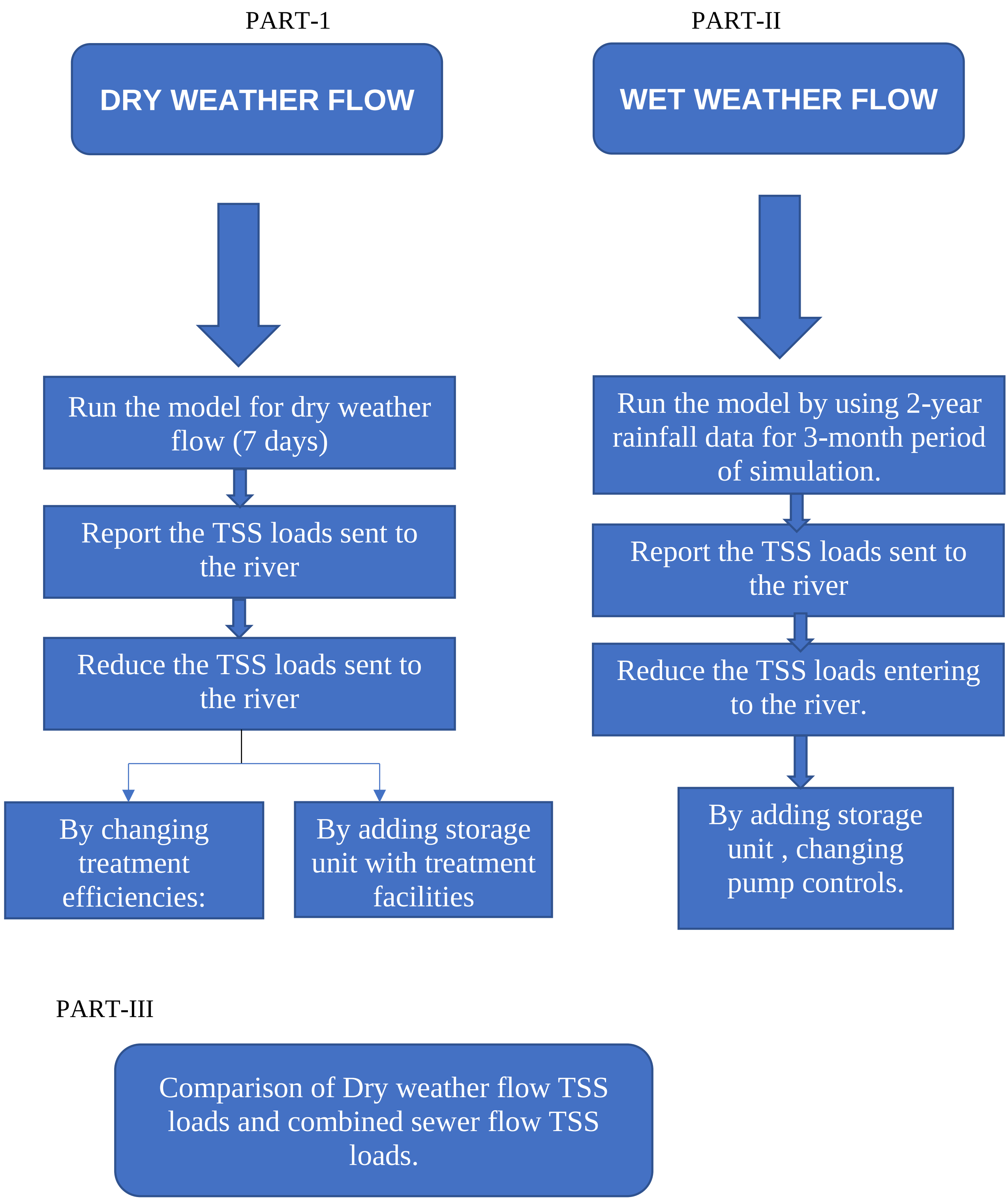
This project includes various tasks for dry weather flow and combined sewer outflow. Three main objectives of this project are:

1. Report and analyze the TSS loads sent to the river during dry weather flow conditions.
2. Analyze the impact of Combined sewer flow with respect to the dry weather flow.
3. Reduce the loads by making changes to the system in such a way that it results in a 30% reduction of TSS loads to the river during both dry weather flow and combined sewer flow.

Other specific tasks include:

- Represent the TSS loading before and after the WWTP for dry weather flow conditions.
- Daily and average TSS loading before and after the WWTP for dry weather flow conditions.
- Increasing the size of WWTP during dry weather flow conditions led to 30% decreases in TSS delivery.
- Analyze the load using time series plot (long term simulation)
- Focus on the outfall nodes.
- Check if storage units and pumps are used optimally.
- Reduce TSS loading by 30% for combined sewer flow.

Methodology



Results

PART-I
Dry Weather flow simulation

Time series named zero for no rainfall is used for dry weather flow simulation. Simulation period 7 days is used by considering 5 antecedent days. Routing time step 5 seconds and reporting step 10 minutes is selected for this dry weather flow simulation.

Simulation results:
Continuity Error
Surface runoff: 0.00%
Flow Routing : -0.71%
Quality Routing : -0.54%

Highest Continuity Errors
Node 117 (44.46%)
Node 121 (6.51%)
Node 138 (5.62%)
Node 137 (4.57%)
Node 120 (3.81%)

To reduce continuity error pump controls are adjusted for node 117 as it had the highest continuity error. Pump controls adjusted to 20.28 from 21.28. The following are the results after the adjustments made and continuity errors are reduced.

Pump Controls
RULE 117.1_ON
IF NODE 117 HEAD >= 21.530000
THEN PUMP 117.1 STATUS = ON

RULE 117.1_OFF
IF NODE 117 HEAD <= 20.280000
THEN PUMP 117.1 STATUS = OFF

Highest Continuity Errors

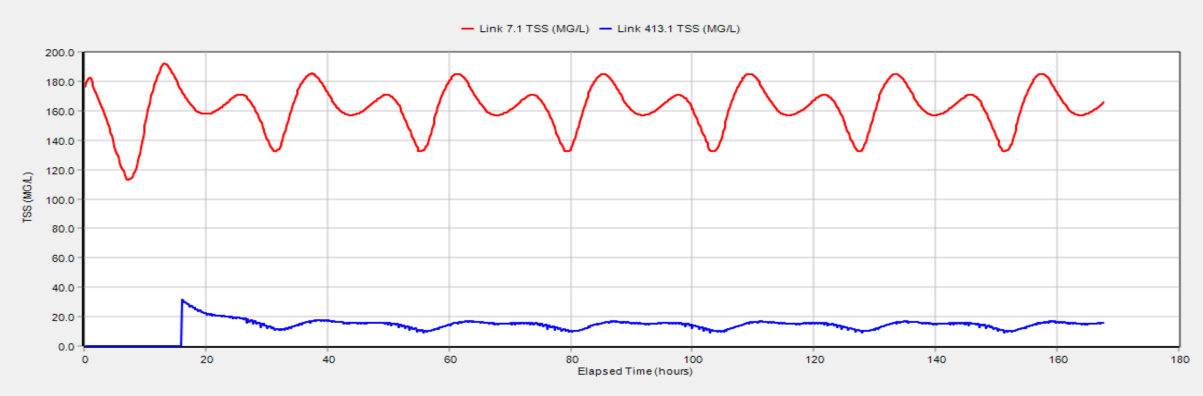
Node 120 (8.32%)
Node 121 (6.51%)
Node 138 (5.62%)
Node 137 (4.57%)
Node 176 (3.47%)

Task-1

Task-1 involves, showing the TSS loads before and after the WWTP for dry weather flow. The following are the results after running a simulation for dry weather flow and showing the TSS loads sent to the rive rat node 414.

Total suspended solids (TSS) loading before and after the Wastewater treatment plant (WWTP) for dry weather flow. It can be seen from the (graph.1) that link 7.1 which acts as the entrance of the WWTP, showed a high level of TSS in the water whereas a low level of TSS showed in water leaving the WWTP. WWTP has 2 treatment facilities, one at storage unit 381 and second at settling basin 412. After the water treated by WWTP, water has TSS loads at 413.1 as shown in table.1 and table.2.

Link 7.1 has an average of 23388 kg TSS loads entering the WWTP after the waster water treated and water flows to the river that waster has an average of 2060 kg of TSS loads. This level of TSS in water is entering the river. Wastewater treatment plant removed 91% of the TSS loads in the water.



Graph.1 Representing TSS at link 7.1 and 413.1

Table.1 Representing the TSS loading before and after the WWTP for dry weather flow conditions.

DAY	Link 7.1	Link 413.1
2	23388	2073
3	23388	2063
4	23390	2061
5	23389	2044
Average	23388	2060

TSS loads at outfalls

This sewer system has 3 outfalls, outfall 1 which is emergency outfall, outfall node 116 and WWTP outlet 114 after WWTP. Table 2 represents the Total TSS loads during dry weather flow for outfall nodes. Node 414 has the maximum TSS pollutant because it has a maximum flow of water.

Table.2: Representing the TSS loads for outfalls

Outfall Node	Avg. Flow CMS	Max. Flow CMS	Total Volume 10^6ltr	Total TSS kg
1	0.000	0.000	0.000	0.000
116	0.000	0.000	0.158	25.842
414	0.027	0.050	10.938	162.39
Total				188.232

Daily Total TSS loads

Another representation of Total suspended solids at conduit 7.1 and 413.1 is showed in the form of daily total loads (table.3) and (table.4).

Table.3: Representing Daily Total TSS loads at 7.1
DESSEL Sewer Network

Start Date	Daily Total Load (mg/l)	Return Period
01/02/2001	288.075	0.20
01/03/2001	290.109	0.33
01/04/2001	289.212	0.25
01/05/2001	290.318	0.50

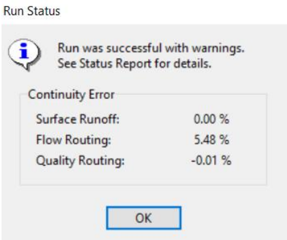
Table.3: Representing Daily Total TSS loads at 413.1
DESSEL Sewer Network

Start Date	Daily Total Load	Return Period
01/02/2001	27.453	1.00
01/03/2001	25.961	0.50
01/04/2001	25.032	0.20
01/05/2001	25.541	0.25

Task 2
30% Reduction in TSS delivery during dry weather flow

TSS delivery needs to be reduced by 30% by changing the size of the WWTP for dry weather flow. In this sewer system as link 7.1 is the entrance for WWTP and link 413.1 is the conduit connected to outfall node 414, both conduits 7.1 and 413.1 are considered to compare TSS loads. A storage unit is added with a treatment facility in the WWTP to reduce TSS loads with the following properties.

- Name of the Storage unit = 483
- Invert(bottom) elevation = 16m
- Max. Depth of the storage unit =2.5m
- A weir (482.2) is placed to the storage unit 483 and then a pump 483.1 is used to pump water from storage unit 483 to node 413



TSS loads at outfalls

After adding a storage unit with treatment facilities TSS loads have been decreased as shown in table 5 at node 414 from 162.39 kg to 101.658 kg, which more than 30% reduction with respect to the previous simulation.

Table.5 Representing TSS loads at Outfalls
DESSEL Sewer Network

Outfall Node	Avg. Flow CMS	Max. Flow CMS	Total Volume 10^6ltr	Total TSS kg
1	0.000	0.000	0.000	0.000
116	0.000	0.000	0.158	25.841
414	0.016	0.035	6.702	101.658
Total				127.49

Daily Total TSS loads

After storage unit with treatment facilities, TSS loads reduced at link 413.1 as shown in the following table.4. It can be seen that after adding a storage unit Daily total loads are decreased comparison can be seen from Tables 3 and 4.

Table.4 representing TSS loads at Link 413.1

Start Date	Daily Total Load	Return Period
01/02/2001	10.482	0.20
01/03/2001	14.567	0.25
01/04/2001	18.193	1.00
01/05/2001	18.033	0.50

Task 3
Running a simulation using 2-year rainfall data
Long term Simulation

In this simulation, the 3-month period is used for long term simulation to analyze the effect of rainfall on TSS loads. In the WWTP, treatment facilities kept the same as for dry weather flow treatment facilities 381 and 412 with the same treatment expression. To show the TSS reduction after wastewater treatment plant link 7.1, 413.1 and node 5 and node 414 are selected.

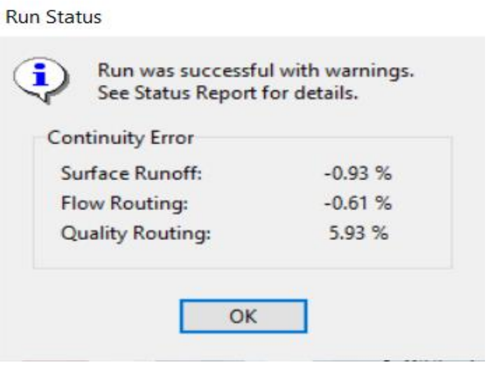


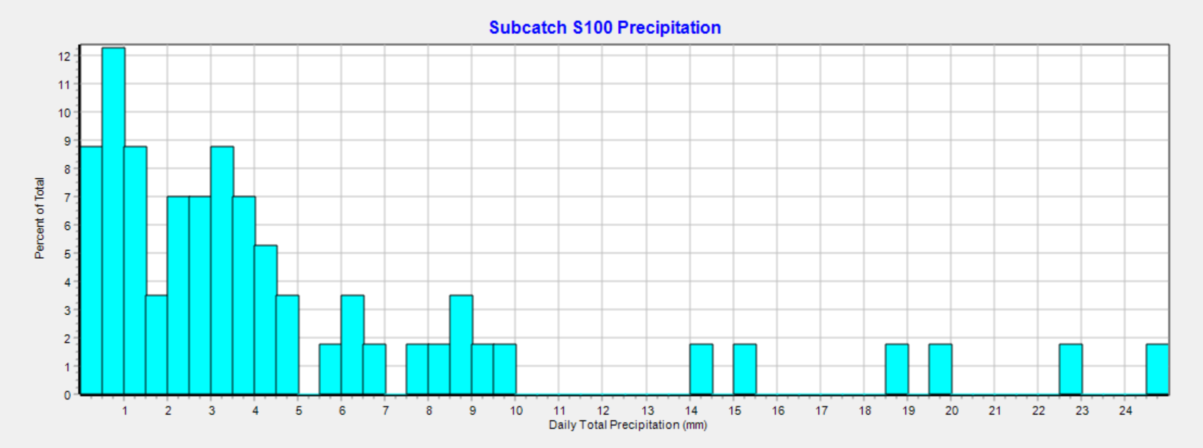
Fig.3.1 Represents the Continuity errors

After 1st simulation by considering 3-month time period and rainfall data continuity errors needs to be consider in the Quality part of the system as it is 5.93% shown in fig.3.1

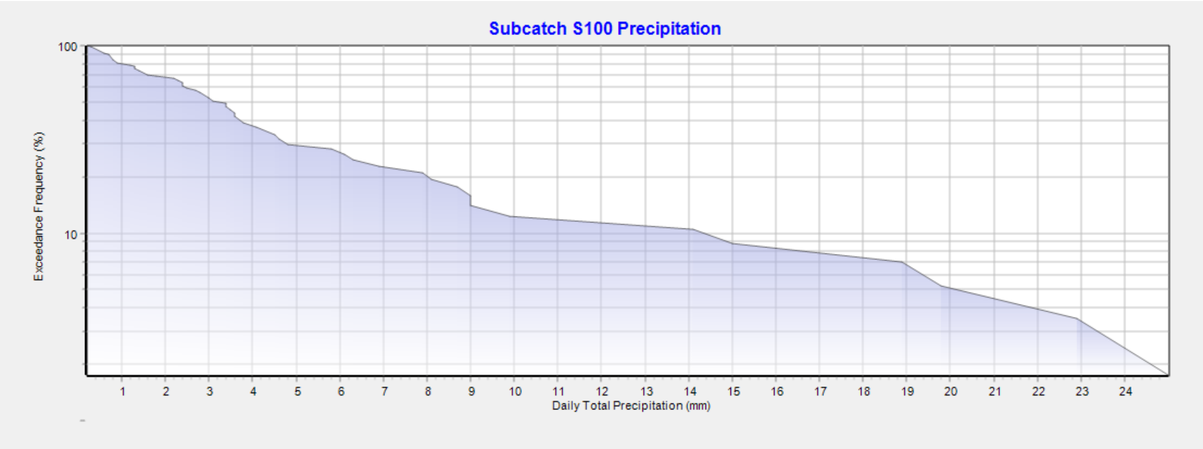
To represent the Precipitation details for the sewer system, sub-catchment 100 is selected and rainfall event details are represented as below.

```
S U M M A R Y   S T A T I S T I C S
===================================
Object .............. Subcatch S100
Variable ............. Precipitation (mm/hr)
Event Period ......... Daily
Event Statistic ...... Total (mm)
Event Threshold ...... Precipitation > 0.0000 (mm/hr)
Event Threshold ...... Event Volume > 0.0000 (mm)
Period of Record .... 01/01/2001 to 03/30/2001
Number of Events .... 57
Event Frequency*...... 0.648
Minimum Value ........ 0.200
Maximum Value ........ 25.000
Mean Value ........... 4.968
Std. Deviation ....... 5.689
Skewness Coeff. ...... 1.996
*Fraction of all days containing an event.
```

Graphical representation of precipitation events



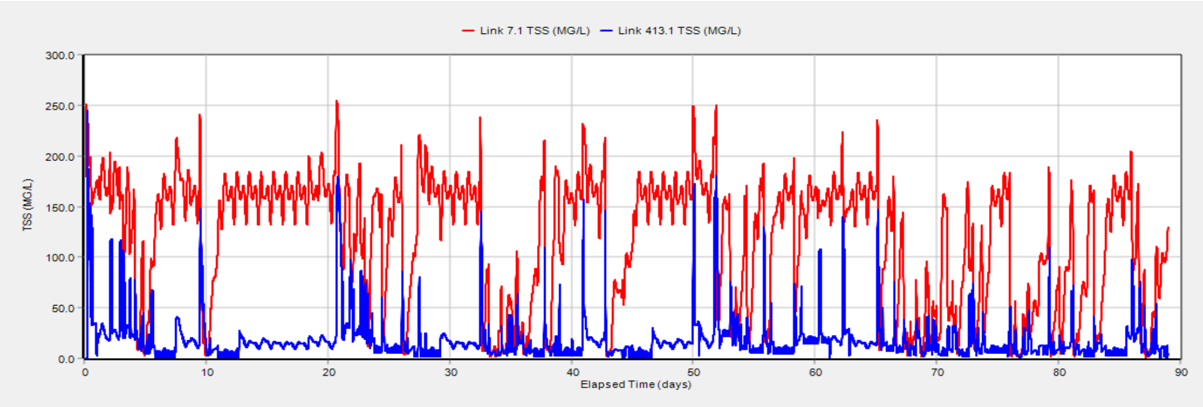
Graph.3.1 Representing the event mean Precipitation (mm/hr)



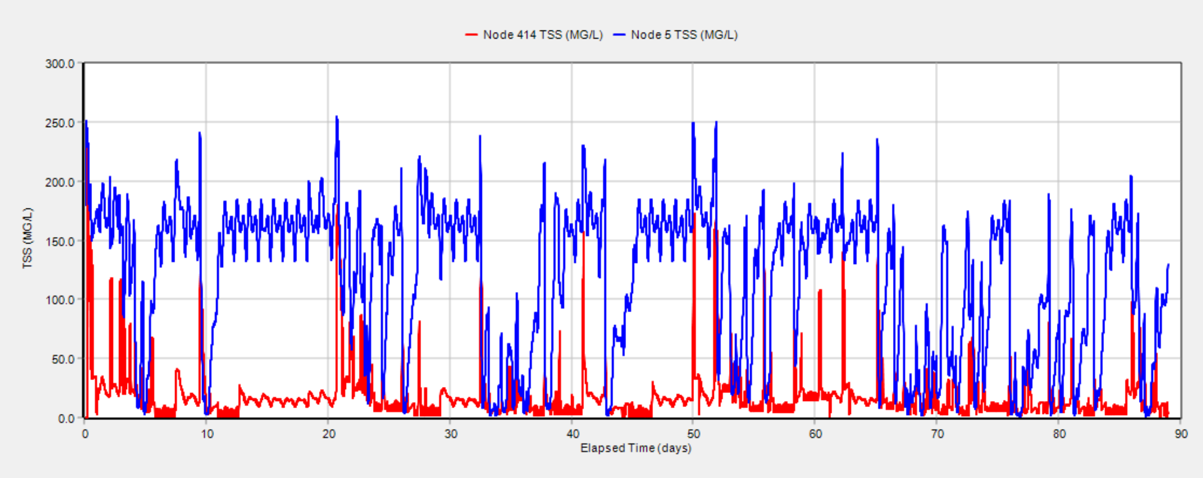
Frequency plot for precipitation events.

Time series plot

After the first simulation following are the results. Graph 3.2 and 3.3 represents the TSS loads before and after the WWTP during rainfall events. It seems there is a huge change in the TSS loads at the outlet 414 after wastewater treatment plant with treatment facilities at node 381 and 412.

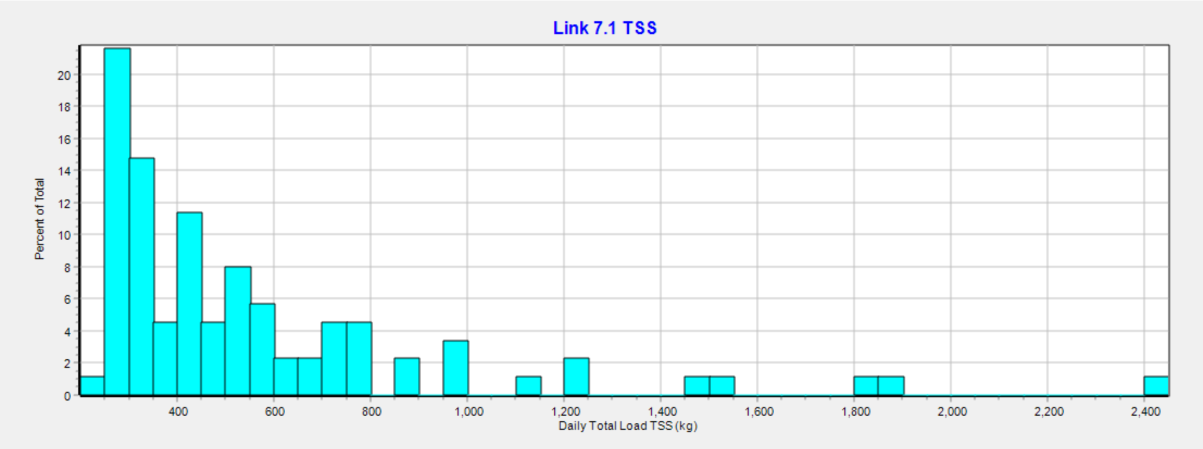


Graph.3.2 Representing the TSS loads at link 7.1 and 413.1



Graph.3.3 Representing the TSS loads at node 5 and 414

Graphical representation of TSS loads at link 7.1



Graph.3.4 representing TSS loads at link 7.1

S U M M A R Y   S T A T I S T I C S

====================================

Object .... Link 7.1
Variable .... TSS (MG/L)
Event Period .... Daily
Event Statistic ...... Total Load (kg)
Event Threshold ...... TSS > 0.0000 (MG/L)
Event Threshold ...... Event Volume > 0.0000 (m3)
Period of Record .... 01/01/2001 to 03/30/2001

Number of Events 88
Event Frequency*...... 1.000
Minimum Value 242.456
Maximum Value 2412.393
Mean Value 565.406
Std. Deviation 392.338
Skewness Coeff. 2.372

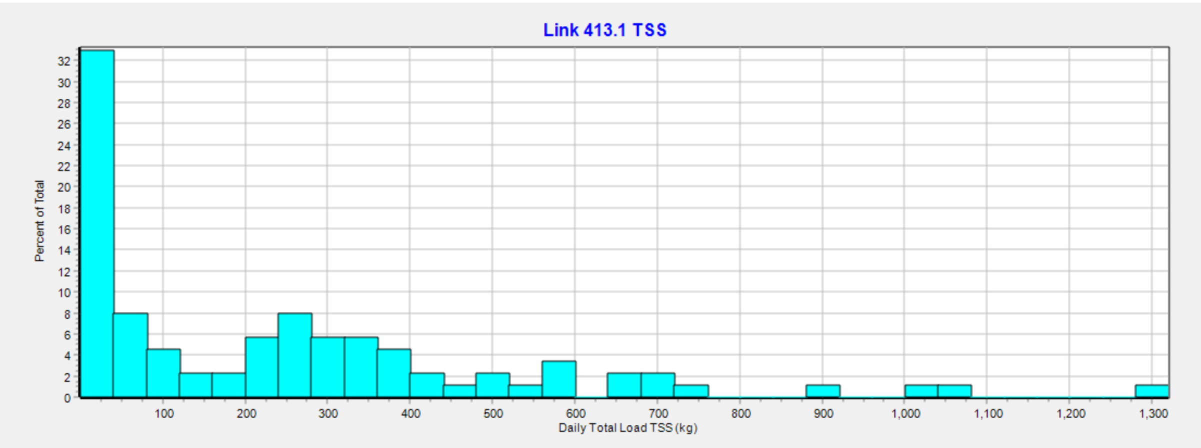
Table 3.1 Representing the TSS loading before and after the WWTP for wet weather conditions.

DAY	Link 7.1	Link 413.1
2	24613	5442
3	19886	4928
4	8384	3029
5	11079	2023
Average	15990	3855

Table 3.2: Representing the TSS loads for outfalls

Outfall Node	Avg. Flow CMS	Max. Flow CMS	Total Volume 10^6ltr	Total TSS kg
1	0.786	2.193	213.217	1455.81
116	0.006	0.278	29.861	899.363
414	0.180	1.150	1011.405	22551.899
Total				24907.1

<u>Graph 3.5 Graphical representation of TSS loads at link 413.1</u>



S U M M A R Y   S T A T I S T I C S

===================================

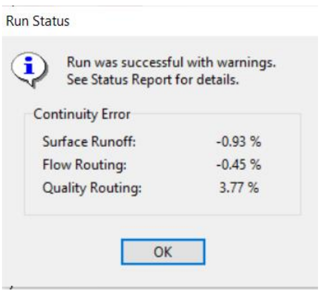
Object .... Link 413.1
Variable .... TSS (MG/L)
Event Period .... Daily
Event Statistic ...... Total Load (kg)
Event Threshold ...... TSS > 0.0000 (MG/L)
Event Threshold ...... Event Volume > 0.0000 (m3)
Period of Record ..... 01/01/2001 to 03/30/2001
Number of Events 88
Event Frequency*...... 1.000
Minimum Value 10.156
Maximum Value 1318.232
Mean Value 252.842
Std. Deviation 271.320
Skewness Coeff. 1.554
*Fraction of all days containing an event.

Pump controls

Pump	Percentage Utilized	Maximum Flow CMS
117.1	34.48	0.03
374.1	7.36	0.49
372.2	7.36	0.49
379.1	67.19	0.05
379.2	21.80	0.13
412.2	16.86	0.05

Task 4
Reduce TSS loads by 30% during rainfall events

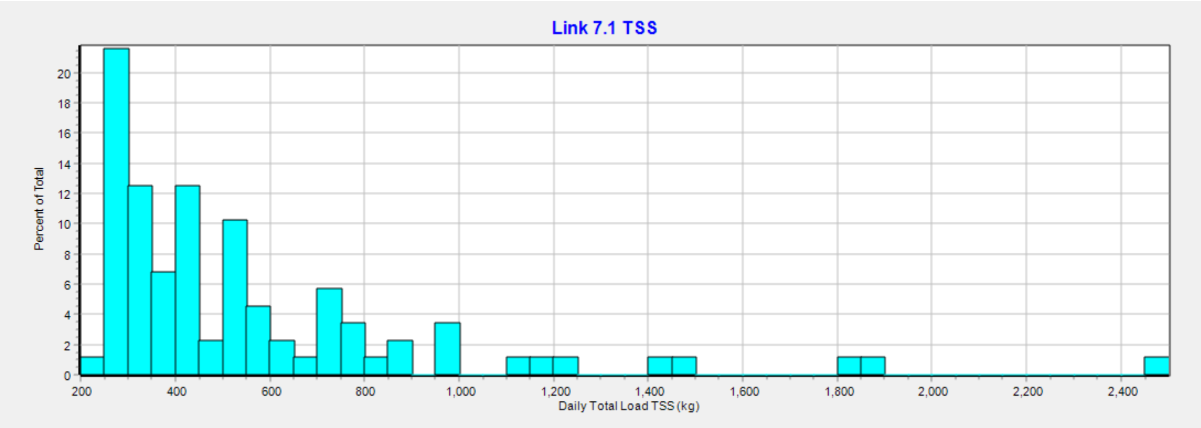
In this Simulation, the purpose is to reduce the TSS loads sent to the river by 30% and in this case treatment facilities are not considered to reduce the TSS loads as it is mentioned in the requirements of this project. Without making any changes to the system, the previous simulation showed TSS loads, those loads considered to be reduced by 30% in this simulation. A period of 3 months is selected for this combined sewer flow.



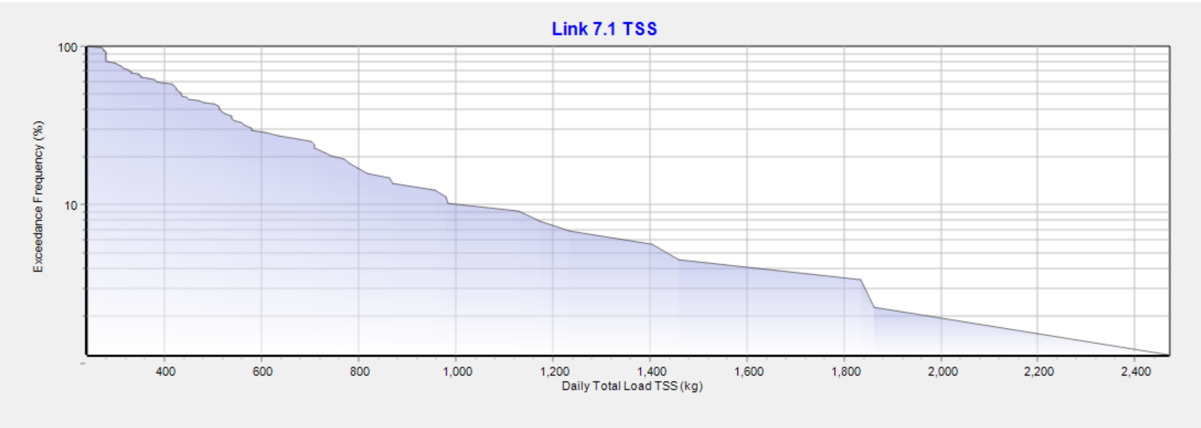
After the 1st simulation above are the continuity errors represented in figure 4.1, it can be seen that quality routing shoed 6.28% continuity error. This error is very high as compared to the dry weather flow, the reason behind that is rainfall runoff promotes the TSS loads in the flow.

```
S U M M A R Y   S T A T I S T I C S
====================================
Object  .............. Link 7.1
Variable ............. TSS  (MG/L)
Event Period ......... Daily
Event Statistic ...... Total Load (kg)
Event Threshold ...... TSS > 0.0000  (MG/L)
Event Threshold ...... Event Volume > 0.0000 (m3)
Period of Record ..... 01/01/2001 to 03/30/2001

Number of Events ..... 88
Event Frequency*...... 1.000
Minimum Value ........ 240.031
Maximum Value ........ 2469.776
Mean Value ........... 566.510
Std. Deviation ....... 392.127
Skewness Coeff. ...... 2.437
*Fraction of all days containing an event.
```



Graph 4.1 representing TSS loads at link 7.1



Frequency plot for TSS at link 7.1

S U M M A R Y   S T A T I S T I C S

==================================

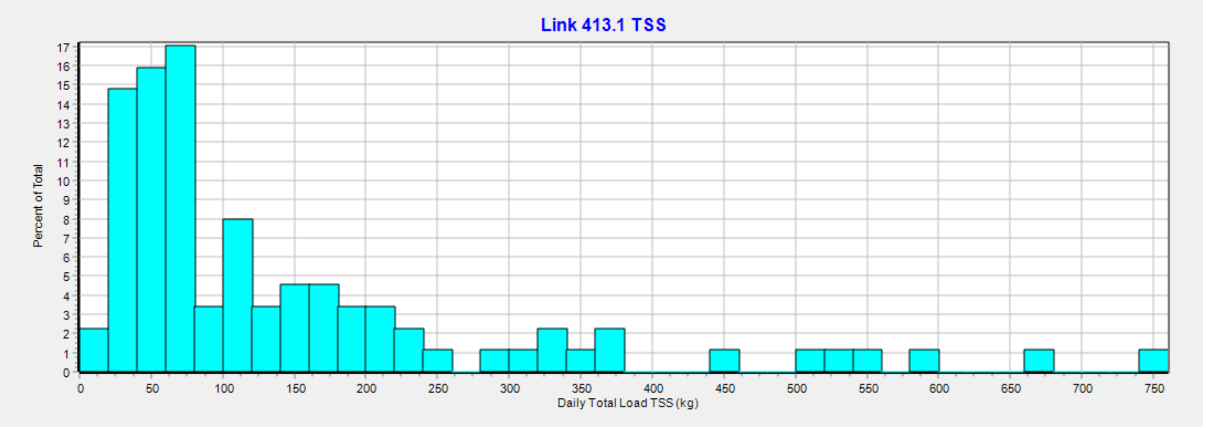
Object .... Link 413.1
Variable .... TSS (MG/L)
Event Period .... Daily
Event Statistic ...... Total Load (kg)
Event Threshold ...... TSS > 0.0000 (MG/L)
Event Threshold ...... Event Volume > 0.0000 (m3)
Period of Record ..... 01/01/2001 to 03/30/2001

Number of Events 88
Event Frequency*...... 1.000
Minimum Value 13.421
Maximum Value 742.706
Mean Value 148.800
Std. Deviation 155.883
Skewness Coeff. 1.927
*Fraction of all days containing an event.

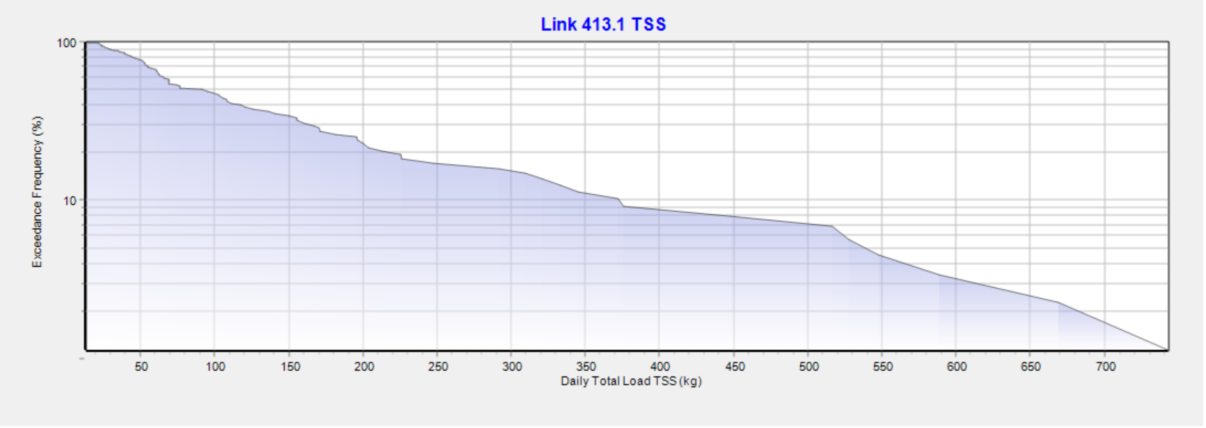
Table.2: Representing the TSS loads for outfalls

Outfall Node	Avg. Flow CMS	Max. Flow CMS	Total Volume 10^6ltr	Total TSS kg
1	0.000	0.000	0.000	0.000
116	0.007	0.285	29.860	899.328
414	0.082	0.542	405.652	13.122.878
Total				14022.2

Graphical representation of TSS loads at link 413.1



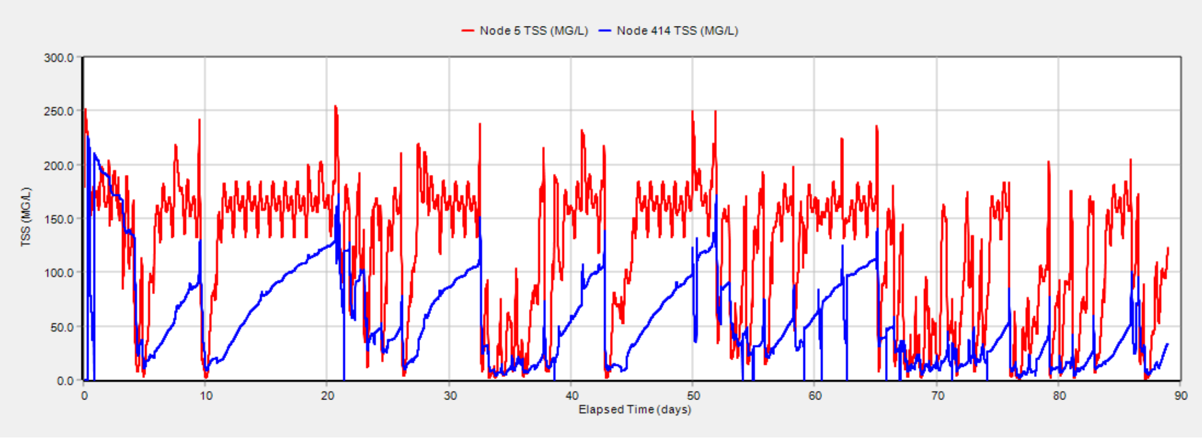
Graph 4.2 representing TSS loads at link 413.1



Frequency plot for TSS loads at link 413.1

Time series plot

The graph below representing the TSS loads at nodes 5 and 414 before and after the WWTP.



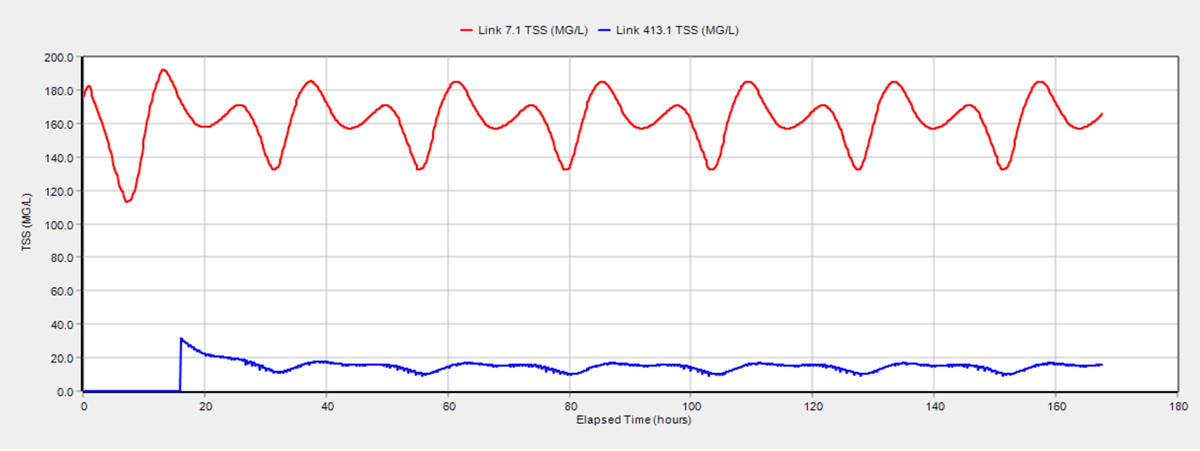
Graph 4.3 representing TSS loads before and after the WWTP

Discussion

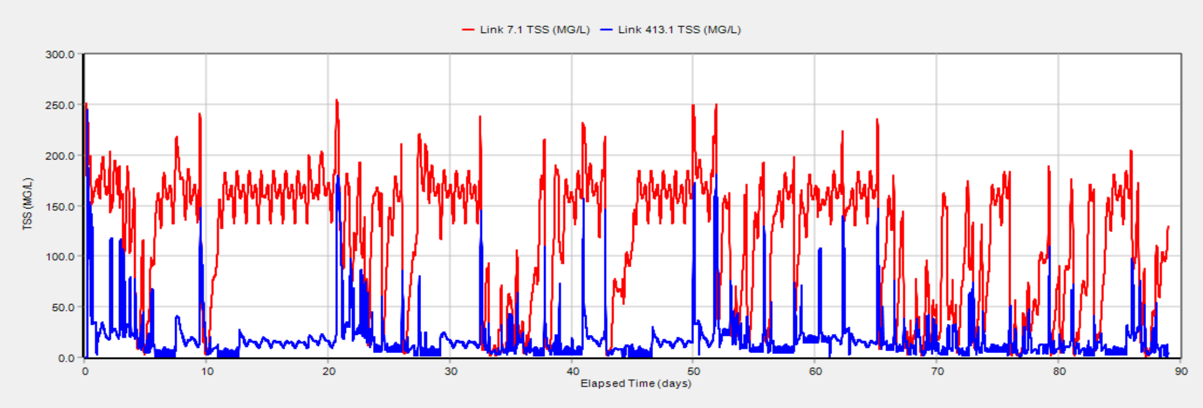
Task 5

To represent total suspended solids (TSS) loading before and after the Wastewater treatment plant (WWTP) for dry weather flow, link 7.1 and 413.1 are selected as Link 7.1 is just before the WWTP and Link 413.1 is after the WWTP where it sends flow into the river. It can be seen that TSS loads before the WWTP are very high as compare to TSS loads in the water leaving WWTP.

Graphs below representing the TSS loads before and after the WWTP for both dry weather flow and wet weather flow. It is easy to compare the TSS loads by these graphs as it can be seen that there is a high impact of rainfall on TSS loads sent to the river.



Representing TSS loads for dry weather flow



Representing TSS loads for long- term simulation

TSS Loads sent to the River

TSS loads at outfalls during both dry weather flow and rainfall events are represented below in the tables. It is clear from the tables that rainfall events contribute a lot to the pollutant discharge as node 1 is an emergency outlet which is not used during dry weather flow and has no pollutant discharge. While during rainfall events it contributes to the pollutant discharges as represented in table 2 about (1455 kg). For outfalls 116 and 414 has a huge difference in the TSS loading to the river can be easily compared from table 1 and 3.

Table1: Representing the TSS loads for outfalls(dry weather flow)

Outfall Node	Avg. Flow CMS	Max. Flow CMS	Total Volume 10^6ltr	Total TSS kg
1	0.000	0.000	0.000	0.000
116	0.000	0.000	0.158	25.842
414	0.027	0.050	10.938	162.39
Total				188.232

After making changes TSS loads decreased to the following Table. Resulted in 31% removal of TSS loads sent to the river.

Table.2 Representing TSS loads at Outfalls (dry weather flow)

DESSEL Sewer Network

Outfall Node	Avg. Flow CMS	Max. Flow CMS	Total Volume 10^6ltr	Total TSS kg
1	0.000	0.000	0.000	0.000
116	0.000	0.000	0.158	25.841
414	0.016	0.035	6.702	101.658
Total				127.49

Table 3: Representing the TSS loads for outfalls (wet weather flow)

Outfall Node	Avg. Flow CMS	Max. Flow CMS	Total Volume 10^6ltr	Total TSS kg
1	0.786	2.193	213.217	1455.81
116	0.006	0.278	29.861	899.363
414	0.180	1.150	1011.405	22551.899
Total				24907.1

After making adjustments to the WWTP for long-term simulations. Loads sent to the river reduced by 40% which can be seen from table 3 and 4. (reduced from 24907 to 14022)

Table.4: Representing the TSS loads for outfalls

Outfall Node	Avg. Flow CMS	Max. Flow CMS	Total Volume 10^6ltr	Total TSS kg
1	0.000	0.000	0.000	0.000
116	0.007	0.285	29.860	899.328
414	0.082	0.542	405.652	13.122.878
Total				14022.2

References

Rossman, L. (2015). *Storm Water Management Model User's Manual Version 5.1*. Retrieved from Cincinnati: