Web Based Water Quality Management System
For
National Water Supply and Drainage Board

R.W.M. NandaThilak
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A thesis submitted for the Degree of Master of Information Technology

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University of Colombo School of Computing
2018

Declaration

The thesis is my original work and has not been submitted previously for a degree at this or any other university/institute.
To the best of my knowledge, it does not contain any material published or written by another person, except as acknowledged in the text.

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This is to certify that this thesis is based on the work of Mr. R W M Nanda Thilak under my supervision. The thesis has been prepared according to the format stipulated and is of acceptable standard.

Certified by:
Supervisor Name: Prof. G Kapila Dias

Signature: Date: 30/11/2021

Abstract

The National Water Supply and Drainage Board (NWSDB) is a government organization which is providing safe drinking water to nation and sanitation service in Sri Lanka. Currently NWSDB serves approximately 2.5 million of Consumers Island wide. NWSDB have 40 regional support centers (RSC) and 325 water supply schemes (WSS).

The problem identified that the process of water quality of the drinking water was not recorded in a repository. All documentations were in manual forms and stored in papers, which was inefficient as no security on the historical information about the water quality. Therefore, NWSDB required web-based solution to capture and store water quality data and provide alerts to act and correct the issues popup during the quality testing at laboratories.

To overcome the above issues and to increase the productivity of the laboratory staff was the concern of introducing the software product. All data stored in repository can be used by the top management to make decisions promptly.

After carefully studying the operational aspects of the laboratory process, the system which is capable to capture test results with minimum errors was introduced. The system was integrated with the testing parameters, tolerance limits and the sample location as a key input and validate for errors. Sample points were changed time to time and sample registration done through the system process. It reduced manual documentation and proceeded with the flow. All data were stored in the central database and produced dashboards, reports, and alerts at relevant time to correct stakeholder. There are 34 laboratories for testing the water quality island wide which facilitated to capture tested sample results to the system. This information is fully transparence to all the regions in NWSDB.

This online system has been used to the Rapid Application Development approach which is well applicable for this project. The online system was developed using .NET framework 4 environment using C #, MS SQL, IIS web server, HTML5 and JavaScript. Object oriented concepts have been used to build the system throughout the entire development process.

According to the design, development, and implementation process of the project up to now it fulfilled the NWSDB requirement such as keeping historical data, alerts for necessary actions, improved the laboratory efficiency etc. Proposed system properly supports to overcome the manual process and operate online water quality management System Island wide.

Acknowledgements

I would like to thank all those who gave me the support to complete this thesis. First of all, I am grateful to my supervisor Prof. G Kapila Dias, who helped with stimulating suggestions, guidance, and encouragement during the completion of the project especially in the research area and writing of this thesis.

I have gained knowledge of the laboratory process from the Assistant General Manager (Laboratory Services) Mr. Wijesinghe and the staff from National Water Supply & Drainage Board. I give my special thanks to them for helping me to understand the whole process of the laboratory services to design, develop and implement the project during this period.

Also, I would like to thank all the members of the academic and non-academic staff at UCSC for the support that was given.

I would also like to express my thanks to my friends for their valuable guidance and support that I will never forget.

Finally, I wish to thank my family for giving me support and helping me in many ways to complete my project successfully and on scheduled time.

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List of Abbreviations

HRM	-	Human Resource Management
HTML	-	Hyper Text Mark-up Language
NWSDB	-	National Water Supply and Drainage Board
OIC	-	Officer in Charge
RSC	-	Regional Support Center
SMS	-	Short Message Service
WQM	-	Water Quality Management
WSS	-	Water Supply Scheme
UI	-	User Interface

Chapter 1 – Introduction

This report is the final outcome of the thesis study for the Master of Information Technology (MIT) at University of Colombo School of Computing. National Water Supply and Drainage Board (NWSDB) operates laboratories island wide to check the quality of the water providing to the consumers. Operations related to water quality analysis was continued as a manual work for years. It is identified maintaining a central data repository for the water quality data of the NWSDB is important and selected as my academic project which has become a solution to the NWSDB and solves their burning issue on data management.

1.1 Project Overview

1.1.1 About NWSDB

The NWSDB has been established in 1973 as a public sector organization which was providing safe drinking water to the nation and reclamation the wastewater of Sri Lanka. NWSDB currently operated under ministry of water supply. We covered 45% of the water coverage and cater 2.5 M of customers. To provide safe drinking water, organization required to check and double check the water quality and store information to make decision.

1.1.2 Current Method

In present we have 31 labs island wide. They have responsible to test water samples and inform any water quality tolerance to relevant official to take remedial action. All tests are based on SLS standard. We are dealing with the 2.5M customers to provide safe drinking water by testing and maintain water quality standard. All labs are collected samples around the region define by the central lab and tested for quality of the water. All results are recorded in manual (book or paper). At the end of the month, they were entered to the excel sheet and send to central lab located in Head Office Ratmalana. There are issues during this monthly process and history is not in data format all are entered in Excel forms. Therefore, very difficult to analyse and prepare reports very quickly. (Refer figure 1.1).

Current Water Quality Testing and Recording Process

Sample Point

Management

Water Quality Progress Report

Collecting Sample

Test Results

Laboratory

Tolerance Information

Sample Testing

Water Supply Scheme

Figure 1.1: Current Water Quality Testing & Recording Process

1.2 Motivation

There are several barriers identified in this process are as follows.

1. All the chemist and snr. Chemists who are used to this process and they must keep all data manually. When need historical data for any requirement they must find the record manually
2. They have released the pressure of keeping documents in manual format.
3. No need to do manual process to find out issues during their testing recordings
4. There are communication barriers which is important to inform unsatisfactory result to the relevant officials. For their action to provide safe drinking water to consumers. There is more sophisticated mechanism, and they have to waste their time for communication
5. Raw water analytical data required to future improvement of NWSDB. They do not fulfil the nation requirement for giving all people to water. Therefore, historical test result required for raw water is essential for build water supply schemes in the island.
6. No online information system to find out the results whenever required. To take decision they need unacceptable time to analyse from historical data.
7. Manual process was slower than time for the analysis is higher. When computerized it become low and officers can do more other required work to the organization

1.3 Objective

Final goal for the process is to remove all manual work and utilized central data repository to answer all requirement given by management time to time. Avoid manual document filling process and kept in the record room for years.

Improve the communication gap between OIC and the chemist. Because they have to make decision about the water quality before release to the consumer

Identified Key Objectives are

1. 100% paperless process for Lab operations for sample testing and reporting.
2. Water quality data in central data warehouse which required NWSDB as well as national need
3. Testing parameter tolerance can be popup where issue occurred.

4. 100% user satisfaction when all operations bundled into single solution
5. Higher management can view all important requirement of water quality management.
6. SMS alerts can be used to communicate within the data flow of the water quality of NWSDB
7. Top to bottom transparency of the water quality throughout the NWSDB
8. Maximum utilization of human resource by reducing manual work and other data entry work

1.4 Background of the Study

I studied the manual process of water quality management of NWSDB and summarise as follows.

- Study based on the Central Laboratory and Regional Laboratory in the NWSDB Island wide. There is day to day operations and record keeping is the most important fact.
- Water quality checking sample points and the scheme identified in this study
- SLS standard parameters were introduced to the WQM system as a master data
- All tolerance of parameters defines based on the water quality type (Raw Water, Treated Water and Wastewater)
- Water quality testing based on the Region, Cost Centre, Scheme, Source and Sample Point. They were identified through regional laboratory staff. All master data elements feed by regional Laboratory as a one-time job.

Water Quality Management Process with Repository

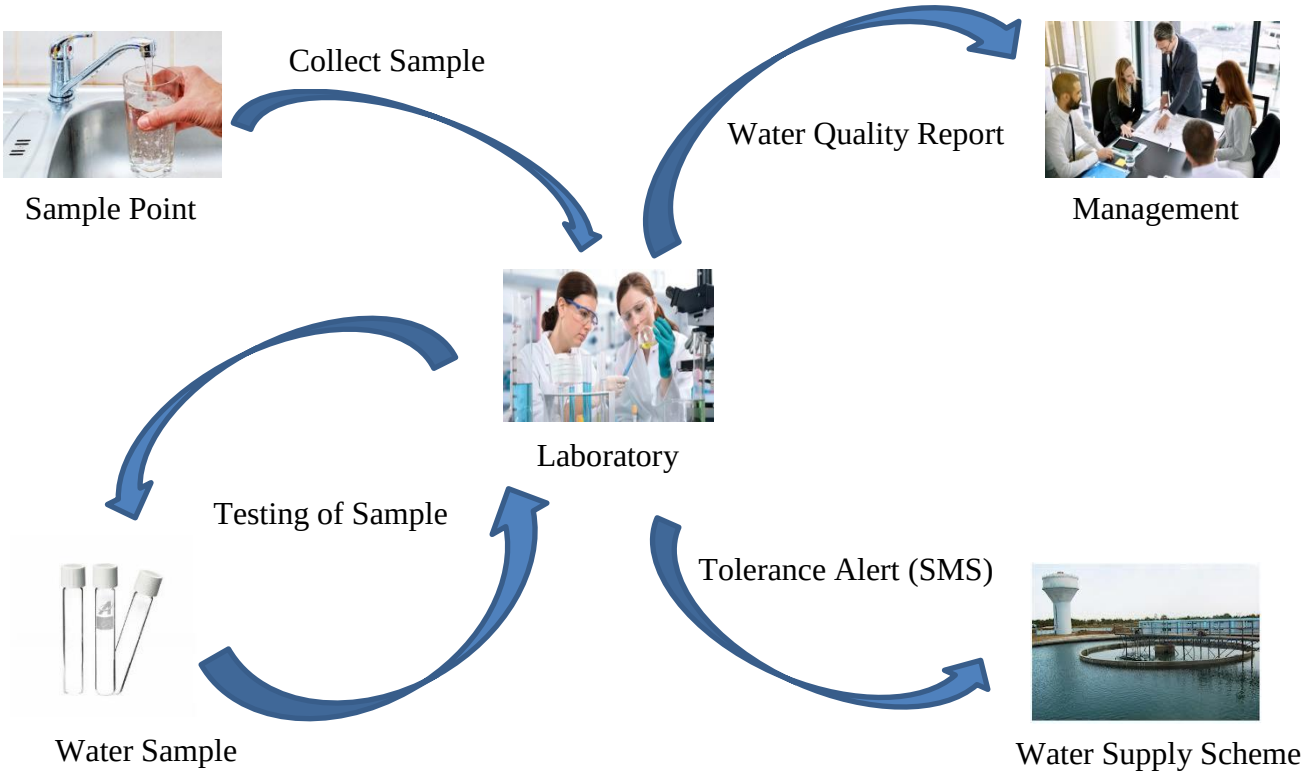


Figure 1.2: Water Quality Testing & Recording Process with Repository

1.5 Scope of the Study

Real time water quality capturing process through the Laboratory from island wide is necessary. Sample point water quality analysis is the most important factor. Therefore, we have decided to have water quality data viewed by single click on relevant GPS on the map

Data capturing basis dashboard produce to top management as a decision-making tool. They can view relevant information for the selected region (Refer Figure 1.2).

Through google map stakeholder can easily reach the destination wherever requirement occurred. There should be a possibility to visit physically to rectify the water quality issue obtain from the sample point.

Warning alerts are setting up to proper exclamation within the organization. Using this method, we can minimize the water quality issues arose during the water production/distribution process.

To reduce the manual work and provide reports warning alerts and other information from the system. Not necessary to collect Data Island wide and prepare the reports minimize the HRM issues.

NWSDB design new water supply scheme, design people required water quality for that area before finalizing the project. For this project scope raw water quality must needed requirement for past years. When we kept those data in central repository system is important to make decision to complete the new water supply scheme development process.

1.6 Feasibility Study

I have carefully done the feasibility of the project and identified 4 main categories as follows.

1.6.1 Economic Feasibility

As a first step we need to analyse whether the manual system than computerized system economical to the organization. There are lot of improvement can identify during this study as follows.

- Reduce time by removing separate data entry and analysis process
- Test result capturing to the central system. Therefore system must be capable of producing island wide test results and unsatisfied test easily
- SLS standards (Tolerance) are mapped to the testing parameters. It is very useful to produce warnings and quick SMS to get the precaution to minimize the water quality issue
- Minimize the printing cost by introducing dashboard concept to the NWSDB. We can reduce work force use to produce reports and other important documents.'
- System designed developed based on the user requirement. All the user interfaces are user friendly and minimize the data entry work at point of capturing test results to the system.

1.6.2 Technical Feasibility

This web-based solution developed to chief chemist, senior chemist and chemist located in the island wide Labourites. They are highly educated employees in the NWSDB and get their support is very easy. This product use as a in-house system and all labourites are connected to one NWSDB hub. NWSDB having datacentre to minimize the data losses by automated backing up facility and solution can be deployed in virtual environment which enabled high tech infrastructure available in the organization. NWSDB having system administrators stationed in regional level and they have a technical capability to solve the technical issues.

1.6.3 Operational Feasibility

To run the web-based solution each and every laboratory must need following requirement

- Newest computer which is capable to run web-based solution
- Connection to the NWSDB virtual private network as the web client.
- Computer literacy of every chief chemist, senior chemist, and chemist
- System integrated with the NWSDB HRM system to control the employee status
- Datacentre having 24x7 data security and reliability. Automated backup facility with 100% guarantee of data.

1.6.4 Legal Feasibility

Water Quality Management System should be fully capable with the security policy of NWSDB. System can access only for the valid employees in the NWSDB. These invalid statuses are retired, suspend interdict etc. Therefore, considering all these facts system will legal feasible than manual system.

1.7 Structure of the Dissertation

This dissertation is compiled with the following component as follows.

- Introduction:
  Introduction to the problem domain identified as water quality management of NWSDB. This Solution converts the manual process to computerised solution.
- Background:
  In this chapter we discuss about the functional and non-functional requirement. Also find out similar products in the problem domain.
- Methodology:
  About this chapter I will produce my approach to solve problem domain. All analysis and evaluation of my methodology to solve the problem
- Evaluation:
  Using evaluation forms distributed among the system users and get their consent about the product and product features which is over the manual system.
- Conclusion:
  Introduction to conclusion will be produce based on the careful analysis of the project. Everything explains one by one and provides clear comparison of each scenario as

Chapter 2 – Background

2.1 Introduction

This chapter consists of requirement analysis, fact gathering, and interviews to identify the real situation of water quality management domain of NWSDB

2.2 Requirement Analysis

Requirement Analysis is the very first activity in SDLC followed by Functional Specification and so on. Requirement analysis is a important step in SDLC as it resonates with acceptance testing that is critical for product acceptance by customers. There are various steps involved, outcomes, challenges, and corrective measures in requirement analysis.

Requirement analysis starting from:

- Requirement gathering which is also called as elicitation.
- After that analysing the collected requirements to understand the correctness and feasibility of converting these requirements into a possible product.
- At last, documenting the requirements collected.

2.2.1 Requirement Gathering

Central Laboratory is the main customer of this system. There are another 30 Regional Laboratories around the NWSDB as users of the system. I have gathered information from central laboratory and regional laboratory to identify their operation in NWSDB. They are fully responsible to test water samples and produce reports to management and unacceptable tolerance limit must be informed to relevant water sample stakeholders. There are proven techniques to gather requirement from the stakeholders. These techniques are as follows.

2.2.1.1 Interviews

Interviews are one of the easiest and most powerful techniques available for gathering requirements. Accordingly, I have conduct interviews with the laboratory staff including chief

chemist, senior chemist, chemist and other people involved in the sample testing. To do this I have prepared questions and get the stakeholder acceptance to design the water quality management system.

These questions are.

- How many samples are tested for the day?
- Are they satisfied with the operational method used in the current (Manual) process?
- What are the parameters frequently check?
- Current methods of storing testing results are secured, accessible to the management, generating reports etc.

Discuss about easiness of having software solution instead of doing manually. These interviews allow giving quick answers and justifying with the manual process. I have examined the stakeholder reaction and get an idea of the new solution response during the interview. This method enables the collection of the most important information, the definition of the requirements, stakeholder roles and responsibilities, a clear understanding of the manual process and what is expected from the proposed system.

2.2.1.2 Stakeholder Observations

I have Observed the users in the water quality testing environment is a good accurate method to identify system requirements. In addition to the information that I collected from interviews there were hidden information's that I collect by observations.

My observations start from the Central Laboratory in Head Office. I observed how they test water samples and record in manual form and store in the record room. This process was totally manually driven system having more risk. Finally, I visited to the Regional Laboratory and observed their process and identified that, they have to communicate with WSS for their water quality tolerance exceed the SLS requirement. This is the important requirement where unsatisfactory of water quality cause issues in our drinking water distribution.

2.2.1.3 Analyzing Existing Documents

NWSDB water quality recording documentation was fully manual work. At the end of each month, they have entered to the excel form and send it to Central Laboratory for report generation. In this analysis I found that there is no method to get the information quickly whenever required?

I have analyzed the documents and generated reports based on the frequency used and the need of the report. These monthly reports are important to management for their decision making.

Analyzing existing documents can prove to be a useful technique in requirement gathering, on its own as well using it to supplement other techniques.

2.2.2 Functional Requirements

I have identified the functional requirement during the requirement analysis. In this project web based water quality management system is the solution provided to the laboratory to capture and reporting their sample testing process. Following are the list of functional requirements.

- System should provide facilities to manage Schemes as a master data.
- System should provide facilities to manage water sources with mapping to the schemes.
- System should provide facility to maintain testing parameters and their tolerance limits
- Sample points are maintained by the system which is the most required data element to capture water quality.
- System should provide facilities to capture daily water quality results to the system
- System should provide Reports and online Dashboard to monitor the water quality of the organization
- System should be able to send SMS in relevant stages to relevant users.
- System should provide facility to view all relevant details of captured water quality.
- System should provide secure access for each user only to relevant region and under relevant access rights

2.2.3 Non-Functional Requirements

There are non-functional requirements identify for the water quality management system as follows.

Performance - The solution should respond quickly to user request initiated from client machine. After processing data at server, the data will be ready and the request for information from the system will be available to view in the screen. The screen should load immediately.

User Friendly – The web-based application must be user friendly. NWSDB users are not fully fluent in computer literacy. Therefore, input screens must be in standard format, and then users can use system easily. User trainings are important to educate the users in the organization which they don't having fully awareness of the system otherwise they reject the system.

Reliability – Laboratory users are not using any software solution right now. Therefore, I have to build trust about the data and the outputs. To do this, I have to prove the reliability by demonstrating the structure of the data ware housing and connectivity of the solutions.

Availability - The water quality management system will be available to the user on VPN for all time. If we need a down time of the system, advance notification will be required to minimize data capturing process.

Security – User account for the water quality management system will be created and managed by system administrators in island wide. They are also responsible for the access rights of the users to prevent unauthorized transaction to be entered to the system. System and database backups are scheduled and transferred to the data store located in separate device.

Maintainability - System will be maintained by the IT division. All documentations and source codes of the system will be provided, and it will give instruction about use of and maintenance of the system.

2.3 Review of Similar Systems

I have gone through the internet and find out software solutions available which is applicable for my development. These solutions are as follows.

1. Locus technologies provide cloud-based software solution manage water quality data and provide varies dashboards, reports and mobile app's to water utility companies. (Refer figure2.3.1) (Technologies, 2021)
2. Some of the key features are as follows.
    - Take control of your drinking water and ops data and ditch the spreadsheets.
    - Whether testing for the latest UCMR list, taste and odour, corrosion, customer complaints, new main construction, or basic water quality issues, trying to manage the abundance of data from various sources can get overwhelming— especially if you're storing this data in a complex web of spreadsheets and in-house databases.
    - Flexible sample planning for routine sampling
    - Pre-printed COCs
    - Mobile app for samplers/Ops data
    - Coliform and other routine reports
    - Instant results on GIS maps
    - Permits and DMRs
    - CCR calculations and report inputs
    - Custom mobile forms for Ops data
    - Monitor contaminants such as per and polyfluoroalkyl (PFAS)
    - Generate and submit XML via web services to EPA's Compliance Monitoring Data Portal

    Dashboard screen shot.

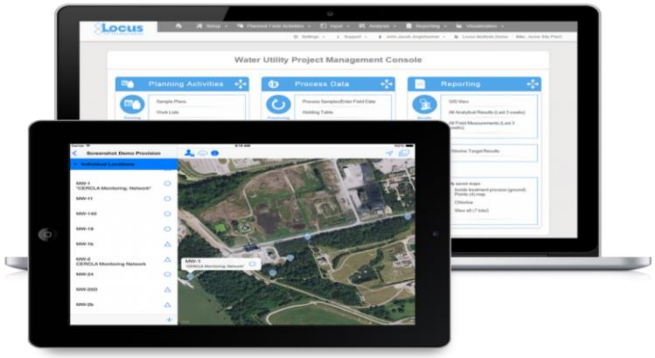


Figure 2.3.1: Water Quality Dashboard

3. Hydro-Comp enterprises provide water quality management software which having varies reports, information screens etc. (Water Quality Management | Laboratories, 2020)

Some of the important features are as follows.

The environmental Integrated Water Quality Management System (IQMS) can be used to monitor water / effluent quality by the Utility / Municipality.

Water quality management includes the systematic collection of physical, chemical, and biological information, and the analysis, interpretation and reporting of those measurements, according to a pre-planned design and structure. Effective quality management programs include the following components:

- Information requirements and objectives.
- Sampling programs including type, scale, and measurement parameters.
- Sampling methodology.
- Laboratory and field analysis.
- Quality assurance and quality control procedures
- Statistical analysis and interpretation of the data
- Reporting and dissemination of information to various stakeholders

The EDAMS Water Quality Management System has been specifically designed to meet the requirements identified above. It supports a proprietary data structure that makes it eminently suitable for use in both monitoring and management of quality data. The system can be used effectively as the main operational monitoring tool acting as a trigger for immediate corrective actions to operational procedures, thereby improving drinking quality.

4. Verdant's Drinking Water Quality Management Web-Based Software Compliance Solution. There are features which are very comprehensive and informative. (Tech, 2021)

Some of the key features are as follows.

- Verdant Web Technologies' Drinking Water Quality Management Software module provides web-based access to drinking water sampling reports and testing results
- Verdant's web-based software system provides a sortable list of buildings, making it easy to locate drinking water quality data for specific facilities. Easily upload new or archived sampling reports. Our drinking water quality management software allows facility owners and maintenance staff to access drinking water quality data paperless and with ease. (Refer Figure 2.3.2)
  dashboard of the system.

Figure 2.3.2: Water Quality Management Screen Shot

2.4 Related Technologies

According to the current technologies I have selected following tools to develop the web based water quality management system. The Server requirement & Client requirement for deployment also discussed.

2.4.1 Development Tools

- Microsoft Windows 10

Windows 10 is a latest operating system and use for my application development OS. This operating system is developed by Microsoft as a part of the Windows NT family.

- Dot Net framework 4.0 or higher

  The .NET Framework is a tool developed by Microsoft and works primarily on Microsoft Windows. It includes a class library called the Framework Class Library, which provides language integration to run many programming languages.

- Visual Studio 2015

  Microsoft Visual Studio is an integrated development environment for Microsoft. It is used to develop my web-based applications. There are many more facility to develop websites, web applications, web services and mobile applications.

2.4.2 Server Requirement

- Microsoft Windows Server 2012

  Windows Server 2012 is the fifth version of Microsoft's Windows Server operating system, It also a part of the Windows NT family of operating systems.

- IIS web server

  The Internet Information Service is a web server to host software developed by Microsoft for use in the Windows NT family.

- MS SQL 2014

  Microsoft SQL Server is a database management system developed by Microsoft. Database Server can manage storing and retrieving data at the request of other software solutions.

2.4.3 Client Requirement

- Microsoft Windows 7 or above

  Windows is an operating system developed by Microsoft and part of the Windows NT family. In client environment manage by Windows OS in NWSDB.

- Web Browser – Internet Explorer/Microsoft Edge, Firefox, Google chrome

  The web browser is a software application that accesses information about the World Wide Web. When a user needs to access the application from a web server, the browser downloads the necessary content from the web server and displays the page on the user’s

device. NWSDB users can access water quality management system which is hosted in the datacentre webserver by locally.

2.5 Related Design Strategies

NWSDB IT division selected to use rapid application development method to design and develop the systems. This method was more suitable for the environment and culture of the organization. Their business processes are not computerized and manual operations are taken place.

Rapid Application Development Methodology

Rapid Application Development (RAD) is a form of agile software development methodology that prioritizes rapid prototype releases and iterations. Unlike the Waterfall method, RAD emphasizes the use of software and user feedback over strict planning and requirements recording (Refer Figure 2.5.1)

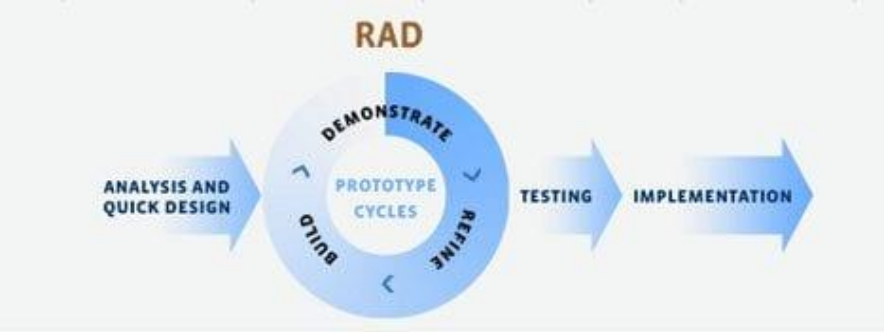


Figure 2.5.1: Rapid Application Development Model

There are 5 steps to use RAD as a standard. These steps are as follows.

Step 1: Define and finalize project requirements

During this step, stakeholders sit together to define and finalize project requirements such as project goals, expectations, timelines, and budget. When you have clearly defined and scoped out each aspect of the project's requirements, you can seek management approvals.

Step 2: Begin building prototypes

As soon as you finish scoping the project, you can begin development. Designers and developers will work closely with clients to create and improve upon working prototypes until the final product is ready.

Step 3: Gather user feedback

In this step, prototypes and beta systems are converted into working models. Developers then gather feedback from users to tweak and improve prototypes and create the best possible product.

Step 4: Testing

This step requires you to test your software product and ensure that all its moving parts work together as per client expectations. Continue incorporating client feedback as the code is tested and retested for its smooth functioning.

Step 5: System Presentation

This is the final step before the finished product goes to launch. It involves data conversion and user training.

Object Oriented Programming (OOP)

I have decided to use OOP method to develop the system. NWSDB have an existing OOP framework, which is used for existing system development. Therefore, I have used the same framework to develop water quality management system. (Refer Figure 2.5.2)

Object-oriented programming (OOP) is a computer programming model that organizes software design around data, or objects, rather than functions and logic. An object can be defined as a data field that has unique attributes and behaviour.

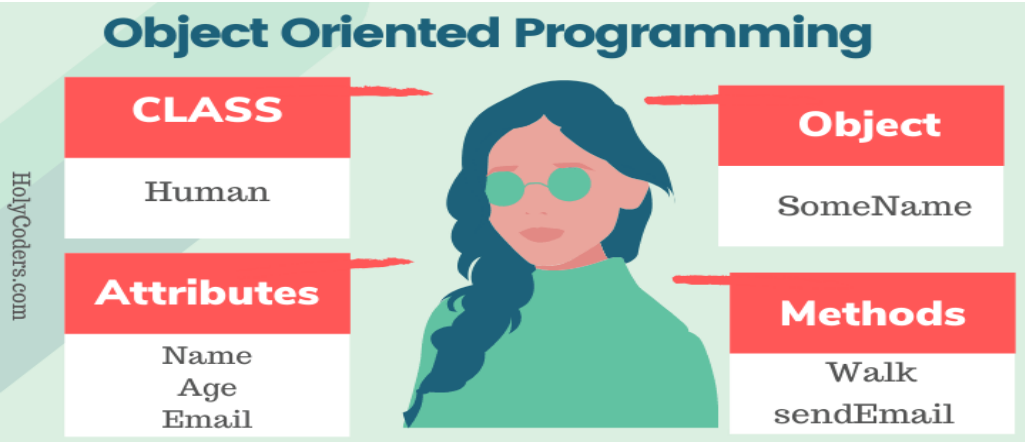


Figure 2.5.2: Object Oriented Programming Technique

Chapter 3 - Design Architecture

3.1 Introduction

Software design architecture refers to the fundamental structures of a software system and the discipline to creating such structures and systems. Each structure complied within software elements, relations between them, and attributes of both elements and relations.

3.2 System Architecture

The systems architecture has defined as architecture of new system that consists of both hardware and software. The main concern of the systems architecture is then the integration of software and hardware as a complete working model of connecting all devices. There is much broader definition, the term applies to the system architecture of any complex system which may be of technical, sociotechnical or social nature.

3.2.1 Proposed System Architecture

The Water Quality Management System is a Web Based solution hosted in centralized virtual server of Datacentre located at the Head Office of NWSDB. For the hosting we use windows 2012 R2 OS with IIS 6.0. This system only uses for the NWSDB users therefore it can be access through an intranet. Access URL is 10.0.0.200\erpapp which can be browse within the organization through VPN or RVPN. Figure 3.1 shows the system architecture diagram of the proposed Water Quality Management System.

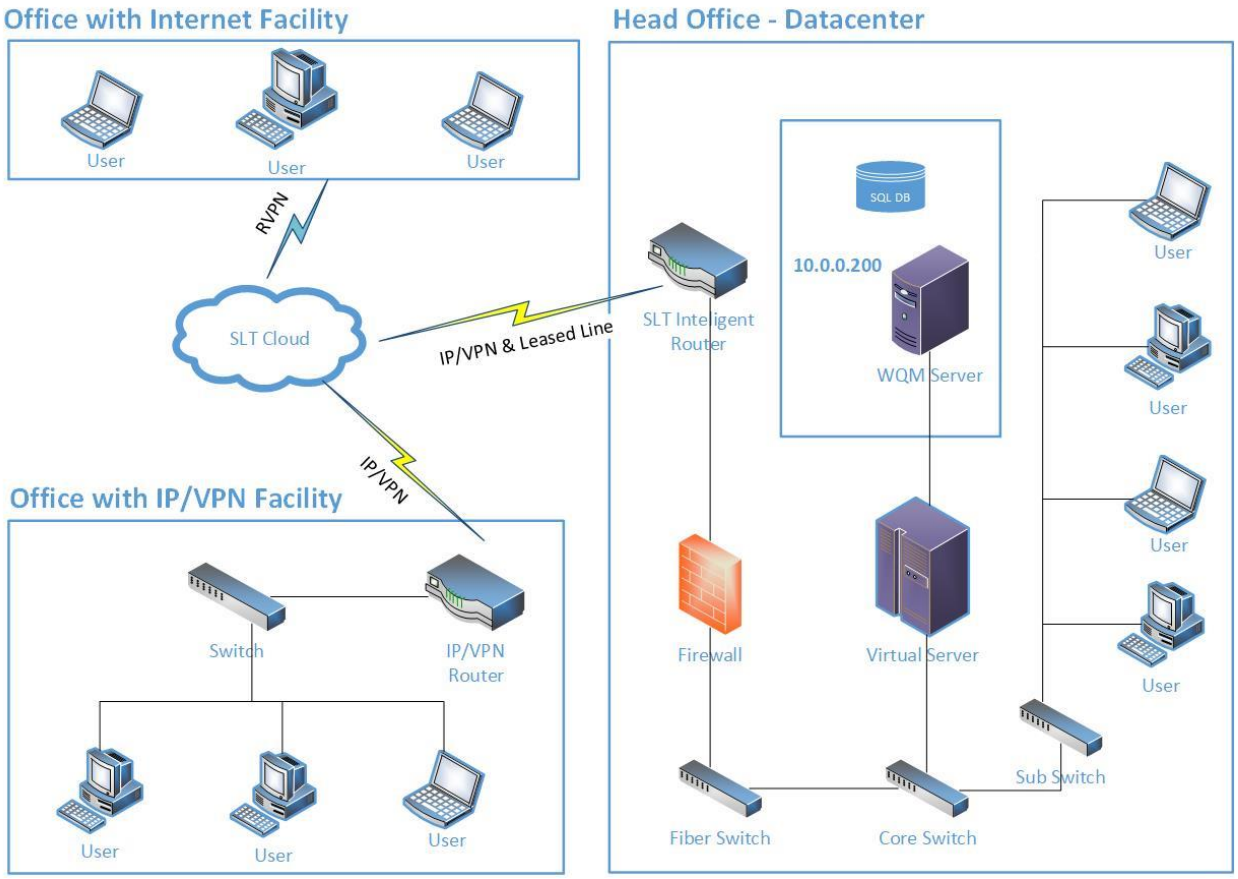


Figure 3.1: Architecture Diagram for the Proposed System

3.2.2 System Users

According to the system requirement we have analyse those four levels of users required to fulfil the operations of WQM system. In manual operation there is no operational levels, all data elements are written in manual document and signed by the higher officer (Chemist) before sending it to management. These proposed four levels are represented in figure 3.2.

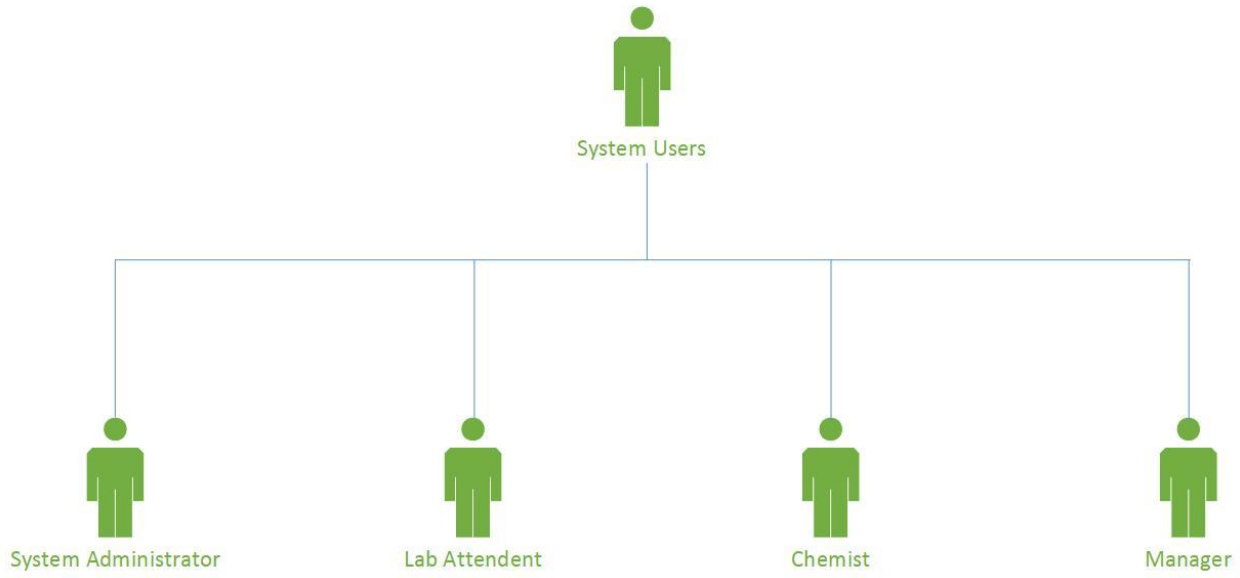


Figure 3.2 WQM User Levels

WQM process above user responsibilities and their roles are as follows.

System Administrator

All user's management responsibility goes to the system administrator. Some of the master data management process also handle by him. Access rights and user training handled by him within the region of NWSDB. All region having IT professional system administrator.

Lab Attendant

Most important job function assigned to him by laboratory service in NWSDB. He is the one responsible to register the sample which was taken from the field and conduct the testing according to the SLS stranded and guidance of the chemist. Maintain master data and the capturing test result also his duty within the WQM system.

Chemist

Approval authority given to him as a chief of the labourites island wide. WQM system generate alerts based on his approval. System checked the tolerance of each parameter and highlighted the un-satisfactory results in the approval stage of the system.

Manager

Dashboards are defined in the system to indicate unsatisfied water quality of the drinking water. This is open to higher management to monitor the WQM system.

3.3 UML Diagrams

In software development process, Unified Modelling Language is a standard visual modelling language intended to be used for following

- Modelling business and similar processes,
- Analysis, design, and implementation of software-based systems

According to the above facilities we have chosen UML as a tool for WQM design and development of the software product. There are two categories called Behavioural Diagram and Structural Diagram in this UML process. We have selected most required diagrams in each category as follows.

Behavioural Diagram

- Use Case Diagram
- Sequence Diagram

Structural Diagram

- Class Diagram

3.3.1 Use Case Diagram

The most known diagram type of the behavioural UML types, Use case diagrams give a graphic overview of the actors involved in a WQM system, different functions needed by those actors and how these different functions interact the process. In this diagram we can easily identify the main actors involved and the main processes of the system. For the WQM system define use case diagram shown in the figure 3.3

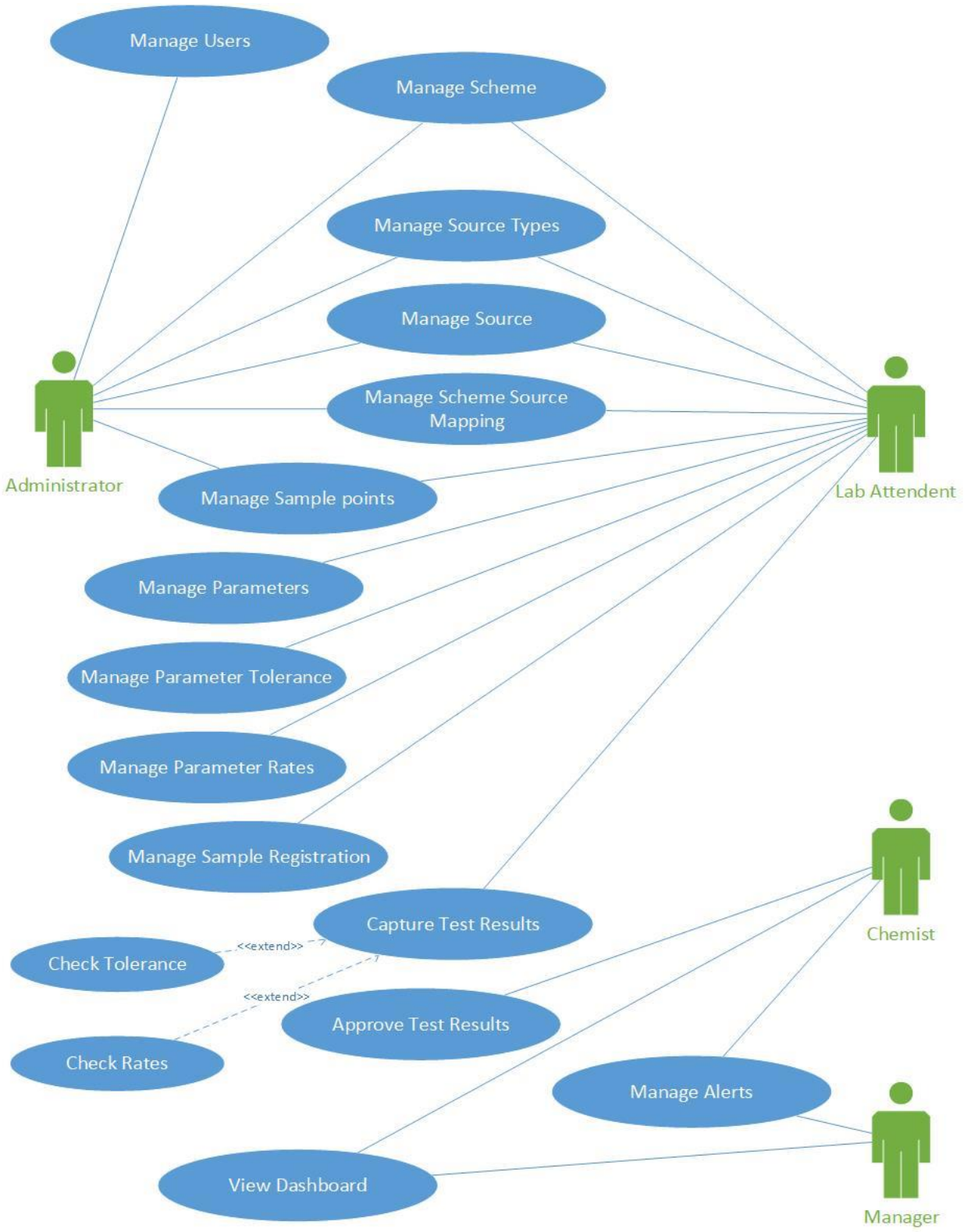


Figure 3.3 WQM Use Case Diagram

3.3.2 Use Case Narratives

Use case narration is represented as a text. Action of the sequence of events encountered when an actor is cooperating with the system. There can be several use cases associated with a system, each of them describes the system in a functional or behavioural point of view. Accordingly, we have developed the format to store use case narratives for the WQM system. We referred the (Google, 2021)to develop the use case narrative format.

3.3.2.1 Manage Users

Use Case ID:	1		
Use Case Name:	Manage Users		
Process Owner:	System Administrator	**Last Updated By:**	NandaThilak
Date Created:	12/03/2021	**Date Last Updated:**	
Business Actor:	System Administrator		
Description:	Manage system users by creating and assign access rights		
Preconditions:	User must be an employee of the NWSDB		
Postconditions:	Retirement of the employee is used as end of the system access		
Performance Goal:			
Basic Workflow:	Create 1. Select User from HRM 2. Assign Default Password 3. Save User Assign Access Rights 1. Select User from HRM 2. Select Modules & Roles to provide Access 3. Save Access Rights		

Table 3.1: Manage Users Use Case Narratives

3.3.2.2 Manage Scheme

Use Case ID:	2		
Use Case Name:	Manage Scheme		
Process Owner:	System Administrator Lab Attendant	**Last Updated By:**	NandaThilak
Date Created:	12/03/2021	**Date Last Updated:**	
Business Actor:	System Administrator, Lab Attendant		
Description:	Manage water supply schemes by selecting appropriate region and the cost centre. GPS coordinate provide locating facility among the organization		
Preconditions:	User must have access rights to create/update /delete scheme in WQM system		
Postconditions:	Cannot remove scheme where source is mapped to the scheme. Also any test result generated for this scheme cannot remove.		
Performance Goal:			
Basic Workflow:	Create 1. Select Region, Cost Centre 2. Input Name, GPS and other details 3. Save Scheme Update 1. Select Scheme from Grid View 2. Modify Elements 3. Save Scheme Delete 1. Select Scheme from Grid View 2. Click Delete Button 3. Delete Scheme		

Table 3.2: Manage Scheme Use Case Narratives

3.3.2.3 Manage Source Types

Use Case ID:	3		
Use Case Name:	Manage Source Types		
Process Owner:	System Administrator Lab Attendant	**Last Updated By:**	NandaThilak
Date Created:	12/03/2021	**Date Last Updated:**	
Business Actor:	System Administrator, Lab Attendant		
Description:	Source types are define based on the water product which are used for the sampling		
Preconditions:	Source types are categorize based on raw water, treated water and waste water		
Postconditions:	Cannot remove where sources are defined for the source type		
Performance Goal:			
Basic Workflow:	Create 1. Enter Source type 2. Check availability 3. Save Source Type Update 1. Select Source Type from Grid View 2. Modify required field 3. Save Source Type Delete 1. Select Source Type from Grid View 2. Delete Source Type		

Table 3.3: Manage Source Type Use Case Narrative

3.3.2.4 Manage Source

Use Case ID:	4		
Use Case Name:	Manage Source		
Process Owner:	System Administrator Lab Attendant	**Last Updated By:**	NandaThilak
Date Created:	12/03/2021	**Date Last Updated:**	
Business Actor:	System Administrator, Lab Attendant		
Description:	All sources used for sample testing were define as master data		
Preconditions:	Cannot remove where sample points or sample test data are available		
Postconditions:	Cannot Delete Source where test results are available		
Performance Goal:			
Basic Workflow:	Create 1. Select Source Type 2. Input Source Details 3. Check Availability 4. Save Source Update 1. Select Source from Grid View 2. Modify relevant fields 3. Update Source Delete 1. Select Source from Grid View 2. Delete Selected Source		

Table 3.4: Manage Source Use Case Narrative

3.3.2.5 Manage Scheme Source Mapping

Use Case ID:	5		
Use Case Name:	Manage Scheme Source Mapping		
Process Owner:	System Administrator Lab Attendant	**Last Updated By:**	NandaThilak
Date Created:	12/03/2021	**Date Last Updated:**	
Business Actor:	System Administrator, Lab Attendant		
Description:	Defined source and scheme were mapped for the relevant RSC, Region and Cost Centre. It will helpful for the data capturing process of the sample test results		
Preconditions:	Source can map for different schemes		
Postconditions:	Mapping relation used to retrieve the source for selected scheme		
Performance Goal:			
Basic Workflow:	Create 1. Select Scheme & Source 2. Enter other details 3. Save Scheme Source Mapping Update 1. Select Scheme 2. Select Update Source 3. Modify data 4. Save Delete 1. Select Scheme & Source 2. Delete		

Table 3.5: Manage Scheme Source Mapping Use Case Narrative

3.3.2.6 Manage Sample Points

Use Case ID:	6		
Use Case Name:	Manage Sample Points		
Process Owner:	System Administrator Lab Attendant	**Last Updated By:**	NandaThilak
Date Created:	12/03/2021	**Date Last Updated:**	
Business Actor:	System Administrator, Lab Attendant		
Description:	Sample Points are defined before capture the test results. Sample point can be change time to time.		
Preconditions:	Cannot capture test result without sample point		
Postconditions:	Test results analyse based on the sample points		
Performance Goal:			
Basic Workflow:	Create 1. Select Region, Cost Centre, Scheme, Source 2. Enter Sample Point Details 3. Save Sample Point Update 1. Select Region, Cost Centre, Scheme, Source 2. View Sample Points in Grid View 3. Select Sample Point 4. Modify required fields 5. Save Sample Point Delete 1. Select Region, Cost Centre, Scheme, Source 2. View Sample Points in Grid View 3. Select Required Sample Point 4. Delete Record		

Table 3.6: Manage Sample Point Use Case Narrative

3.3.2.7 Manage Parameters

Use Case ID:	7		
Use Case Name:	Manage Parameters		
Process Owner:	Lab Attendant	**Last Updated By:**	NandaThilak
Date Created:	12/03/2021	**Date Last Updated:**	
Business Actor:	Lab Attendant		
Description:	Parameters are defined with the unit and test method. These parameters are used to capture the test results		
Preconditions:	Capture test results only for define parameters		
Postconditions:	Cannot remove parameters where Tolerance, Rates and results were captured to the system		
Performance Goal:			
Basic Workflow:	Create 1. Select Analysis Type 2. Enter Parameter Details 3. Save Parameter Update 1. Select Parameter from the Grid View 2. Modify data 3. Save Parameter Delete 1. Select Parameter from the Grid View 2. Delete Record		

Table 3.7: Manage Test Parameter Use Case Narrative

3.3.2.8 Manage Parameter Tolerance

Use Case ID:	8		
Use Case Name:	Manage Parameter Tolerance		
Process Owner:	Lab Attendant	**Last Updated By:**	NandaThilak
Date Created:	12/03/2021	**Date Last Updated:**	
Business Actor:	Lab Attendant		
Description:	Tolerance are used to monitor the satisfaction level of the water sample. It uses to show un satisfaction ratio and alerts to the stakeholders		
Preconditions:	Need parameter before define Tolerance		
Postconditions:	Cannot remove Tolerance where sample data stored in the system		
Performance Goal:			
Basic Workflow:	Create 1. Select Parameter & Water Type 2. Enter Tolerance details 3. Save Tolerance Update 1. Select Tolerance form the Grid View 2. Modify data 3. Save Tolerance Delete 1. Select Tolerance from Grid View 2. Delete Record		

Table 3.8: Manage Test Parameter Tolerance Use Case Narrative

3.3.2.9 Manage Parameter Rates

Use Case ID:	9		
Use Case Name:	Manage Parameter Rates		
Process Owner:	Lab Attendant	**Last Updated By:**	NandaThilak
Date Created:	12/03/2021	**Date Last Updated:**	
Business Actor:	Lab Attendant		
Description:	Parameter rates were define based on the circular issued by the NWSDB. This is the NWSDB cost for testing the sample parameter.		
Preconditions:	Before define parameter rate, system required to enter parameter		
Postconditions:	Rates are not compulsory. There are no rates for the parameter, system shall consider the cost for testing as zero		
Performance Goal:			
Basic Workflow:	Create 1. Select Test Parameter 2. Enter Test Parameter Rate and effective Date 3. Save Test Parameter Rate Update 1. Select Test Parameter 2. Modify Record 3. Save Test Parameter Rate Expire 1. Select Test Parameter Rate 2. Expire the Rate		

Table 3.9: Manage Test Parameter Rate Use Case Narrative

3.3.2.10 Manage Sample Registration

Use Case ID:	10		
Use Case Name:	Manage Sample Registration		
Process Owner:	Lab Attendant	**Last Updated By:**	NandaThilak
Date Created:	12/03/2021	**Date Last Updated:**	
Business Actor:	Lab Attendant		
Description:	Sample received for the laboratory must be register and issue a number. This number required to trace sample within the lab or NWSDB. Number generated from the system based on the cost centre and initialized for each year.		
Preconditions:	Required to fill RSC, Region, Cost Centre, Scheme, Source and Sample point. All these data were selected through lists.		
Postconditions:	After approval cannot remove sample data		
Performance Goal:			
Basic Workflow:	Create 1. Select Region, Cost Centre, Scheme, Source & Sample Point 2. Enter Sample Data 3. Save & Register the Sample Update 1. Select Region, Cost Centre, Scheme, Source 2. View relevant Sample Points 3. Select Sample Point 4. Modify Sample Data 5. Save Sample Data Delete 1. Select Region, Cost Centre, Scheme, Source, Sample Point 2. View Sample Data 3. Delete if not Approved		

Table 3.10: Manage Sample Registration Use Case Narrative

3.3.2.11 Capture Test Results

Use Case ID:	11		
Use Case Name:	Capture Test Results		
Process Owner:	Lab Attendant	**Last Updated By:**	NandaThilak
Date Created:	12/03/2021	**Date Last Updated:**	
Business Actor:	Lab Attendant		
Description:	To capture the test result system required registered sample no. Test results are entered to the system shall be more than one labourite based on the capability of the testing.		
Preconditions:	Sample no required to proceed to entering test results		
Postconditions:	Cannot remove after approval of the test results		
Performance Goal:			
Basic Workflow:	Update 1. Select registered sample by enter registration no 2. View sample details 3. Enter Test Parameter Results 4. Save Sample data with test parameter results Delete 1. Select registered sample by enter registration no 2. View sample details 3. Check whether sample data approved 4. If not delete sample data		

Table 3.11: Capture Test Result Use Case Narrative

3.3.2.12 Approve Test Results

Use Case ID:	12		
Use Case Name:	Approve Test Results		
Process Owner:	Chemist	**Last Updated By:**	NandaThilak
Date Created:	12/03/2021	**Date Last Updated:**	
Business Actor:	Chemist		
Description:	Test results need to approve before published to the NWSDB. This approval must be important to the quality of the water and relevant remedial action must be taken from the stakeholders.		
Preconditions:	Popup the un satisfaction parameters to the user. Chemist must be check before approval.		
Postconditions:	Cannot reverse results after approval		
Performance Goal:			
Basic Workflow:	Approve 1. Select registered sample by enter registration no 2. View sample details 3. Verify with test results 4. Approve sample data		

Table 3.12: Approve Test Result Use Case Narrative

3.3.2.13 Manage Alerts

Use Case ID:	13		
Use Case Name:	Manage Alerts		
Process Owner:	Chemist, Manager	**Last Updated By:**	NandaThilak
Date Created:	12/03/2021	**Date Last Updated:**	
Business Actor:	Chemist, Manager		
Description:	Alerts are generated based on the parameter tolerance compare with the results achieved from the testing. At the approval of the test results with the selected remedial action also send to the relevant officer in NWSDB		
Preconditions:	Parameter tolerance must be defined before operation		
Postconditions:	Cannot reverse the alert which is send at the test result approval		
Performance Goal:			
Basic Workflow:	Create 1. Select Region, Cost Centre, Scheme 2. Enter Alerting person details 3. Save Alert data Update 1. Select Region, Cost Centre, Scheme 2. View Alerting persons details 3. Modify data 4. Save Alert data		

Table 3.13: Manage Alert Use Case Narrative

3.3.2.14 View Dashboards

Use Case ID:	14		
Use Case Name:	View Dashboards		
Process Owner:	Manager, Chemist	**Last Updated By:**	NandaThilak
Date Created:	12/03/2021	**Date Last Updated:**	
Business Actor:	Manager, Chemist		
Description:	Multiple dashboards are defined in the system to monitor un satisfactory of test parameters. At the mean time summary of the results, testing performance etc can be view in data as well as graphical representation.		
Preconditions:	Approved data can be view through the Dashboard. Selections are not a must. No selection mean considers results island wide		
Postconditions:	No post conditions, view only facility available		
Performance Goal:			
Basic Workflow:	View 1. Select Region, Cost Centre, Scheme, Source, Sample Point, Analysis Type, Water Type etc 2. Generate filter criteria based on the selection 3. View data using the filter criteria		

Table 3.14: View Dashboards Use Case Narrative

3.3.3 Sequence Diagrams

According to the water quality management system design, we have selected important sequence diagrams are to be present for better understanding of the system. These are categorized as follows.

Master Data

- Manage Sample Points
- Manage Parameters

Transaction Data

- Capture Test Results

Information

- View Dashboard

3.3.3.1 Manage Sample Points

Create Sample Point (Refer Figure 3.4)

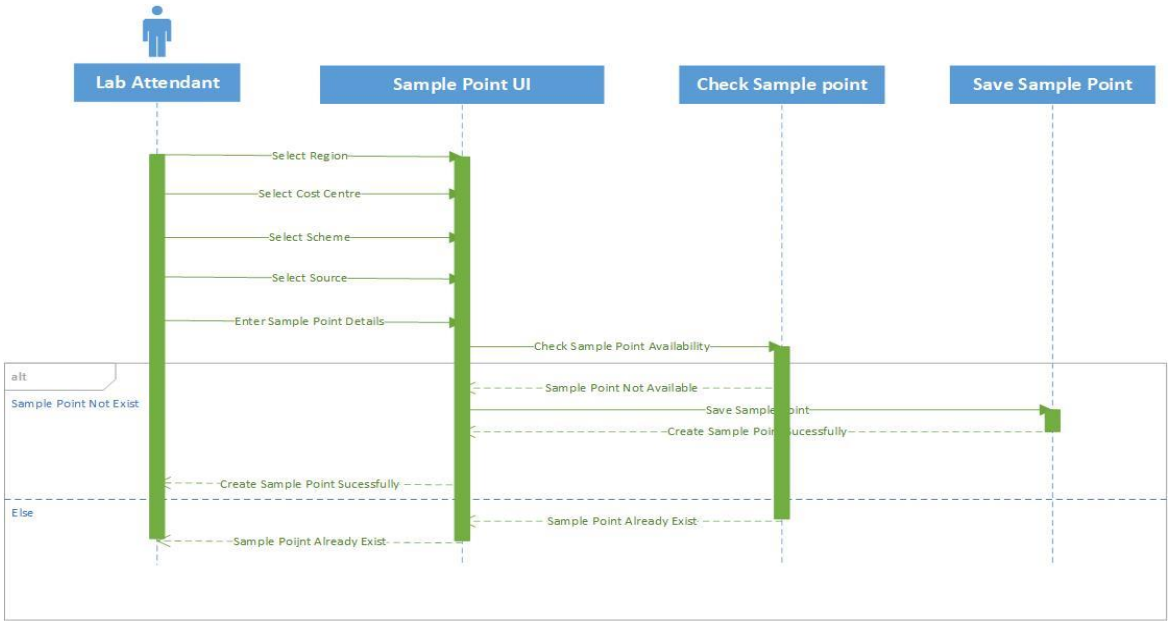


Figure 3.4: Create Sample Point Sequence Diagram

Update Sample Point (Refer Figure 3.5)

Figure 3.5: Update Sample Point Sequence Diagram

Delete Sample Point (Refer Figure 3.6)

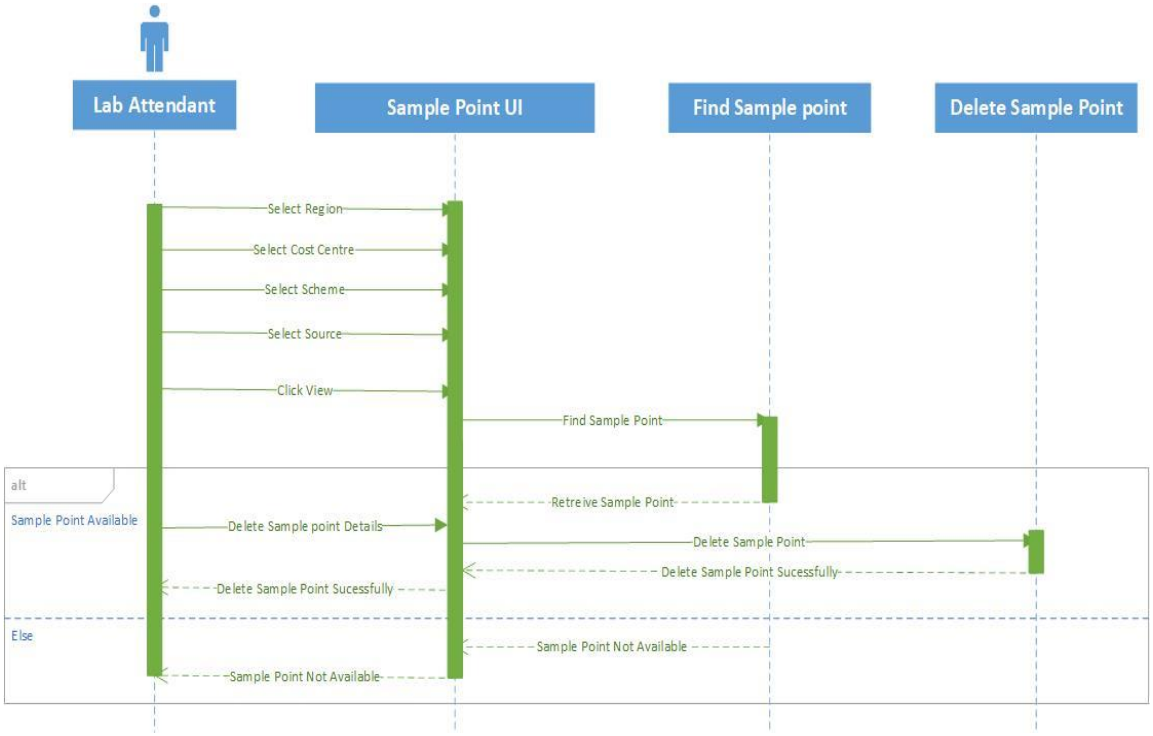


Figure 3.6: Delete Sample Point Sequence Diagram

3.3.3.2 Manage Test Parameters

Create Test Parameter (Refer Figure 3.7)

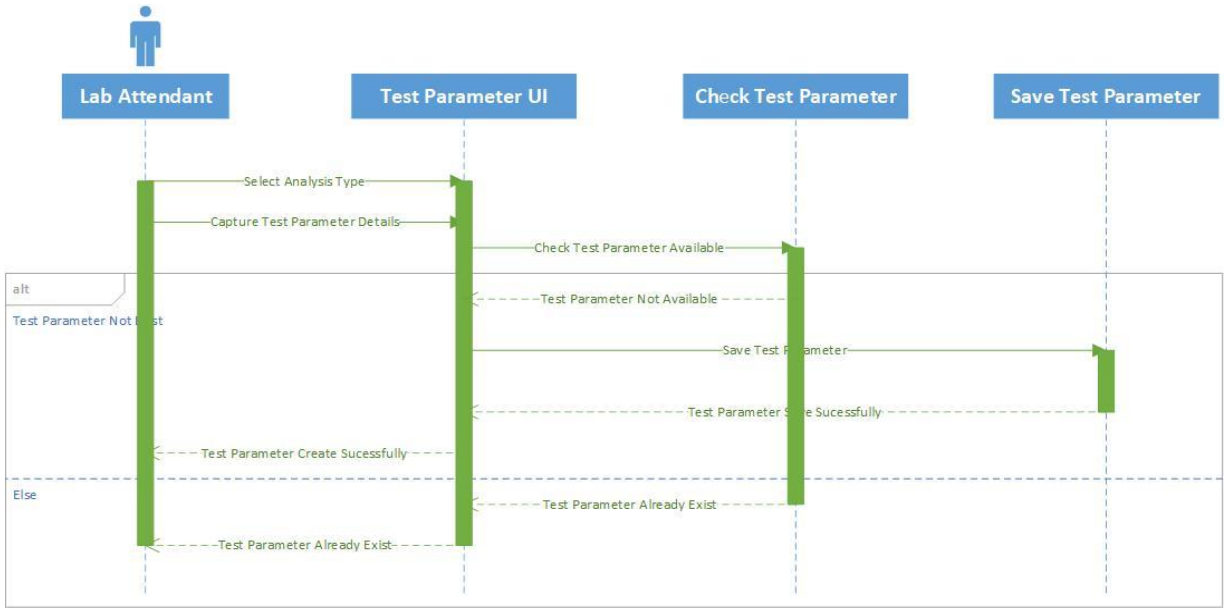


Figure 3.7: Create Test Parameter Sequence Diagram

Update Test Parameter (Refer Figure 3.8)

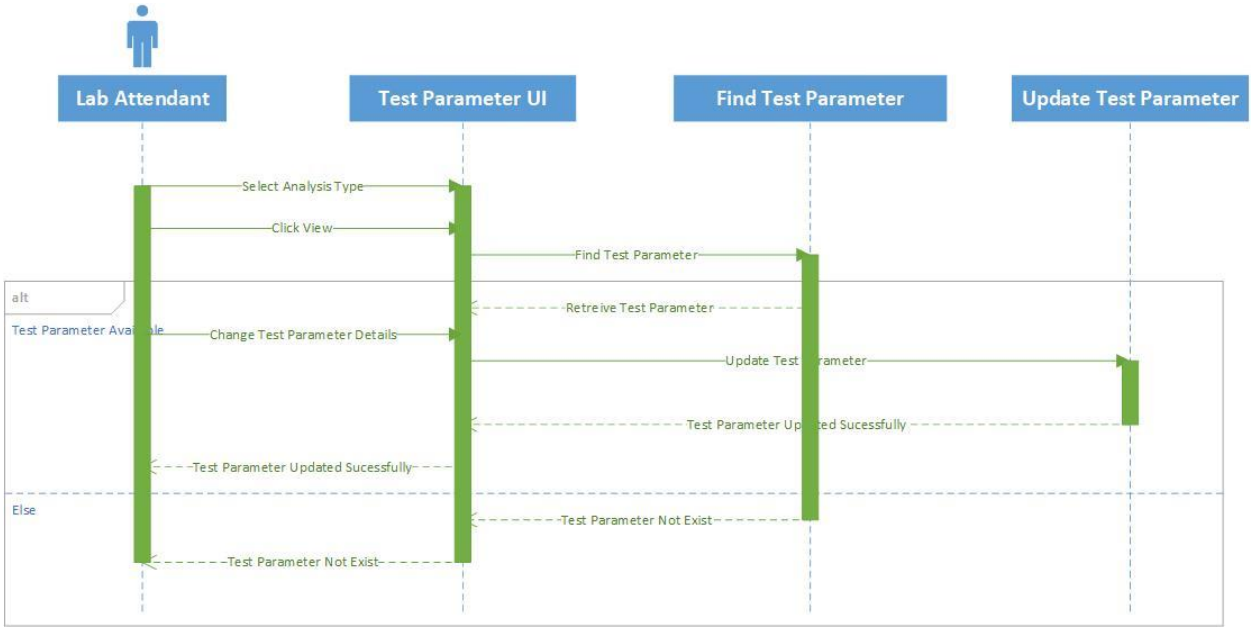


Figure 3.8: Update Test Parameter Sequence Diagram

Delete Test Parameter (Refer Figure 3.9)

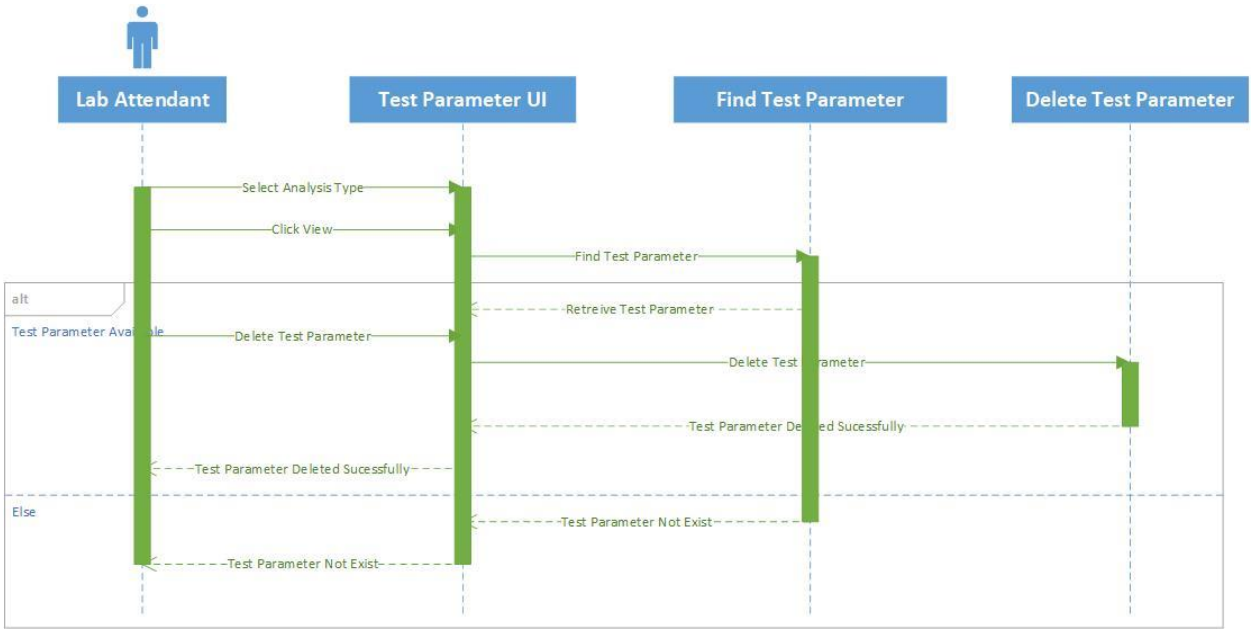


Figure 3.9: Delete Test Parameter Sequence Diagram

3.3.3.3 Manage Test Results

Update Test Results (Refer Figure 3.10)

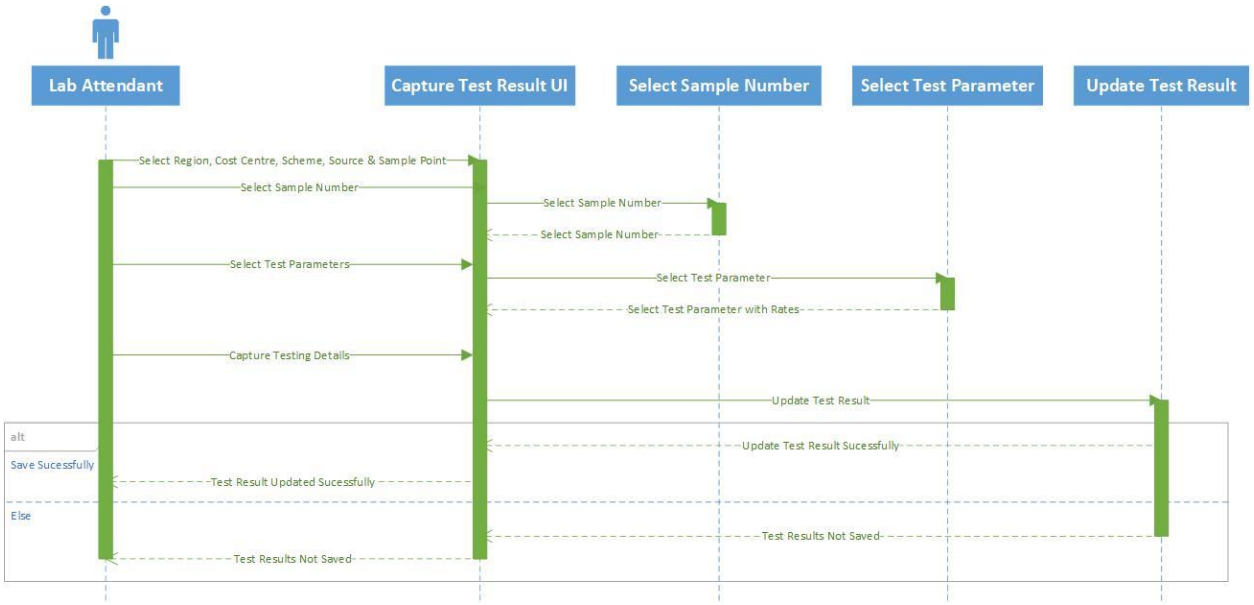


Figure 3.10: Update Test Result Sequence Diagram

Delete Test Results (Refer Figure 3.11)

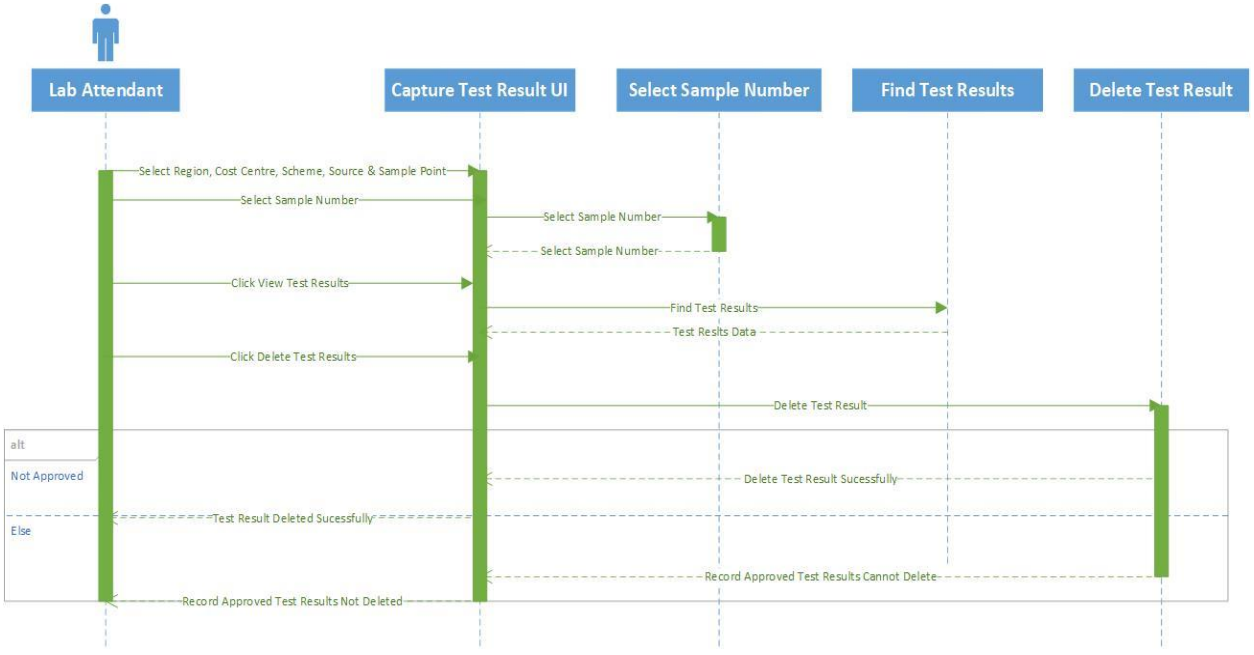


Figure 3.11: Delete Test Result Sequence Diagram

3.3.3.4 Dashboard

View Dashboard (Refer Figure 3.12)

Figure 3.12: View Dashboard Sequence Diagram

3.3.4 Class Diagram

In design stage, main purpose of class diagram is to model the static view of an application. This Class diagrams are the only diagrams which can be directly mapped with object-oriented languages and thus widely used at the time of development of the application. Also, it shows structural view of the application as well. This diagram describes attributes & methods used to develop the application in object-oriented concept.

The figure 3.13 shows the class diagram of the proposed system.

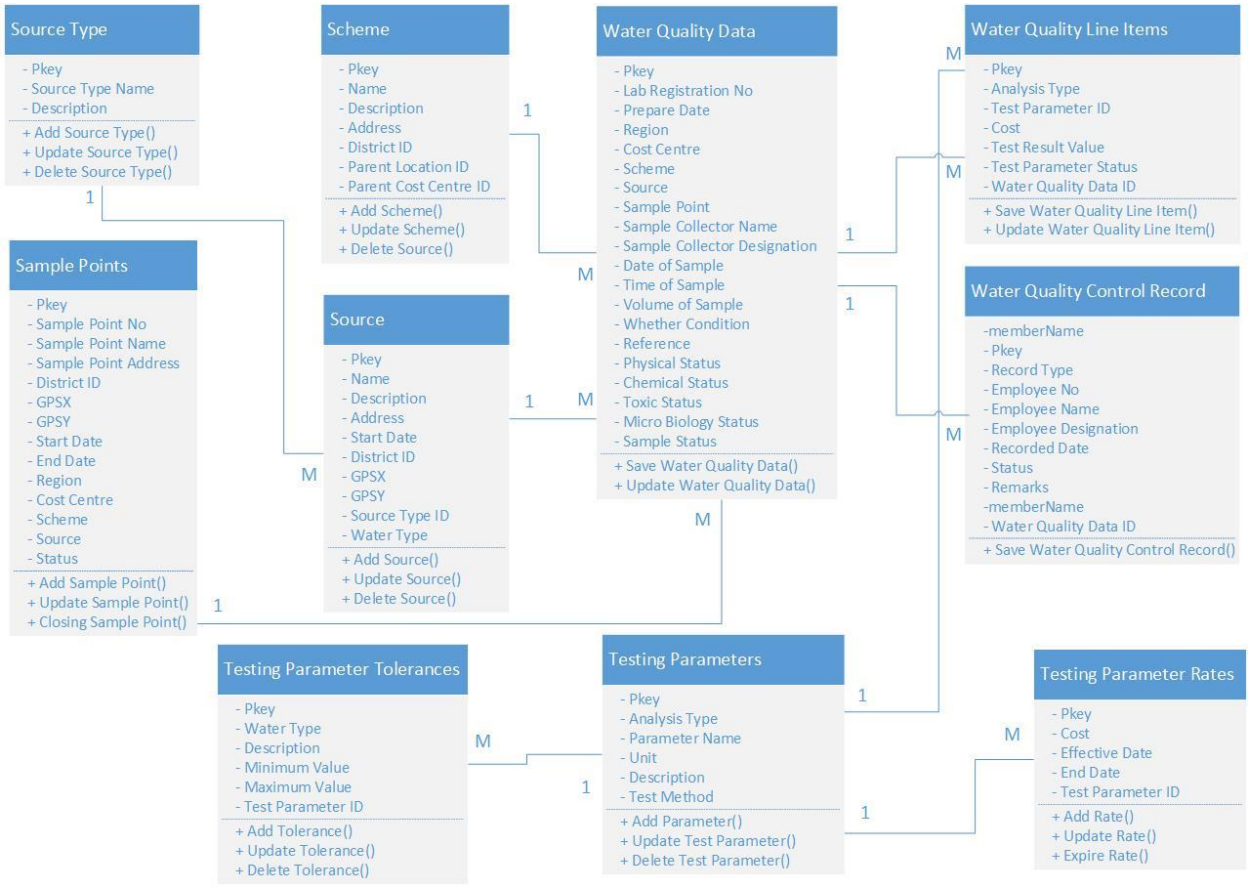


Figure 3.13: Class Diagram for Proposed System

Chapter 4 – Methodology

4.1 Introduction

This is the phase that designed software is being developed. This include all the documents, tools, techniques that are used to develop and implement the system using programming languages, scripting languages, frameworks, designing tools and techniques, database management systems, testing tools etc. Implementation stage consists of system installation (server side), technical support to end users and user training for the new system, etc.

4.2 Tools and Technologies

NWSDB has using the Microsoft technologies for their software development. Therefore very important to select software tools and technologies should be in line with NWSDB current systems. Because this product is a module that will be integrate to the existing system, therefore cannot choose any other platform and stick to the NWSDB development environment.

4.2.1 Microsoft Windows 10

Windows 10 is the newest operating system used in the organization. Therefore all developers are used this platform. This product was relative to the Windows NT family.

4.2.2 Dot net framework 4.0

The .NET Framework facilitate to managed execution environment that provides services to its running applications. This framework having two major components like, common language runtime (CLR), which is the execution engine that handles running applications hosted; and the .NET Framework Class Library, which facilitate a library of tested, reusable code that system developers can call from their applications.

4.2.3 Visual Studio 2015

Microsoft application development environment used to develop User Interfaces of the system. Also used to integrate other tools and the core modules developed in NWSDB.

4.2.4 DHTML Menu

This is the 3rd party product available in the market to generate java script-based menu can used in visual studio. These menu scripts are embedded in development tool.

4.2.5 Hibernate

This is the open-source product available in the market. This product was used to map objects to relational database. This is the method used to implement object-oriented concept with the relational database by using xml file and the classes in the system.

4.2.6 Microsoft SQL Server 2014

Microsoft SQL Server is a relational database management system developed by Microsoft. As a database server, it is a software product with the primary function of storing and retrieving data as requested by other software applications. This product was run either on the same computer or on another computer across a network

4.3 Hardware and Software Requirements

The web-based system required web server and the client machine to run the solution. Organization datacentre maintained by VMware technology to maintain virtual servers to manage systems.

4.3.1 Server Installations

- **Windows Server 2012**

  This is the sixth version of the Windows Server operating system by Microsoft, as part of the Windows NT family of operating systems. This product was used to manage web server for the solution.

- **IIS Server**

  Internet Information Services is extensible web server software created by Microsoft for use with the Windows NT family. IIS supports HTTP, HTTP/2, and HTTPS, FTP, FTPS, SMTP and NNTP.

- **SQL Server 2014**

  Microsoft SQL Server is used to maintain water quality database with the integration of HRM system. This product is used throughout the organization as unique database tool.

4.3.2 Client Installation

Client machines (end user) are windows 10 operating system with the internet explorer as a web browser. There is no any special installation required to manage to run the solution.

4.4 Modularity of the System

Water Quality Management system designed and developed to integrate with the current ERP solution operated in the NWSDB. Therefore some of the key products need to integrate with the new development which will provide reusability and the integrity of the final product. These key integrated modules are as follows.

- **Human Resource Management Module (HRM)**

  This module keeps all human resource details of the organization. System login are maintained with the validity of the employment. When confirmed login provide all information of the employee and retrieve as an object to the integrated solution.

- **Development Framework**

  Organization maintains the development framework which is developed and deployed as dynamic link library. This library facilitate for module integrated and development standard throughout the organization. There is maximum capability of reusability shown in this method and reduce cost factor of the development work.

- **Reporting functionality**

  All reports are standardized base on the crystal report format. All heading, body and the footer are in same structure. Object data source is the data input for the reporting module.

4.5 High Level Programming

According to the standard of the NWSDB, water quality management system development using the user interface and the module packages developed separately and integrated to the core system. User interfaces are developed from HTML5 and the tools available in the framework and the visual studio tool box component.

Module packages are totally couple with the following layers as follows

- User interface layer (IL) – Refer Figure 4.1

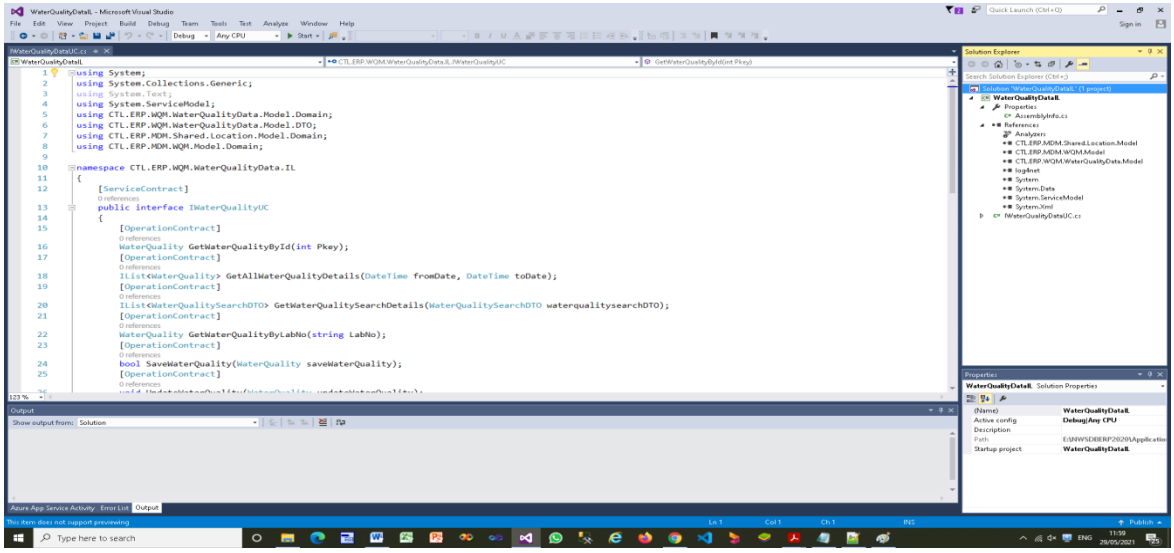


Figure 4.1: User Interface Layer for Proposed System

- Application layer (AL) – Refer Figure 4.2

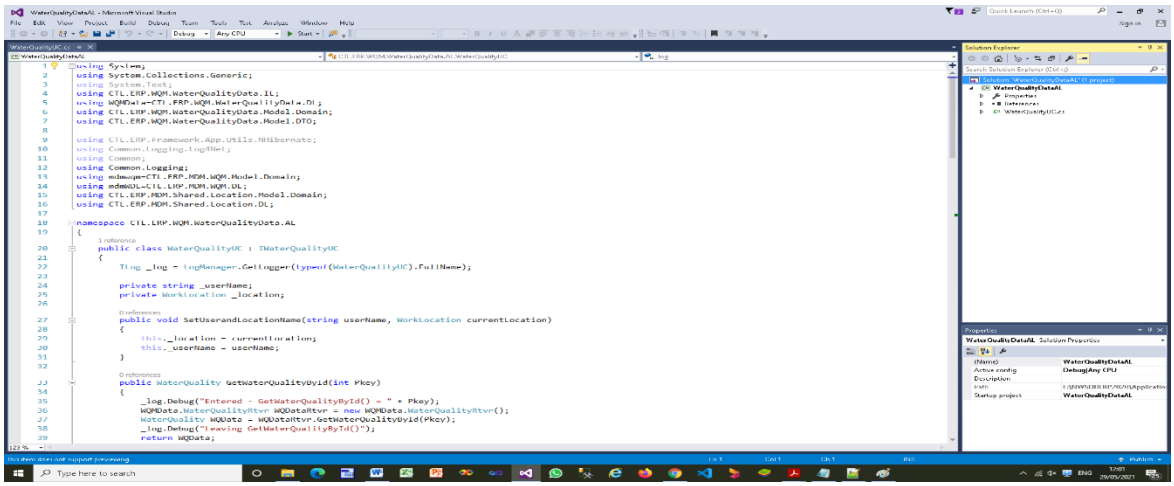


Figure 4.2: Application Layer for Proposed System

- Data mapping layer (DL) – Refer Figure 4.3

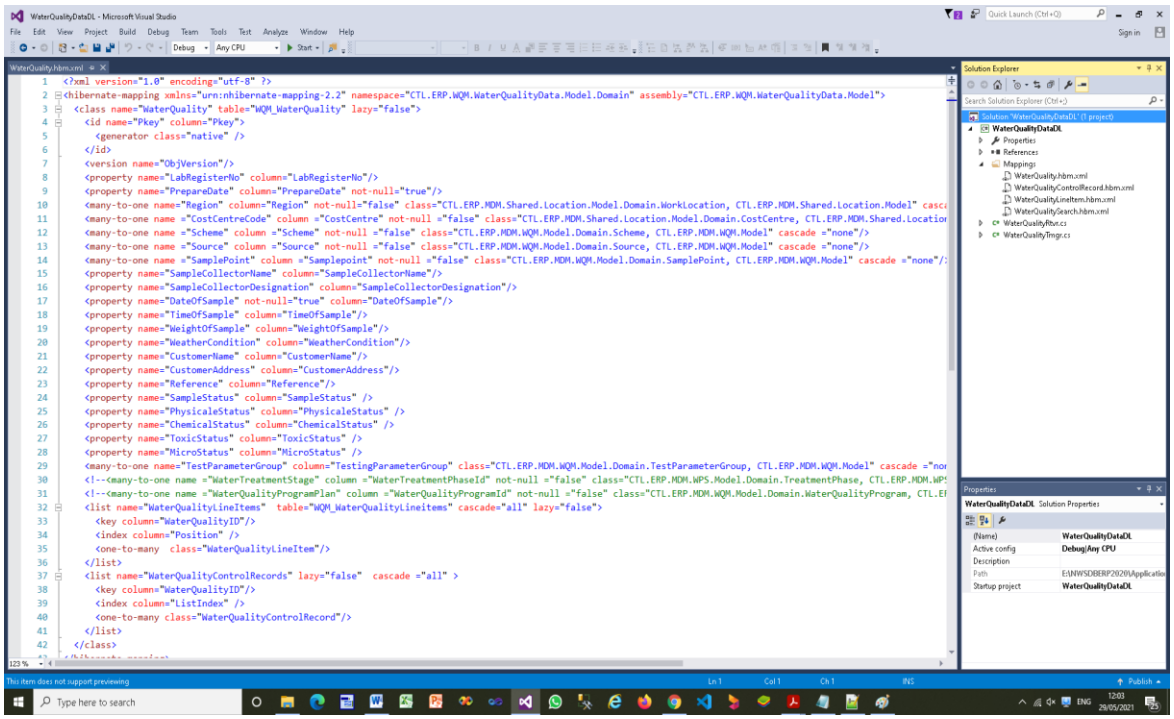


Figure 4.3: Data Mapping Layer for Proposed System

- Domain layer

Definition of classes and other objects (Model) – Refer Figure 4.4

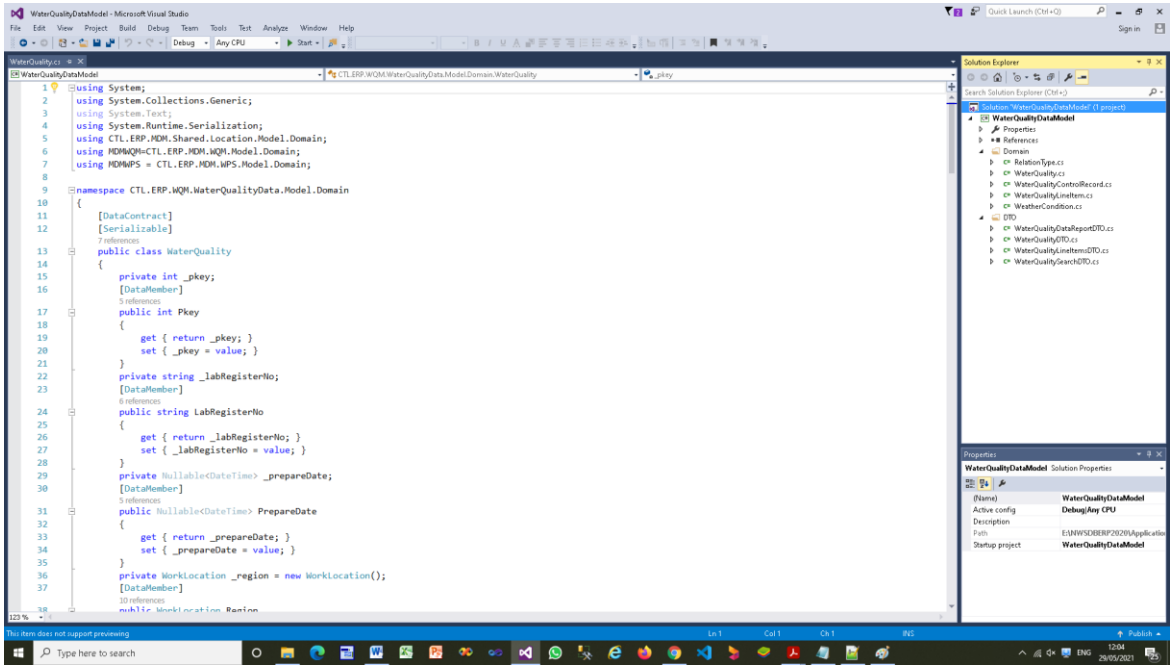


Figure 4.4: Domain Layer for Proposed System

These four packages are used in the user interface development as a communicator between relational database and classes.

During the implementation of the database of the water quality management system following relational database diagram was designed as follows; (Refer Figure 45)

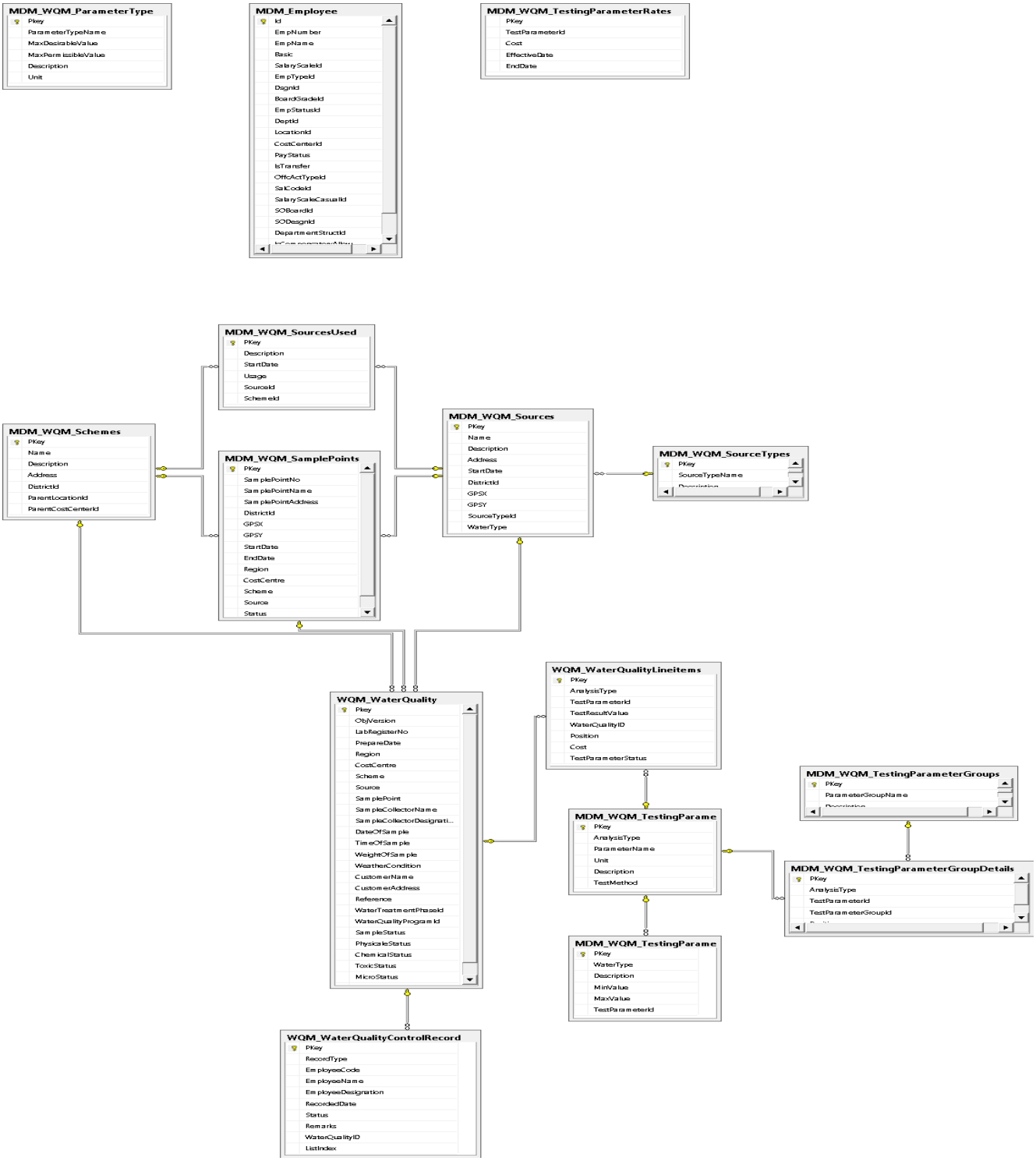


Figure 4.5: Database Structure for Proposed System

Chapter 5 - Testing and Evaluation

5.1 Introduction

Software testing is the process of verifying a system with the purpose of identifying any errors, gaps or missing requirement compare with the actual requirement. Software testing is broadly categorised into two types called functional testing and non-functional testing. There is another method of testing called Maintenance Testing. The diagrammatical representation of the method shown as follows.

5.2 System Testing Methods

There are proven methods of testing of software product are introduce early ages of software Engineering. After following these steps end users shall provide acceptance of the system and ready for the online operation.

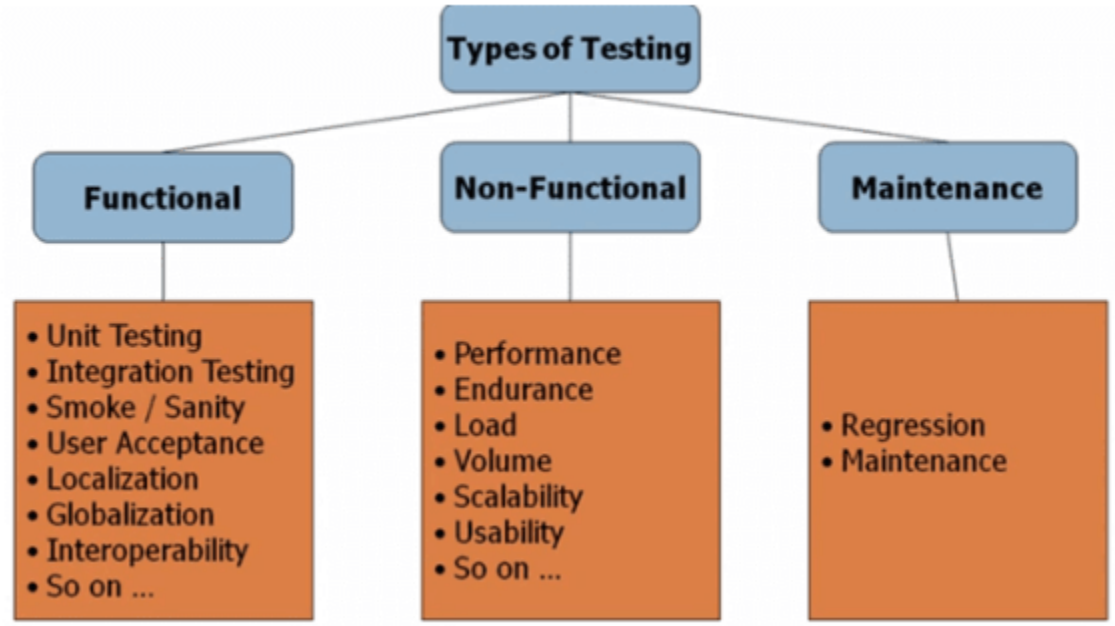


Figure 5.1: Software Testing Types

Figure 5.1 shows the system testing methods used for the project.

To fulfill the testing requirement 3 types of testing methods proposed to test the system. These three types are

- Functional Testing
- Non-functional Testing
- Maintenance Testing

5.3 Functional Testing

This is a type of software testing that validates the software system against the functional requirements and specifications. Purpose of the functional tests is to test each function of the software application, by providing appropriate input, verifying the output against the Functional requirements. To do this need to setup the test plan and proceed and complete the testing phase of the software system.

5.3.1 Test Plan

A Test Plan is a detailed document that describes the test strategy, objectives, schedule, estimation, deliverables, and resources required to perform testing for a software product. Test Plan is determining the effort needed to validate the quality of the application under test.

Water Quality Management System has several inputs which are needed to test for the accuracy. I have selected the important areas and documented as follows.

5.3.1.1 System Login

Test plan for the system login defined in Table 5.1

No	Function	Testing Process	Required Test Output	Priority
1	Login to the application not an employee	Insert employee ID and Password	Invalid user, not authorized	High
2	Login to the system without employee ID or the password	Not enter employee ID or the Password	Ask user to input login details	Low
3	Login to the system without employee ID	Input password only	Ask user to enter employee ID	Medium
4	Login to the system without password	Input employee ID only	Ask user to enter password	Medium
5	Login to the system incorrect Password	Incorrect password	Give a message as incorrect password	High
6	Login to the system with correct employee ID and password	Check user exist in employee table	Login to the system with displaying employee name and the work location	High

Table 5.1: System Login Interface Test Plan

5.3.1.2 Define Schemes

Test plan for the scheme definition defined in Table 5.2

No	Function	Testing Process	Required Test Output	Priority
1	Add without RSC	Without selecting RSC	Ask user to input RSC	Medium
2	Add without Region	Without selecting Region	Ask user to select Region	Medium
3	Add without Cost Center	Without selecting Cost Center	Ask user to select cost center	Medium
4	Add without Scheme name	Without entering Scheme Name	Ask user to enter Scheme name	High
5	Add available Scheme Name	Check Scheme Name	Warn user to Scheme name exist	High
6	Add blank Scheme name	Check Scheme name blank	Warn user to enter Scheme name	High

Table 5.2: Define Scheme Test Plan

5.3.1.3 Define Test Parameters

Test plan for the Test Parameter definition define in Table 5.3

No	Function	Testing Process	Required Test Output	Priority
1	Add without Analysis Type	Without selecting Analysis Type	Ask user to select Analysis Type	Medium
2	Add without Parameter Name	Without entering Parameter Name	Ask user to enter Parameter Name	High
3	Add without Parameter Description	Without entering Parameter Description	Ask user to enter Parameter Description	High
4	Add available Parameter Name	Check Parameter Name	Warn user to Parameter Name exist	High
5	Add blank Parameter Name	Check Parameter Name blank	Warn user to enter Parameter Name	High

Table 5.3: Define Test Parameters Test Plan

5.3.1.4 Define Test Parameter Tolerances

Test plan for the Test Parameter Tolerances definition define in Table 5.4

No	Function	Testing Process	Required Test Output	Priority
1	Add without Water Type	Without selecting Water Type	Ask user to select Water Type	Medium
2	Add without Test Parameter	Without selecting Test Parameter	Ask user to select Test Parameter	Medium
3	Add without Description	Without entering Description	Ask user to enter Description	Medium
4	Add without Minimum Value	Without entering Minimum Value	Ask user to enter Minimum Value	High
5	Add without Maximum Value	Without entering Maximum Value	Ask user to enter Maximum Value	High

Table 5.4: Define Test Parameter Tolerances Test Plan

5.3.1.5 Sample Registration

Test plan for the Sample Registration in Table 5.5

No	Function	Testing Process	Required Test Output	Priority
1	Click “Register” button	Without click “Register” button	User cannot Register Sample, Save Button Disabled	High
2	Add without RSC	Without selecting RSC	Ask user to select RSC, Region, Scheme, Source, Sample Point	Medium
3	Add without Region	Without selecting Region	Ask user to select Region, Scheme, Source, Sample Point	Medium
4	Add without Scheme	Without selecting Scheme	Ask user to select Scheme, Source, Sample Point	Medium
5	Add without Source	Without selecting Source	Ask user to select Source, Sample Point	Medium
6	Add without Sample Point	Without selecting Sample Point	Ask user to select Sample Point	Medium
7	Add without Sample Date	Change Sample Date as Blank	Ask user to enter Sample Date	High

Table 5.5: Sample Registration Test Plan

5.3.2 Test Cases

A test case has components that describe input, action and an expected response, in order to determine if a feature of an application is working correctly. A test case is a set of instructions on “HOW” to validate a particular test objective/target, which when followed will tell us if the expected behavior of the system is satisfied or not. (Anon., 2021)

Accordingly, I have designed a format to record the test cases which are important to check the system. These test cases are execute based on the test plan developed in the above section. For the documentation purpose “Sample Registration Test Plan” which was defined in Table 5.5 was executed and recorded the results as follows.

Table 5.5 Test case for without click Register button in Sample Registration process described in Table 5.6

Test Case No	01
Module Name	Sample Registration
Test Case	Without click “Register” button
Required Test Output	User cannot Register Sample, Save Button Disabled

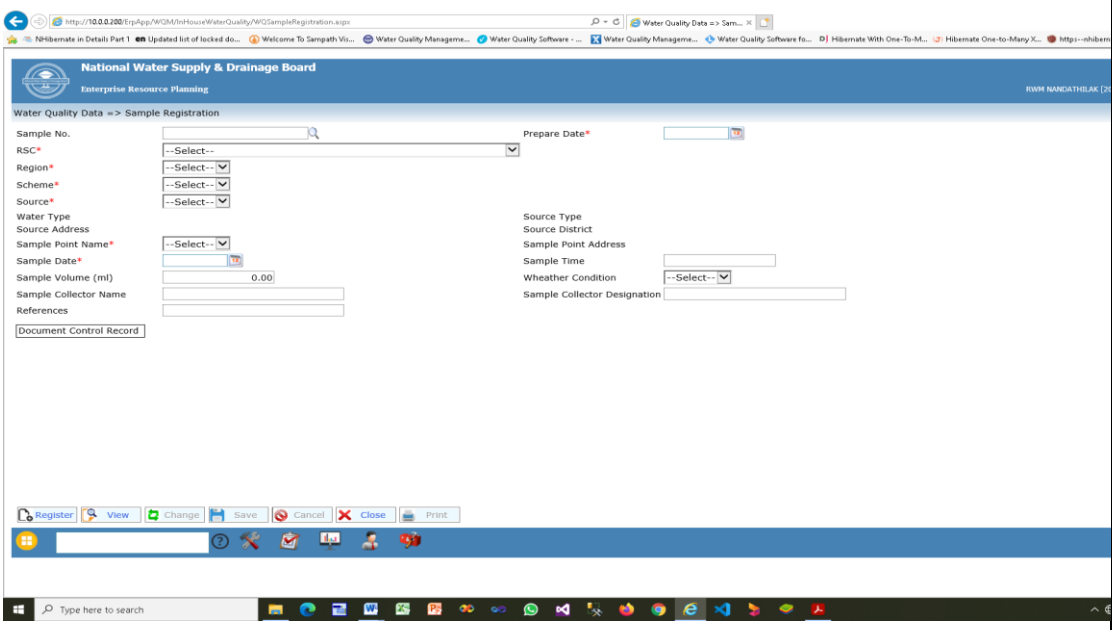
Result Output	Status
	Pass

Table 5.6: Save without click Register button

Table 5.5 Test cases for without selecting RSC in Sample Registration process described in Table 5.7

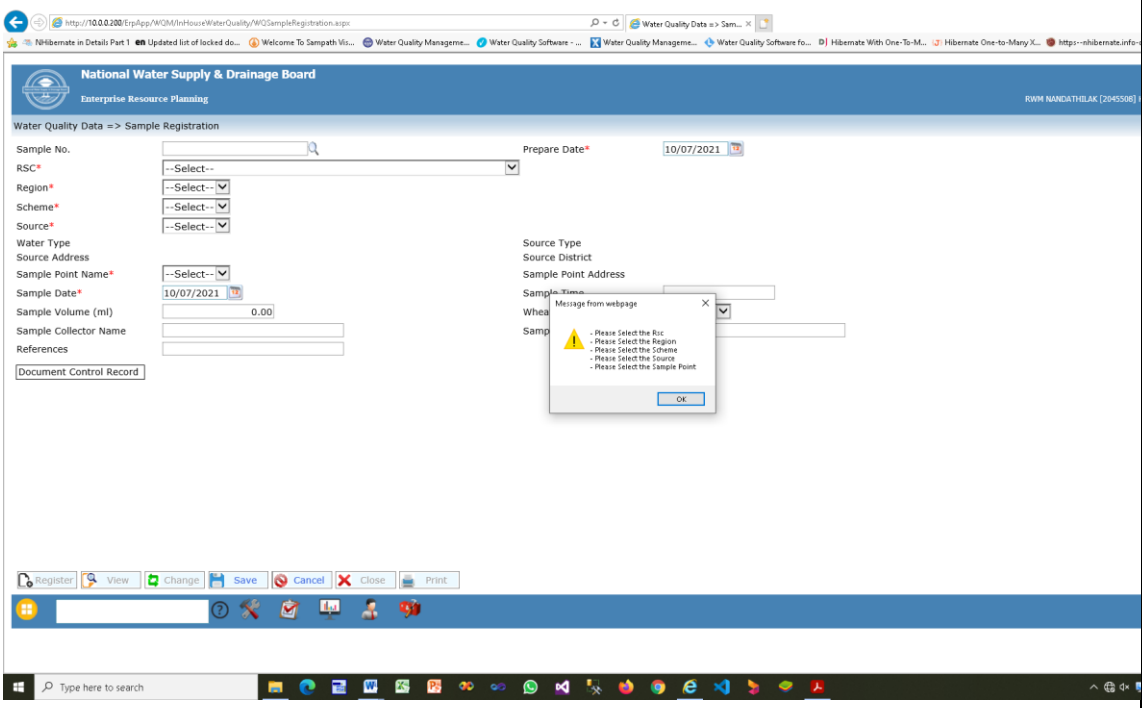
Test Case No	02	
Module Name	Sample Registration	
Test Case	Without selecting RSC	
Required Test Output	Ask user to select RSC, Region, Scheme, Source, Sample Point	
Result Output		Status
		Pass

Table 5.7: Save without Selecting RSC

Table 5.5 Test case for without selecting Region in Sample Registration process described in Table 5.8

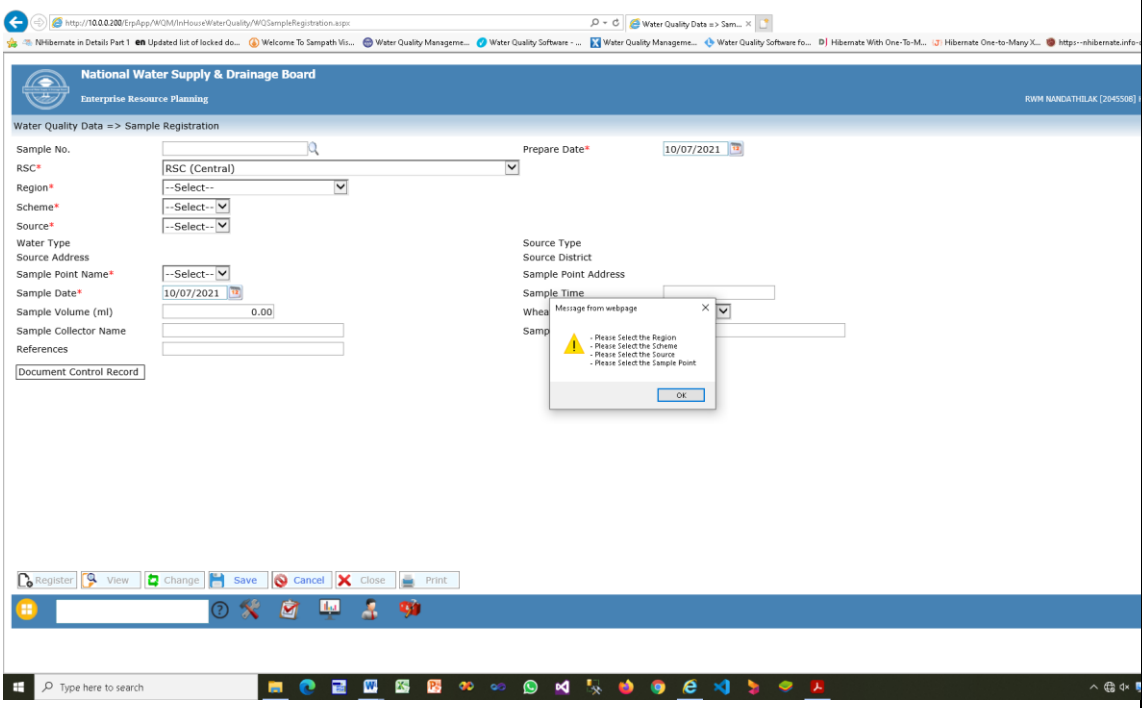
Test Case No	03	
Module Name	Sample Registration	
Test Case	Without selecting Region	
Required Test Output	Ask user to select Region, Scheme, Source, Sample Point	
Result Output		Status
		Pass

Table 5.8: Save without Selecting Region

Table 5.5 Test case for without selecting Scheme in Sample Registration process described in Table 5.9

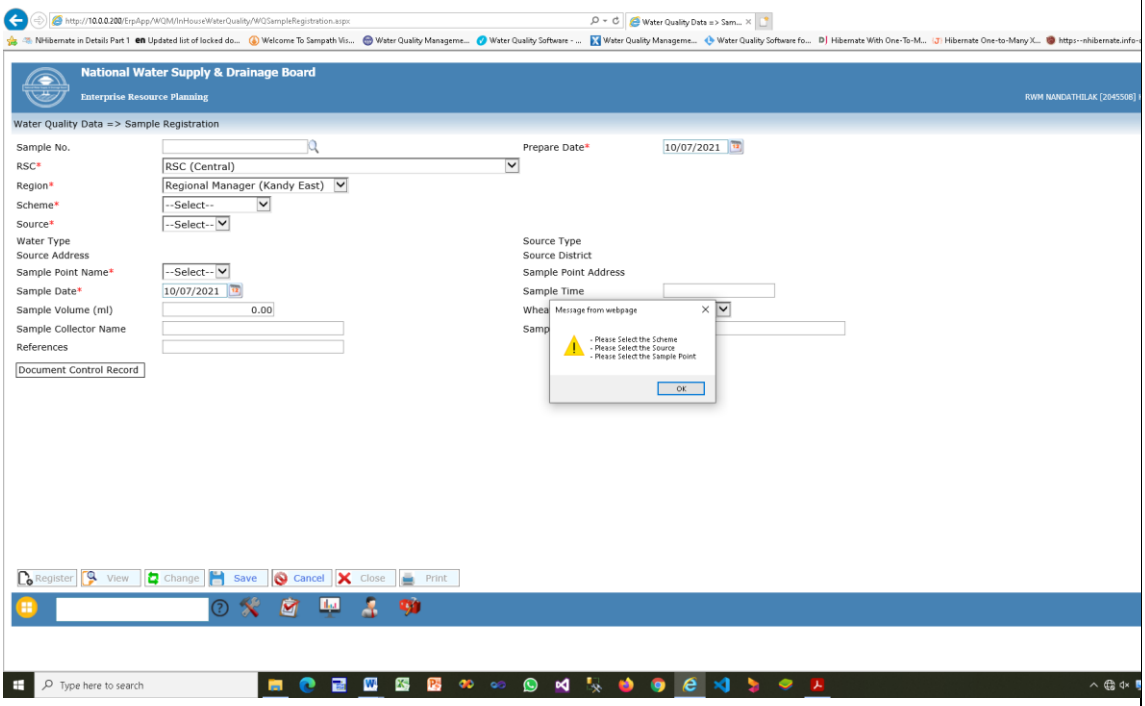
Test Case No	04	
Module Name	Sample Registration	
Test Case	Without selecting Scheme	
Required Test Output	Ask user to select Scheme, Source, Sample Point	
Result Output		Status
		Pass

Table 5.9: Save without Selecting Scheme

Table 5.5 Test case for without selecting Source in Sample Registration process described in Table 5.10

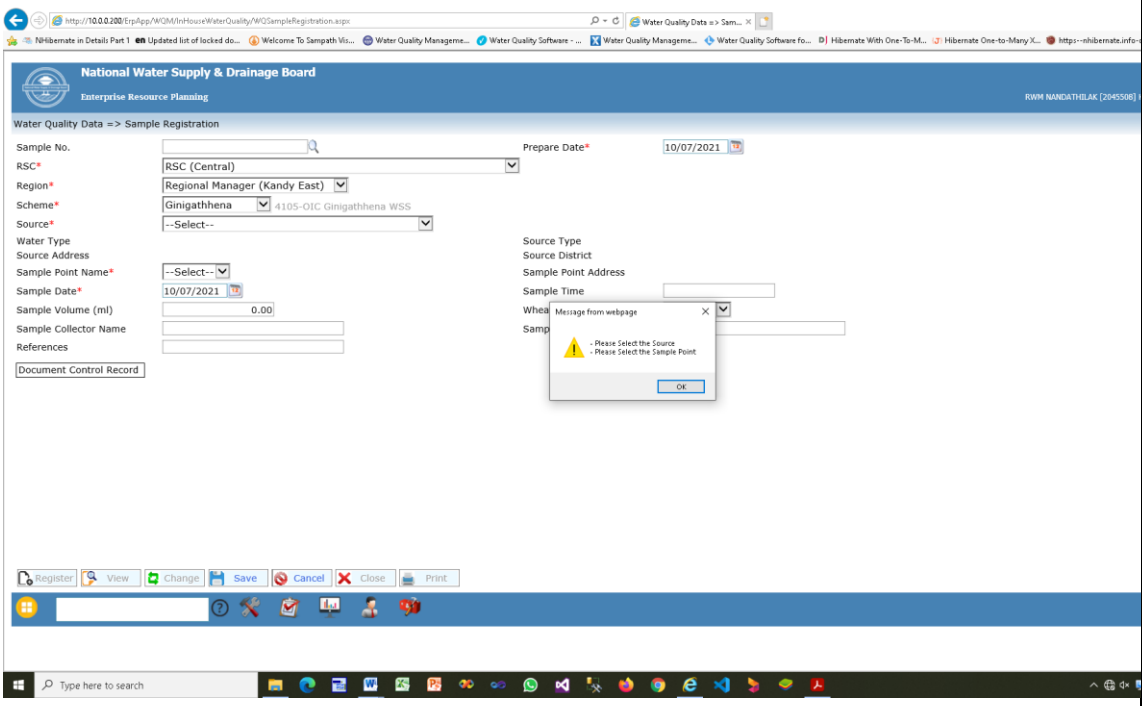
Test Case No	05	
Module Name	Sample Registration	
Test Case	Without selecting Source	
Required Test Output	Ask user to select Source, Sample Point	
Result Output		Status
		Pass

Table 5.10: Save without Selecting Source

Table 5.5 Test case for without selecting Sample Point in Sample Registration process described in Table 5.11

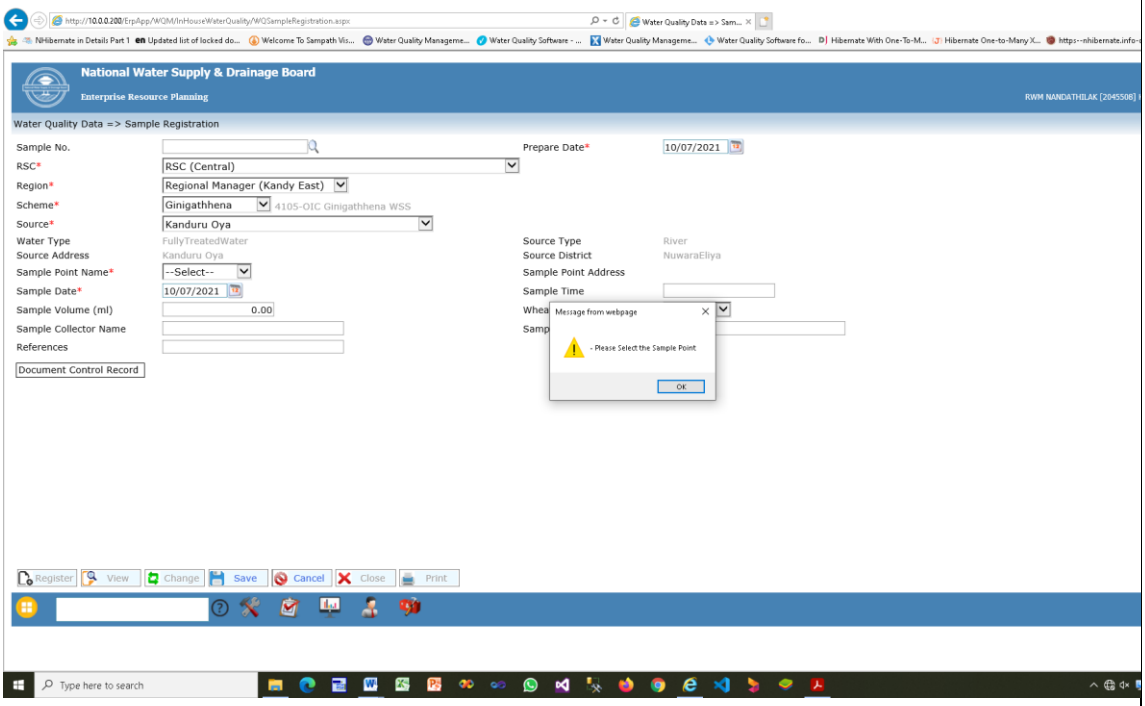
Test Case No	06	
Module Name	Sample Registration	
Test Case	Without selecting Sample Point	
Required Test Output	Ask user to select Sample Point	
Result Output		Status
		Pass

Table 5.11: Save without Selecting Sample Point

Table 5.5 Test case for without enter Sample Date in Sample Registration process described in Table 5.12

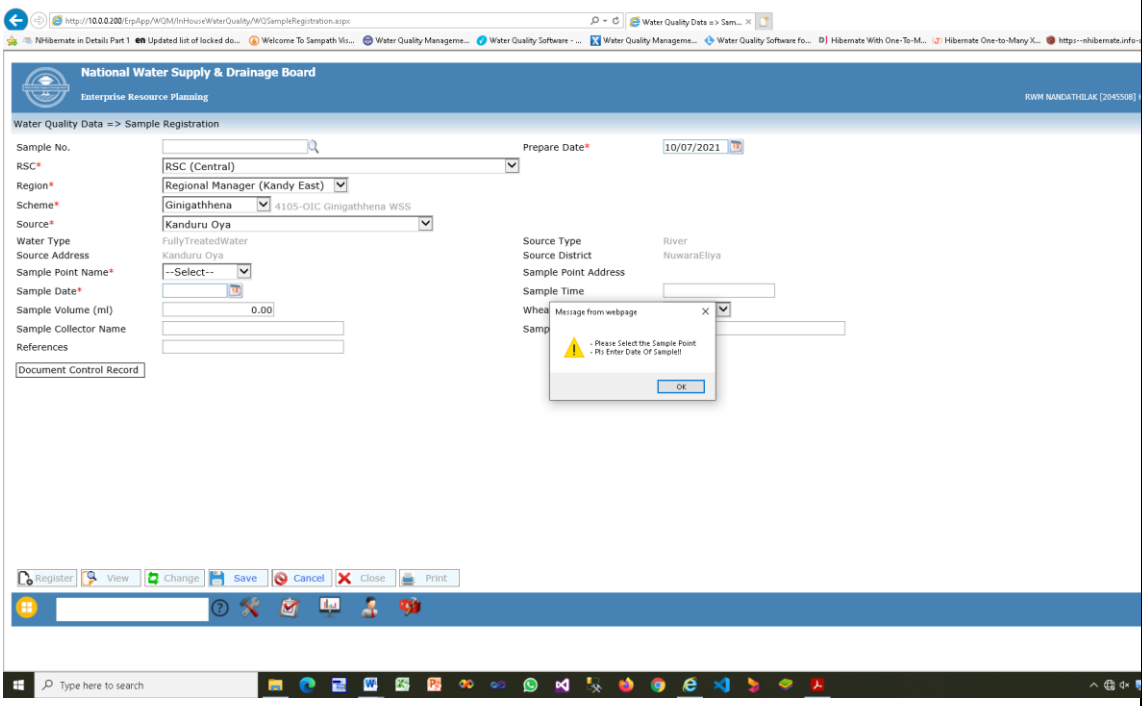
Test Case No	07	
Module Name	Sample Registration	
Test Case	Without enter Sample Date	
Required Test Output	Ask user to enter Sample Date	
Result Output		Status
		Pass

Table 5.12: Save without Entering Sample Date

5.4 Non-Functional Testing

Non-functional testing is defined as a type of Software testing to check non-functional aspects (performance, usability, reliability, etc.) of a software application developed. It is designed to test the readiness of a system as per nonfunctional parameters which are never reviewed by functional testing.

There are key parameters to be check for the readiness of the system. These key parameters are shown in Figure 5.2

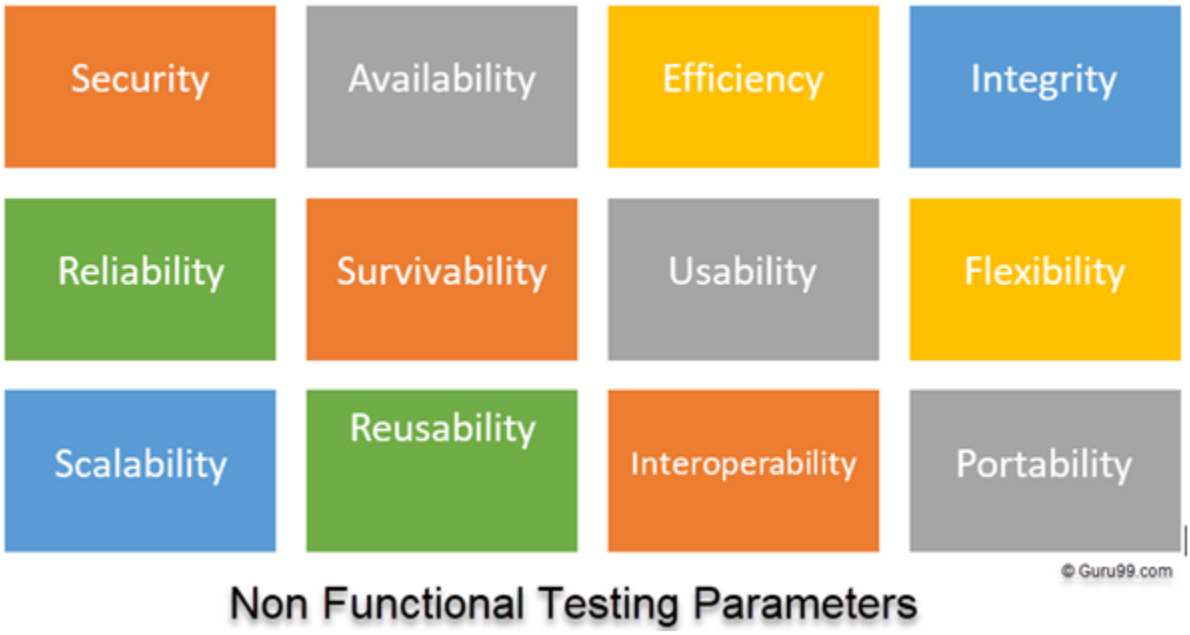


Figure 5.2: Non-Functional Testing Parameters

Some of the important parameters are used to test the project.

5.4.1 Security Testing

In security of the solution followings were checked

- Login to the system with active employees for valid employee no and password
- Can manage Scheme details
- Can manage testing parameters
- Can manage water quality data

5.4.2 Usability Testing

In this process usability testing was conducted based on following instances

5.4.2.1 Onsite usability testing

Central laboratory is the main division used this system to capture testing results and monitor all operations island-wide. As operational users (Chemist) of the lab have used to operate the workflow of the system simultaneously and monitor throughout the process and identify the usability issues.

5.4.2.2 Remote usability testing

There are 36 Laboratories Island wide with more than 36 users to do operational activities like register, capture and approve sample testing to the system. This process was closely monitored by using system logs and the database logs.

5.4.3 Performance Testing

Performance of the product revolves around speed, response time, load time and scalability.

- Speed testing

  As a web based solution measure the startup time for all lab user's login simultaneously to the system and select the test result capturing screen. This was done and most of the locations get less than 10 second result. The best time recorded as 9 second in central laboratory.

- Response time

  In this solution test result capturing is the most important screen. There are selections of information, input data and verify the information within this transaction screen. To check the response time 5 lab users were selected in the network and check for the input data and save data to the system. All users are completed the transaction less than 2 minute. The best time recorded from Western South Laboratory to input the test result in 1.75 minute.

- Scalability testing

  To check the scalability of the product required to log all type of users and complete their transactions and record the time duration. Following Table 5.13 shows the analysis of the results for completion of the transaction.

No.	Transaction Type	No of Users	Time Taken to Complete the Txn.	Status
1	Master Data	5	50 S	Good
2	Transaction Data	25	90 S	Average
3	Dashboard	5	25 S	Good
4	Reporting	10	60 S	Good

Table 5.13: Analysis of the results for execute of transaction

5.5 Maintenance Testing

Maintenance testing occurred due to following reasons.

- Software runs many years after their first released.
- New requirement requested from the end-users to update existing software.
- Changes of operating system, database etc.
- New changes in technology and required to update software.

These changes need to be tested thoroughly. The two testing type that is done during this upgrading or enhancing or migration phase is known as maintenance testing.

- Confirmation Testing

  During this confirmation testing, all the modifications (either big or small) made in the software thoroughly and make sure that there are no functionality issues and downtime. There is no modification during this implementation stage.

- Regression Testing

  The need of the regression testing required for whenever there is requirement to change the code and necessary to test whether the modified code affects the other part of software application or not. When this scenario happens no need to test all test cases but need to test selected test cases which required to confirm the solution running without any errors. There is no new requirement or minor changes requested during the implementation stage. Therefore, regression testing not required executing right now.

5.6 User Evaluation

The purpose of project evaluation is to assess the software development methodology that was used throughout the development of the application, assess the usefulness of the technologies, tools, accuracy of the estimations and the usefulness of the reviews. The solution shall be reviewed and evaluated to decide whether it achieves the ideas presented in the initial overview and for the quality of the software application.

Software engineering model used in this project was RAD model. User evaluation for each delivery was obtained by the client at the time the modules were delivered. They were mainly review meetings and the feedback obtained was used in corrective maintenance or change management.

According to the prepared list of criteria and practical experimentation, a software evaluation makes it possible to check whether the project purposes were satisfied. Figure 5.3 was designed to collect feedback from the end users of the system. This was distributed between the users to get their feedback anonymously. The assessor evaluated the returned forms in order to obtain the actual feedback of the users and to assess that the project purposes have been met. Analysing, a measurement against likers scale was used to quantify the feedback and the values allocated parameters are as follows.

- Poor = 1
- Fair = 2
- Satisfactory = 3
- Good = 4
- Excellent = 5

Water Quality Management System for NWSDB Software Evaluation Form		
	Parameter	**Rating**
Appearance		10
	User Interfaces are attractive	4
	Background colours and colour combination used	2
	Font sizes are compatible and readable	4
Usability		**25**
	Screens are easy to navigate	5
	Menus are easy to understand	5
	Data validations are satisfied	5
	The requested dashboards/results are successful	10
Functionality		**25**
	Accuracy of test parameter results	10
	Displaying History water quality data	5
	Displaying unsatisfactory results	5
	Registration of sample in the system	5
Performance		**20**
	Time taken to retrieve data	10
	Response time for request's events	10
Security		**20**
	Date security	10
	User access rights	10
Total		**100**

Figure 5.3: Software Evaluation Form

5.7 User Evaluation Outcome

According to the feedback results following graphs have been generated and analysed. Important circumstances have been described below with the graphical results of the feedback.

5.7.1 Appearance

Table 5.14 shows evaluation results for the criteria of **Appearance** related to User Interfaces are attractive of water quality management system and graphical view shown in Figure 5.4

Likers Option	**Result**	**Percentage**
Excellent	8	27
Good	12	40
Satisfactory	5	17
Fair	3	10
Poor	1	3

Table 5.14: Evaluation Result for Appearance

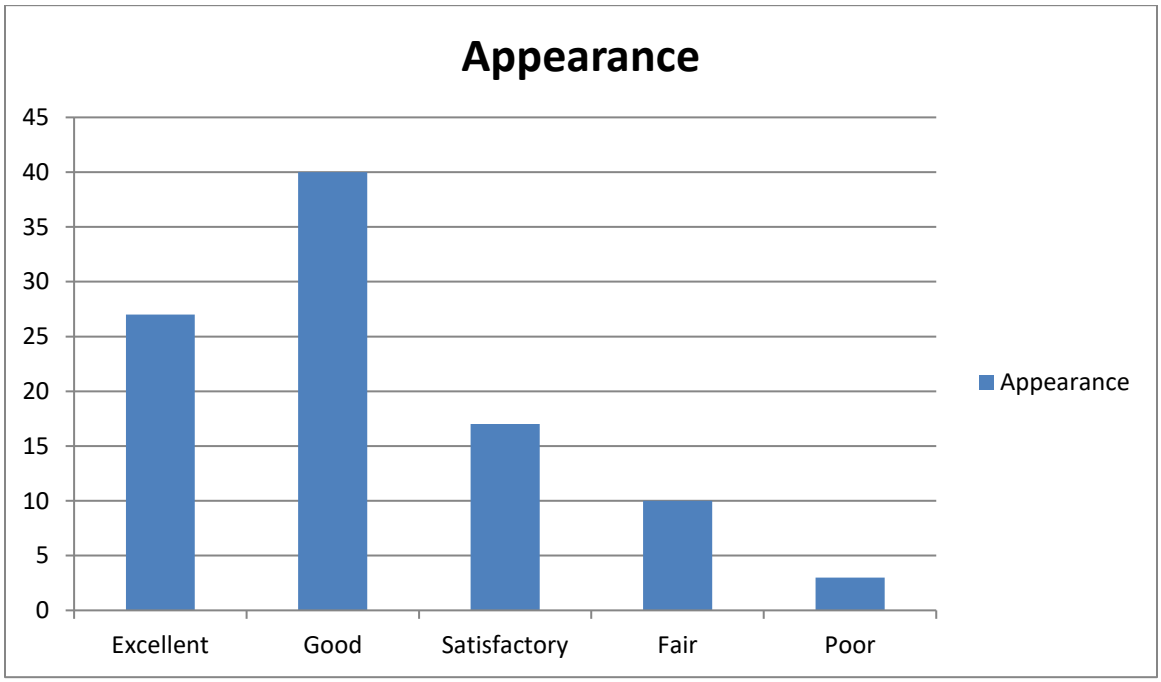


Figure 5.4: Graphical Representation of Evaluation Result for Appearance

According to the Graphical representation most of the users have agreed with the User Interfaces are good-looking of the system. Overall Appearance of the solution is not excellent, but it was not bad according to the results of the feedback. 40% of the results are "Good" while 27% results are "Excellent".

5.7.2 Usability

Table 5.15 shows evaluation results for the criteria of **Usability** related to the "Data validation are satisfied" of the system and graphical view shown in Figure 5.5

Likers Option	**Result**	**Percentage**
Excellent	9	30
Good	13	43
Satisfactory	6	20
Fair	2	7
Poor	0	0

Table 5.15: Evaluation Result for Usability

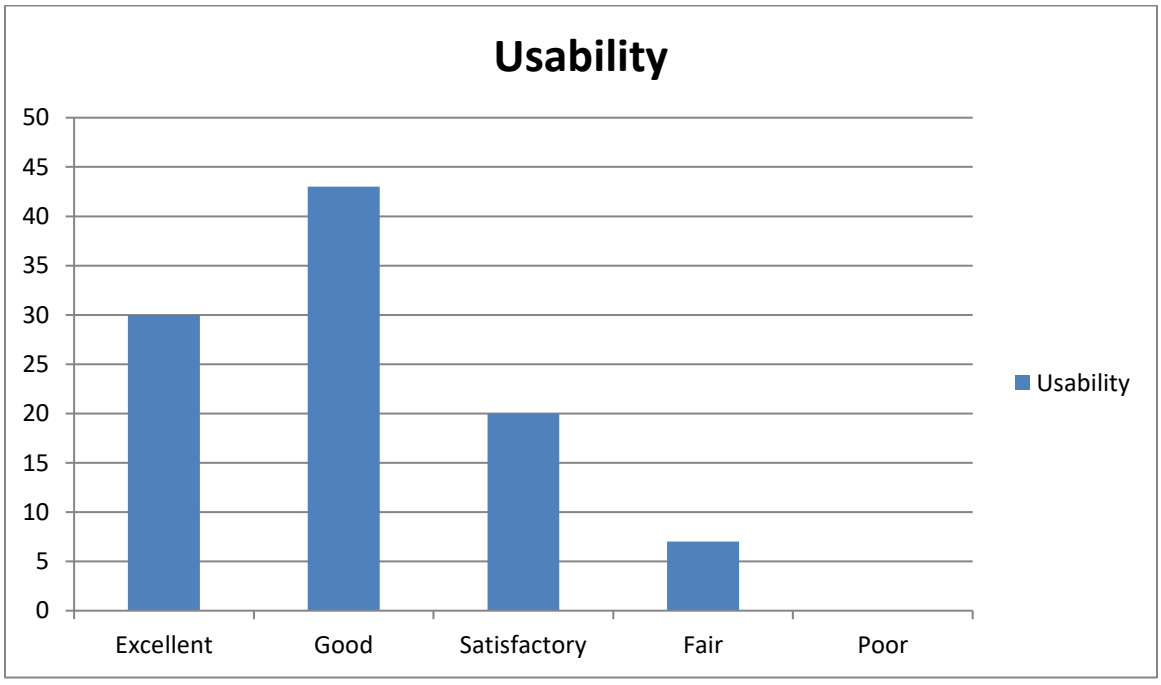


Figure 5.5: Graphical Representation of Evaluation Result for Usability

Usability of the system is acceptable level. 43% of the users are provide as system is ‘Good’ and 30% are commented as ‘Excellent’

5.7.3 Functionality

Table 5.16 shows evaluation results for the criteria of **Functionality** related to the “water quality data and the testing parameters” of the system and graphical view shown in Figure 5.6

Likers Option	**Result**	**Percentage**
Excellent	8	27
Good	10	33
Satisfactory	6	20
Fair	5	17
Poor	1	3

Table 5.16: Evaluation Result for Functionality

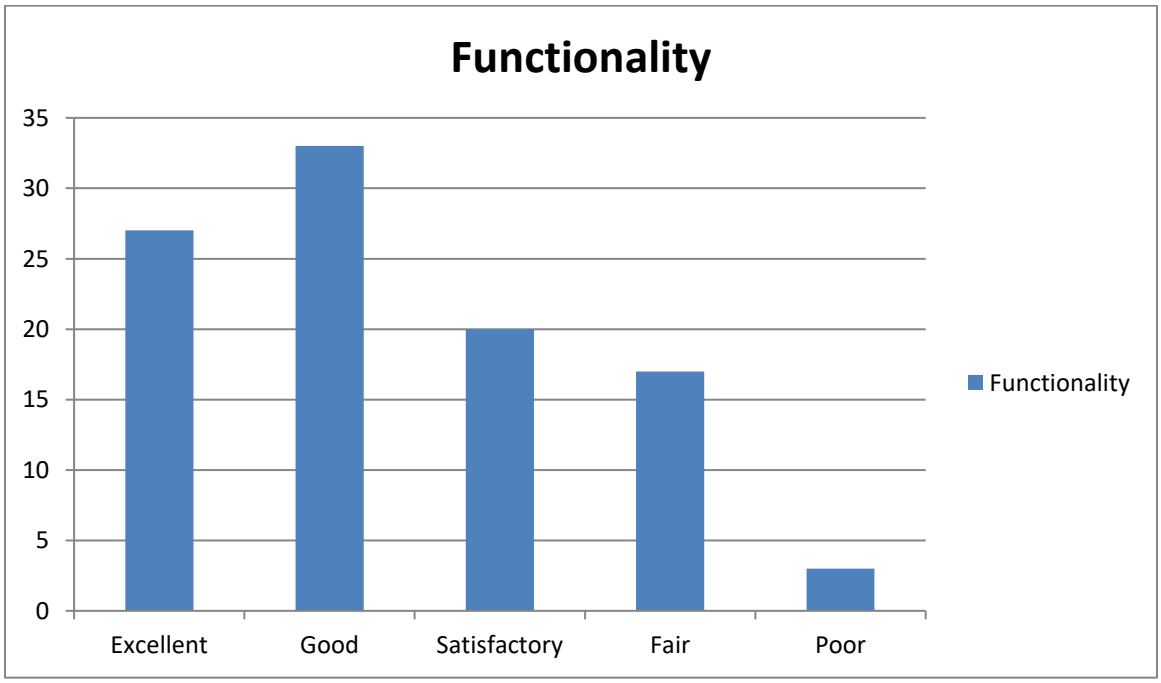


Figure 5.6: Graphical Representation of Evaluation Result for Functionality

Most of the users are satisfied with the Functionality of the system. There are 27% users marked as ‘Excellent’ and 33% users given system functionality is ‘Good’. Some users are identified the functionality is not good they marked 3% as ‘Poor’.

5.7.4 Performance

Table 5.17 shows evaluation results of **performance** of the system. System capability of data retrieval and response time are the key indicators for this question and graphical view shown in Figure 5.7

Likers Option	Result	Percentage
Excellent	7	23
Good	12	40
Satisfactory	5	17
Fair	4	13
Poor	2	7

Table 5.17: Evaluation Result for Performance

Figure 5.7: Graphical Representation of Evaluation Result for Performance

According to the analysis more than 80% of the users are accepted as satisfactory performance during the evaluation. At the same time 7% users are not accepted the performance of the system and indicated as ‘Poor’.

Chapter 6 - Conclusion

According to the evaluation identified following area should be improved. As per the feedback received from the evaluation of Water Quality Management System.

- The evaluation of the "**Appearance**" has overall **40% "Good"**. Therefore, User Interfaces are attractive.
- The **"Usability"** has **43% "Good"** as evaluated. Therefore, input data validations are satisfied for some extend need to improve for better usability of the system.
- The **"Functionality"** has **33% "Good"** for this evaluation. Therefore, online water quality results capturing is important to maintain for NWSDB standard.
- The **"Performance"** has **40% "Good"** as evaluation. Therefor Response time of the system is minimized and acceptable.

The system evaluation was successfully completed with the end users rating the system as being satisfactory level.

The web-based water quality management system has been developed to NWSDB internal users and anyone could access it via VPN which is operated by SLT. Getting the look and feel according to satisfaction of all the users was another challenge successfully faced during design of the screen layouts and themes of the web-based solution.

6.1 Problems Encountered and Lesson learned

During the design, development and implementation process the project face problems which was not solved in long period.
The following problems were encountered during system implementation process as follows.

- There wasn't standard procedure to store water quality data generated from the testing of water in the laboratory. They were use different excel format and procedures in island wide
- Most of laboratory staff refused to give their information during requirement gathering process.

- I have to study and get understand the manual water sample checking process and water quality standards published by WHO and SLS.
- Management required to integrated with the ERP solution which was run as core system in NWSDB. Therefore, I have to use developments patterns, framework of the system, master information maintains by the ERP solution.
- I used this technology and object-oriented concepts, Dot Net frame work version 4, Visual Studio with C#. That was the challenge of this project, I have to learn and complete the project within given time frame
- I have to study to develop Dashboards which required by management for reduce paper work of the organization. They need less printed reports and all reports are in PDF format.

The following lessons were learnt during the projects work.

- Prepared standard procedure to maintain water quality data and the process to display "Unsatisfied" quality of the water which was the key requirement to manage the system and discussing process owners.
- Through the interviewing process it was easy to get necessary details from laboratory staff.
- I have used paper prototype to show the process flow to user, to obtain and stores water quality data and necessary alerts in Dashboard.
- Fast learnt to developed Dashboards during the project life cycle and related sample code using Google search.

The importance of planning and completion work as early as possible was the most important lesson learnt. Initially defined timeline for developing a software project is theoretical aspect. There are deviations from the guideline occur from time to time with the unavoidable circumstances which was happened due to COVID 19. Reviewing project progress often is necessary to ensure that hard work is translated in to meaningful work.

6.2 Future Enhancements

We use this online water quality management system to store water quality data and make decision to developing new water treatment plants around the island. It happens during the process of designing the water treatment plants required to analyses the water quality of the water sources to define their water treatment process.

All laboratories were use manual data storing system and reporting to the higher management as paper-based reports. I have managed to implement Dashboard concept to the management which is overcome the report generating process and further improvement we can implement messaging system to produce online information to attend immediately.

NWSDB was developed and implemented the employee based mobile app with the critical access rights to view important information via mobile interface (monthly water billing, monthly collection, find required items island wide etc.) As an enhancement we can develop the interface to the same mobile app to show water quality data and the remedial action to be taken immediately.

NWSDB is the water specialized organization in Sri Lanka. We have provided water quality testing services to the nation for nominal fee. This process was totally manually operated and paper-based result sheet provided to the customers. As an improvement we can design new module to capture water quality test result and produce reports with the integration of SMS and payment collection through the Pay-In voucher integrated to the NWSDB General Ledger.

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Appendix A – System Manual

The web-based system required web server and the client machine to run the solution. NWSDB datacentre maintained by VMware technology to maintain virtual servers to manage systems. Therefore, Water Quality Management System use the virtual machine to install the solution.

Server Installation

Following installations are required to deploy the solution in house datacentre as follows.

- **Windows Server 2012 R2**
  This is the sixth version of the Windows Server operating system by Microsoft, as part of the Windows NT family of operating systems. This product was used to manage web server for the solution.
- **IIS Server**
  Internet Information Services is extensible web server software created by Microsoft for use with the Windows NT family. IIS supports HTTP, HTTP/2, and HTTPS, FTP, FTPS, SMTP and NNTP.
- **SQL Server 2014**
  Microsoft SQL Server is used to maintain water quality database with the integration of HRM system. This product is used throughout the organization as unique database tool.

Client Installation

Web based solutions are not required client machine installation. But web browser is required to navigate the system. The water quality management system was developed under Microsoft environment and uses internet explorer as a web browser. This system can be used within the virtual private network (NWSDB VPN) not espoused to the internet. System users not required internet facility for their machines.

The URL: 10.0.0.200/erpapp

After typing the URL in browser address bar and navigate login screen will appears. User need to enter User ID and Password to navigate the system.

Appendix B – User Manual

Login/Home Screen

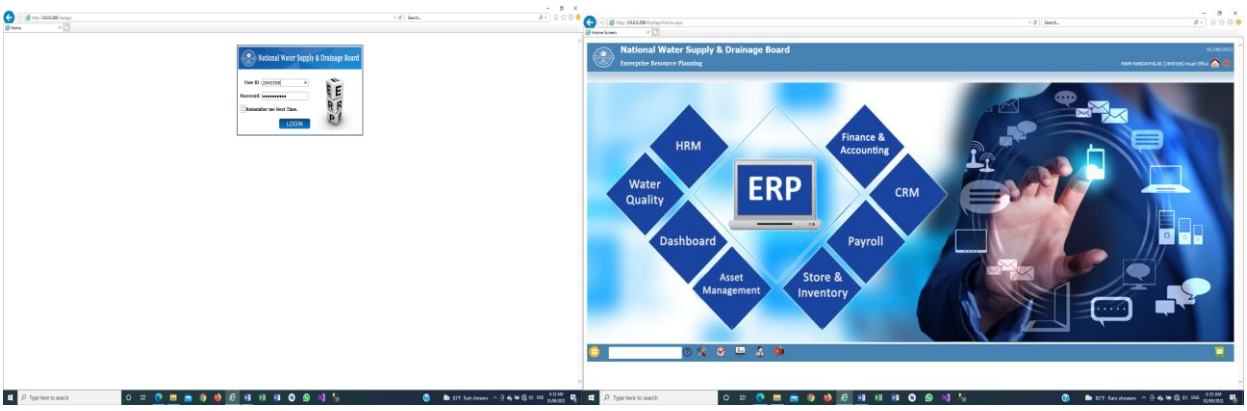

Figure B.1: Login & Home Page

User login requirement define as valid employee in the NWSDB and employee number used for the user ID. At the point of user creation system check the employee number from the HRM database. Figure B.1 shows the login & Home page when user login to the system.

Master Data Management

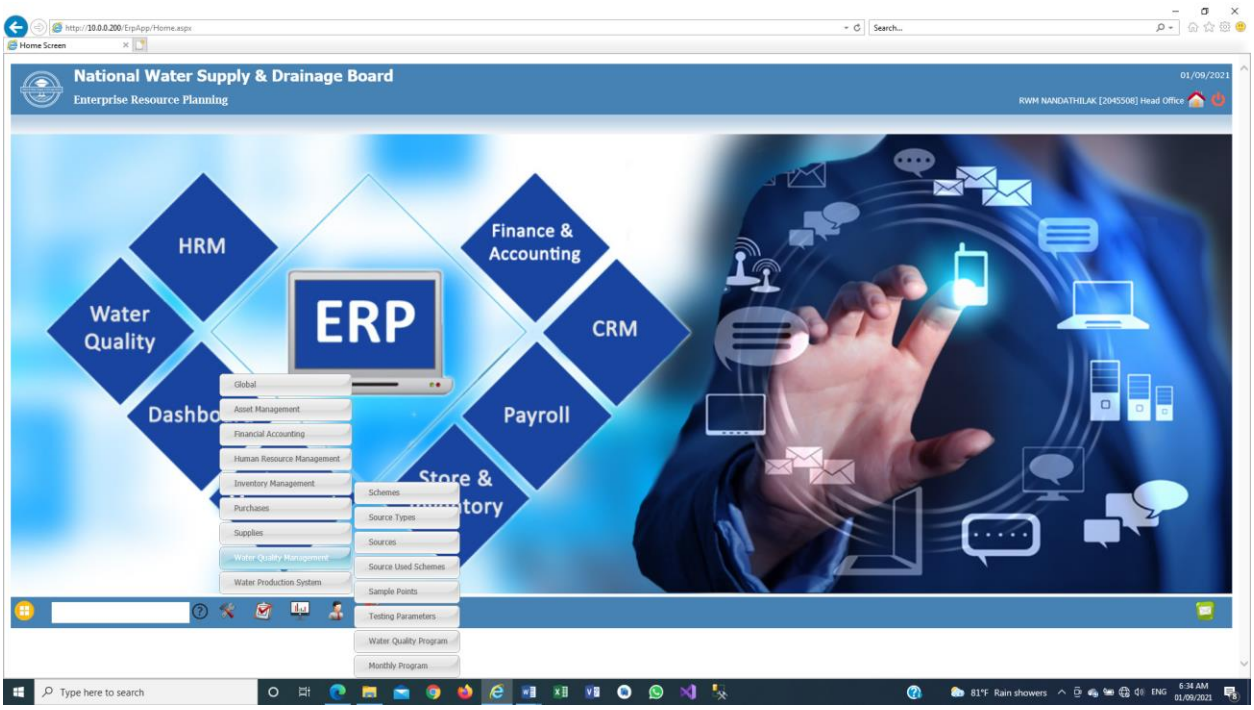

Figure B.2: Master Data Management Menu

There are required master data captured to the system using the menu options shown in the figure B.2 Each menu option used to capture the relevant master data to the system.

Scheme Master Data Management process used to describe the create, update and delete data from the system. All other master data input screens follow the same method and same standard throughout the system. When select the scheme menu option, figure B.3 shows the user interface of the system. The top half represent the form to get input from the user to create or update record in the system. Bottom half shows the all schemes define in the system.

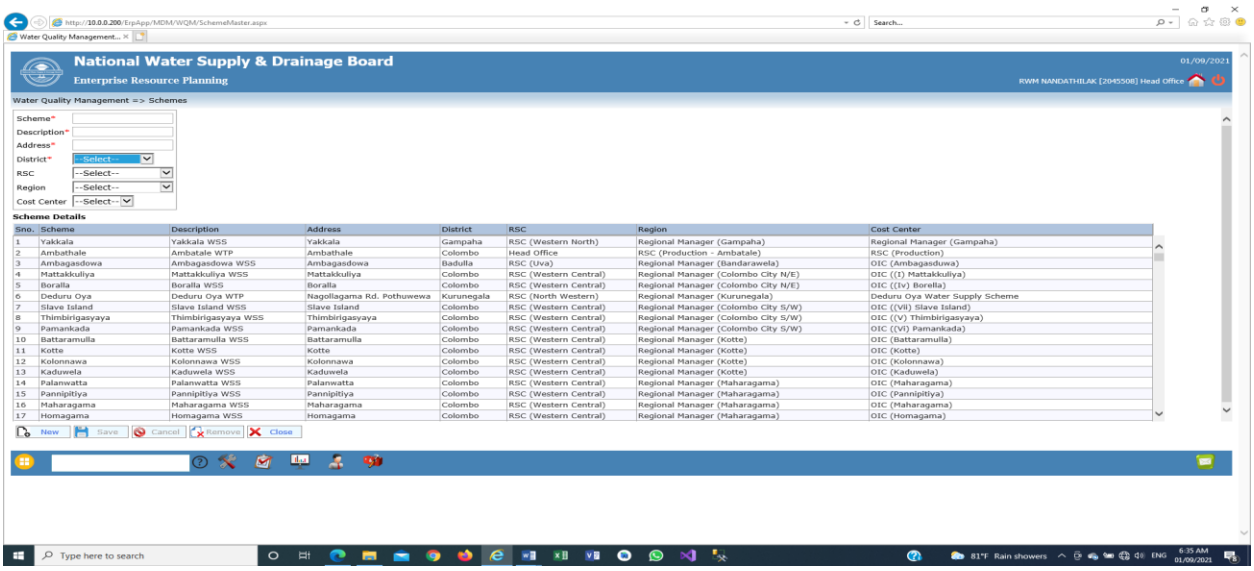

Figure B.3: Scheme Management

When click “New” button, the screen show in the figure B.4 with enabling “Save” button. After input all relevant data, user can save by clicking the button “Save”

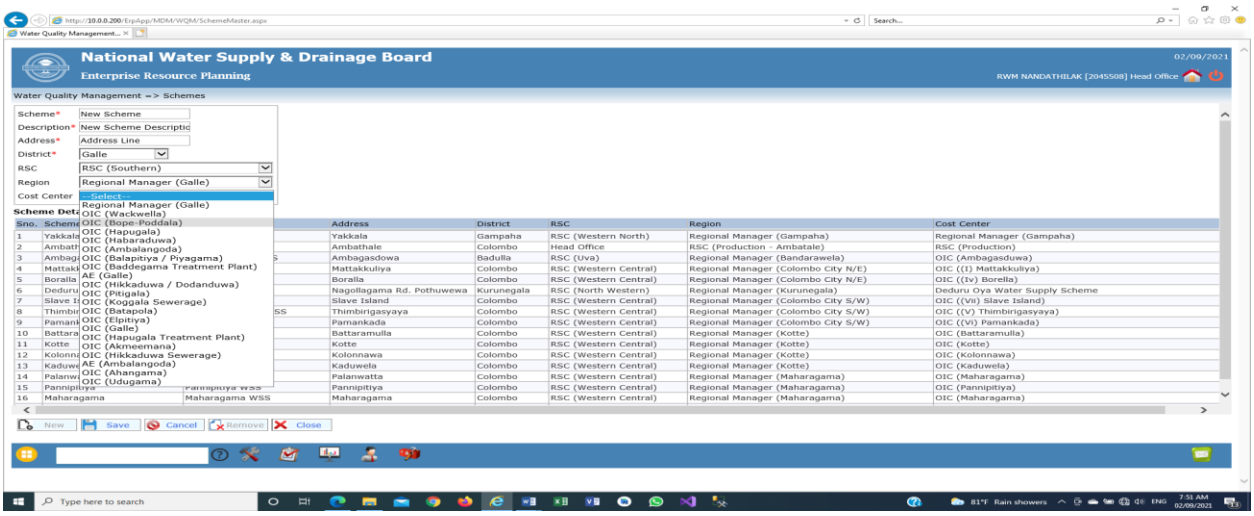

Figure B.4: Scheme Management Add Record

When selecting the record in the grid, user can have a facility to modify the record and save by clicking “Save” button. This screen shown in figure B.5

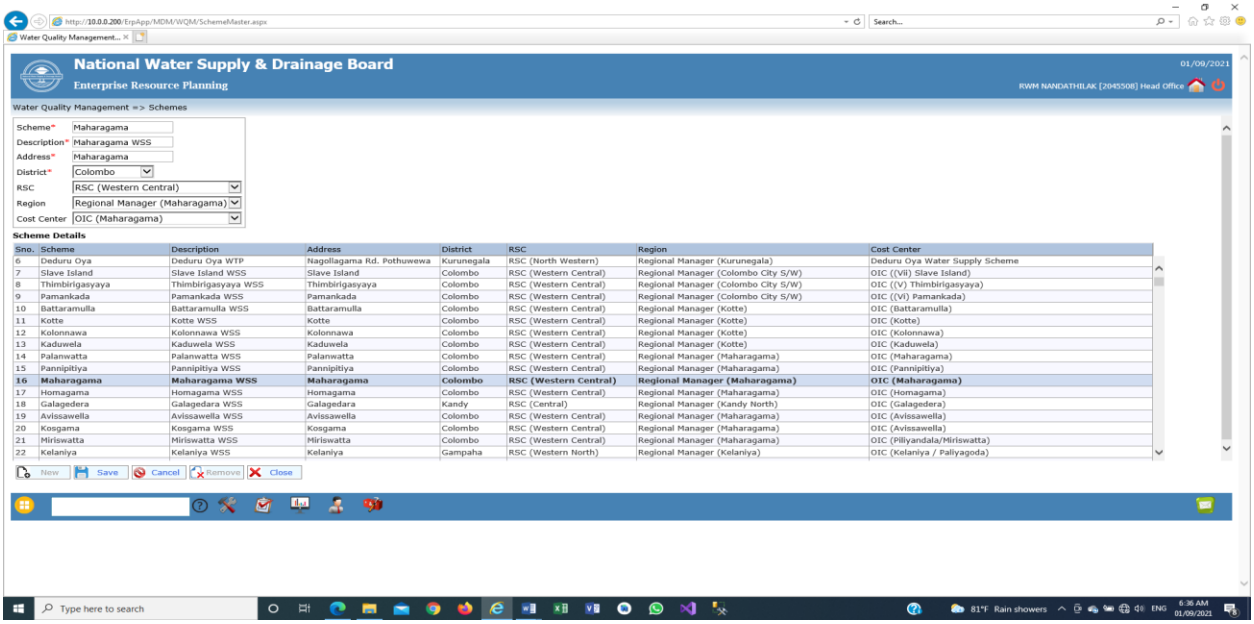

Figure B.5: Scheme Management Modify Record

Same Procedure shall apply for the removing record from the system. There are master data management screens inbuilt to the system which is follow the same procedure. All these screens are listed as follows.

- Source Type - Figure B.6
- Source - Figure B.7
- Source Used Schemes - Figure B.8
- Sample Points - Figure B.9
- Testing Parameters
    - Parameters - Figure B.10
    - Tolerance - Figure B.11
    - Rates - Figure B.12
    - Groups - Figure B.13

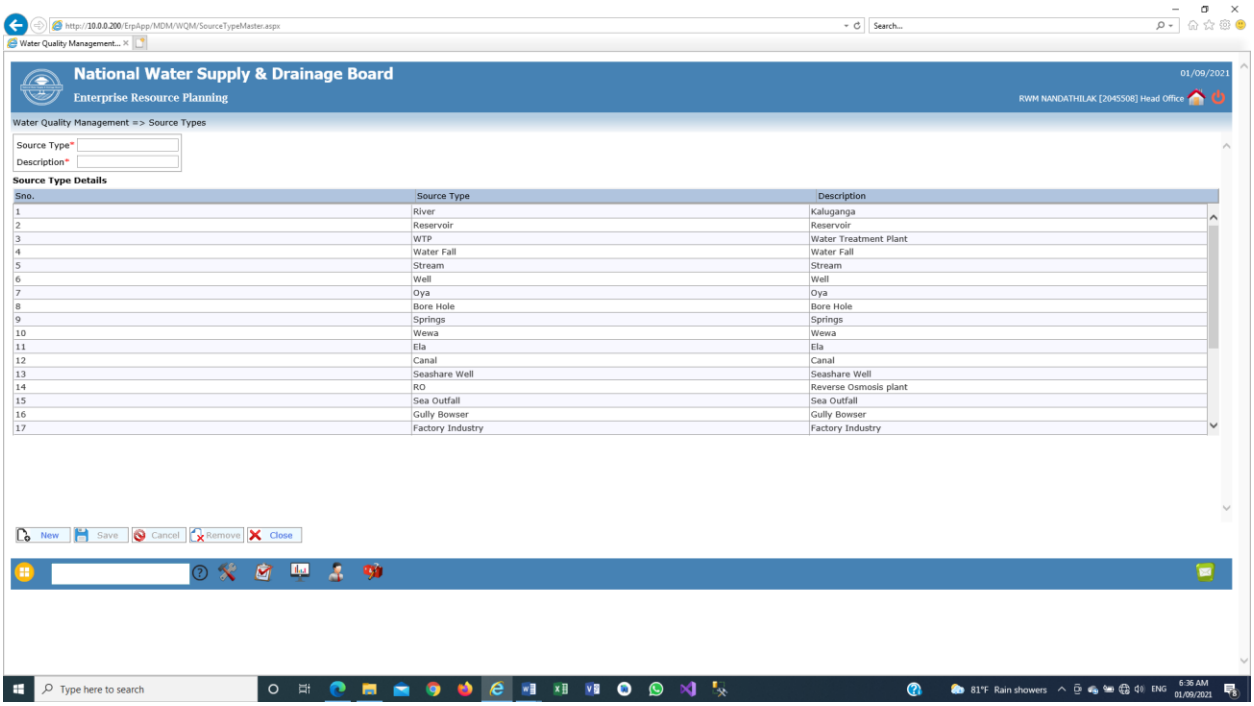

Figure B.6: Source Type Management

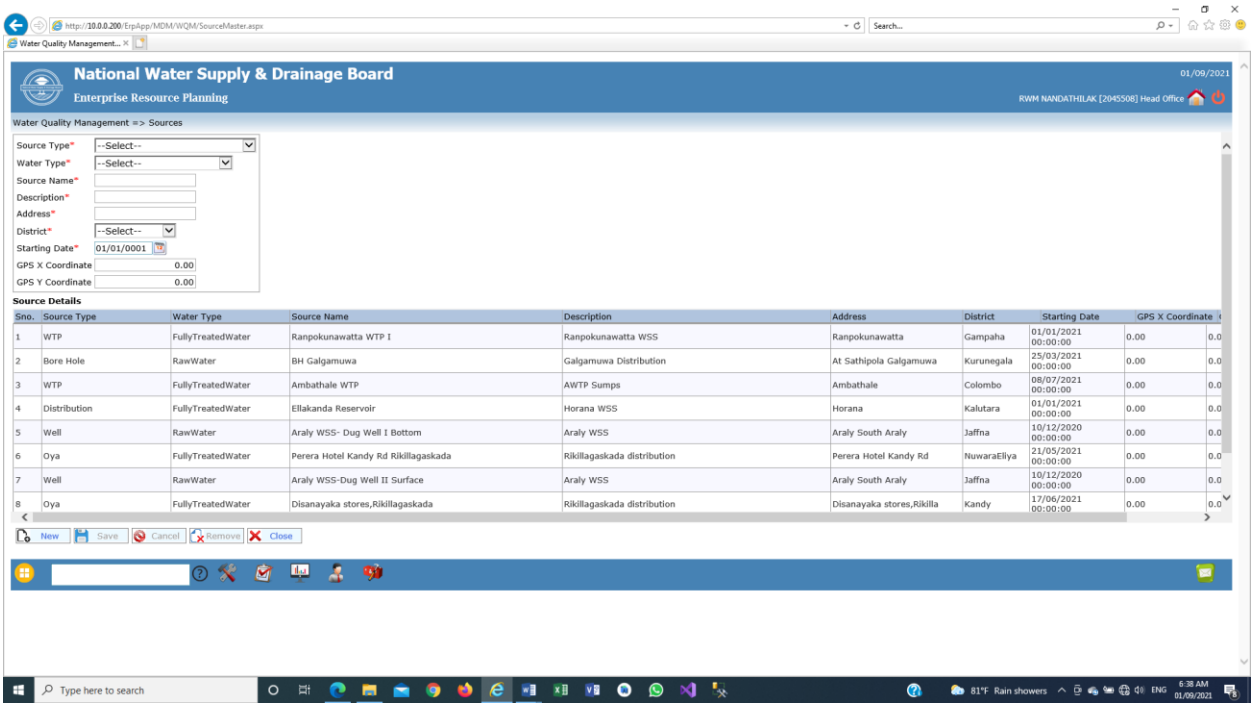

Figure B.7: Source Management

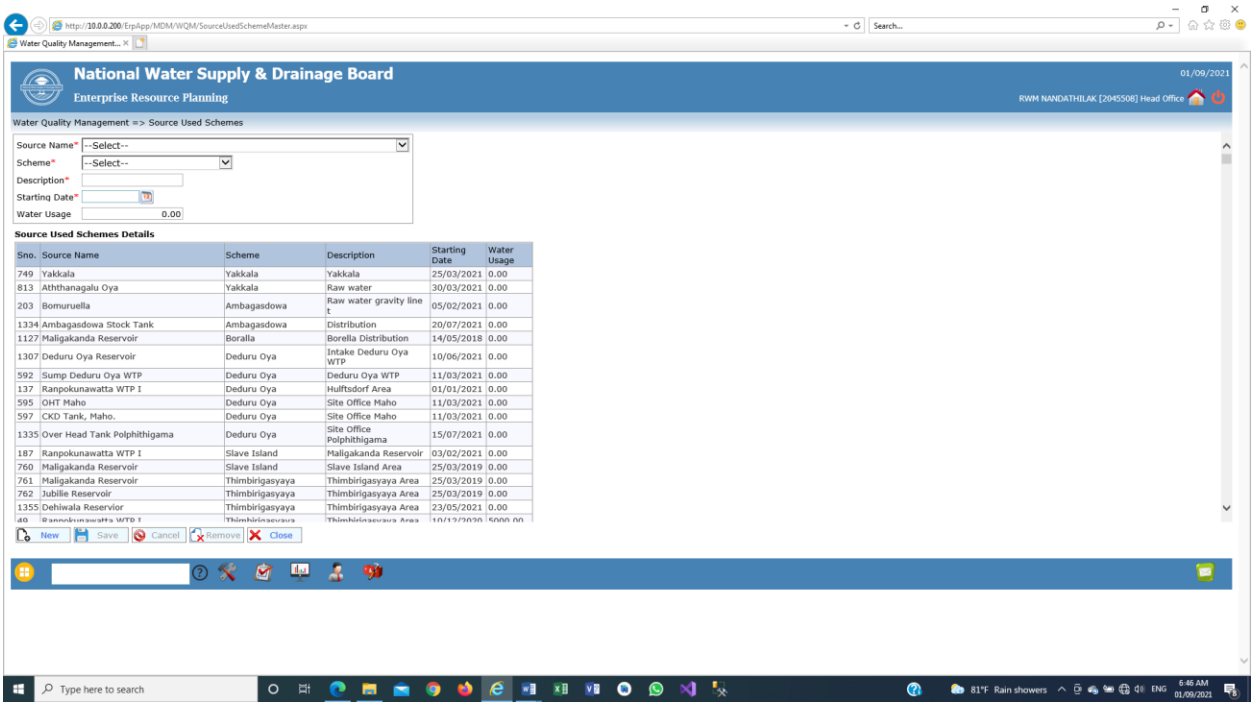

Figure B.8: Source Used Scheme Management

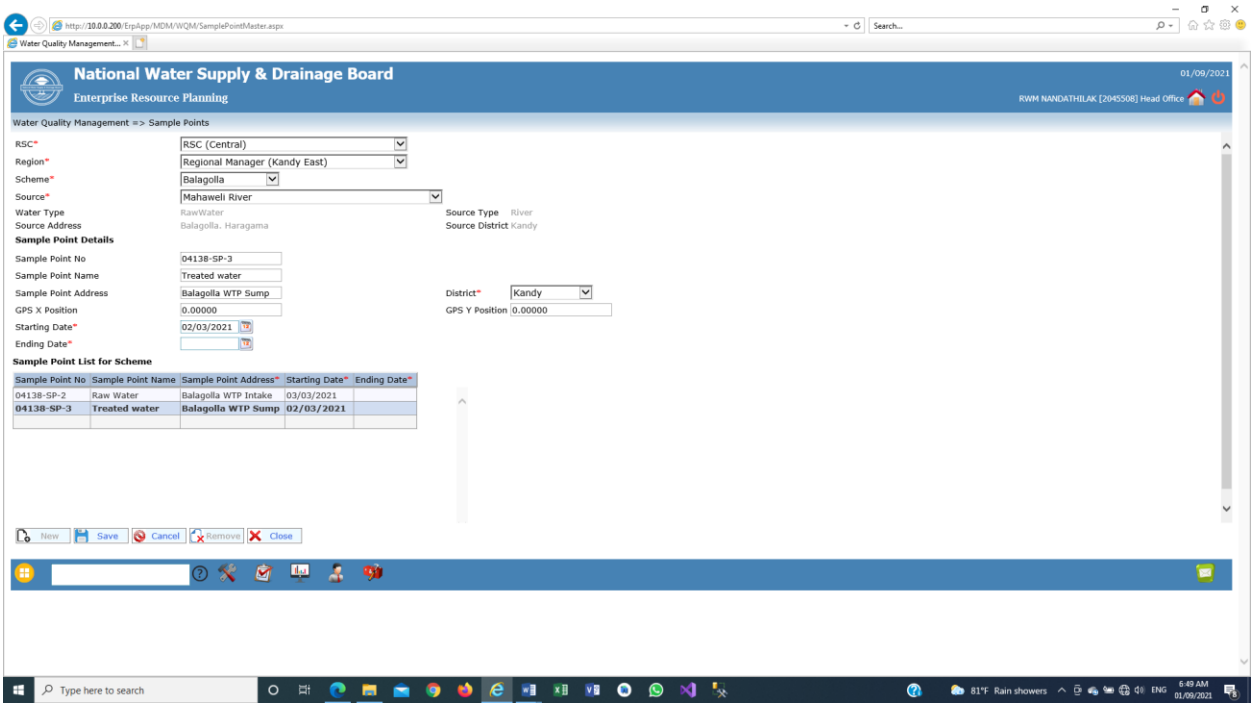

Figure B.9: Sample Point Management

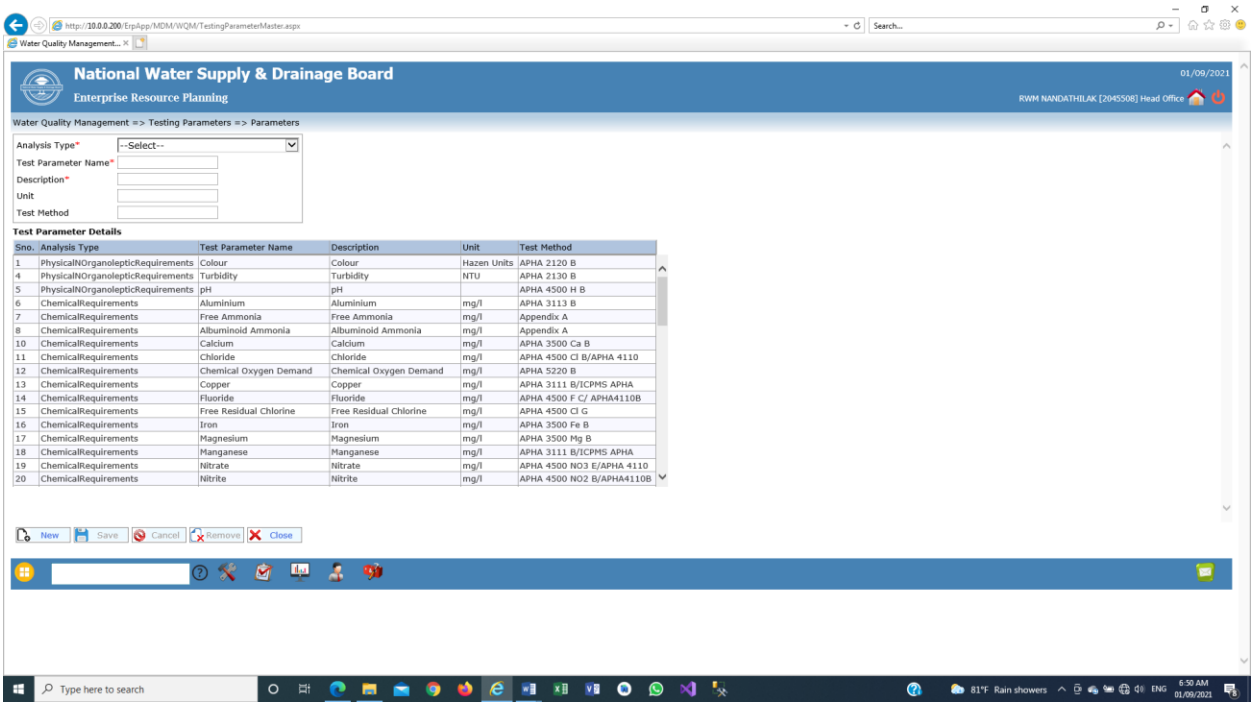

Figure B.10: Testing Parameter Management

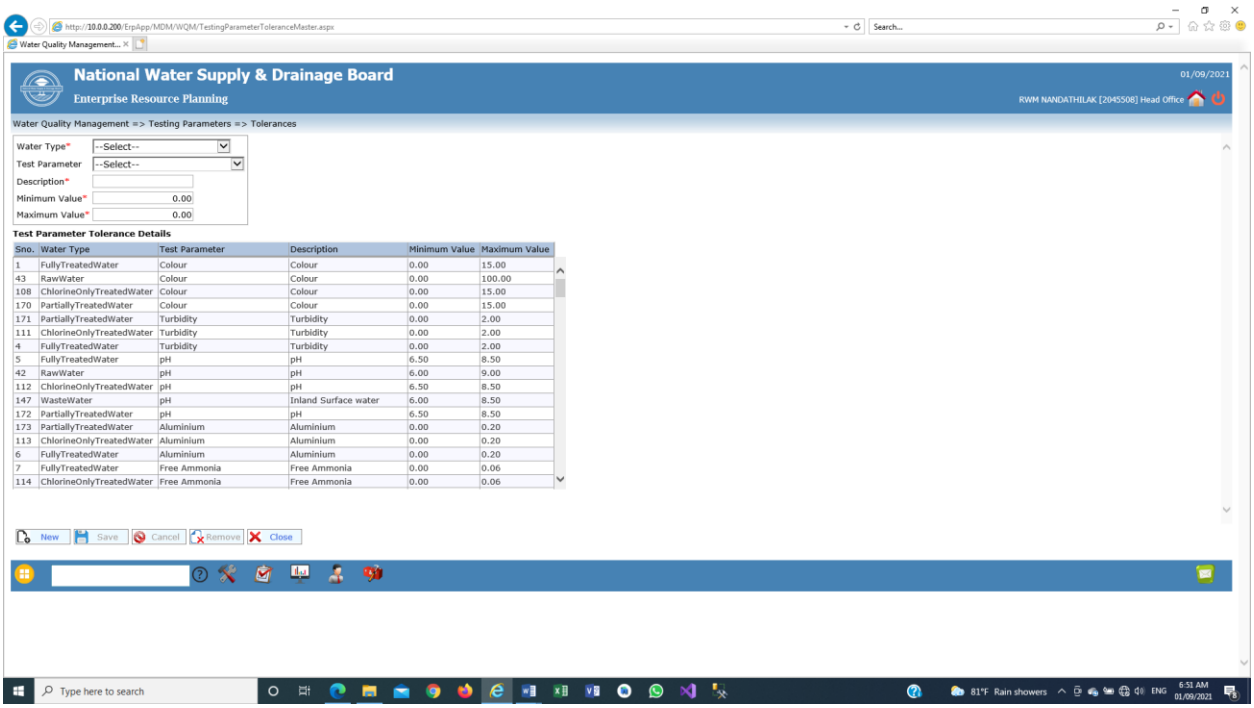

Figure B.11: Testing Parameter Tolerance Management

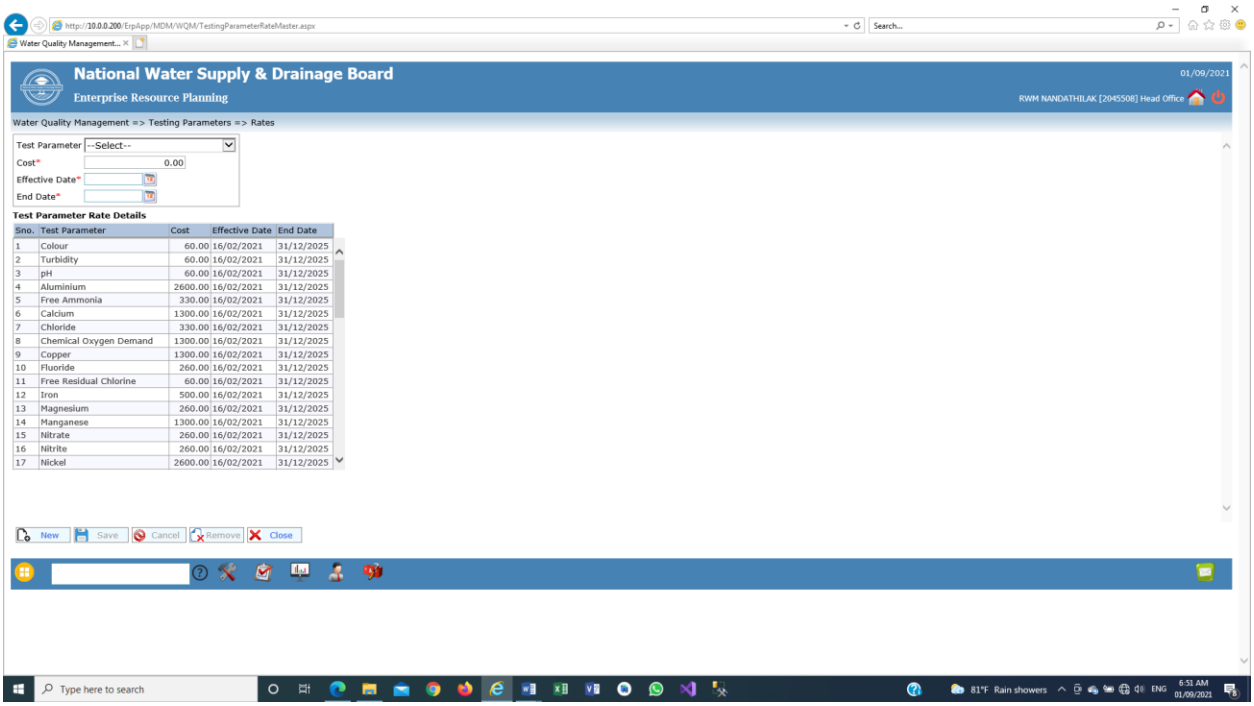

Figure B.12: Testing Parameter Rate Management

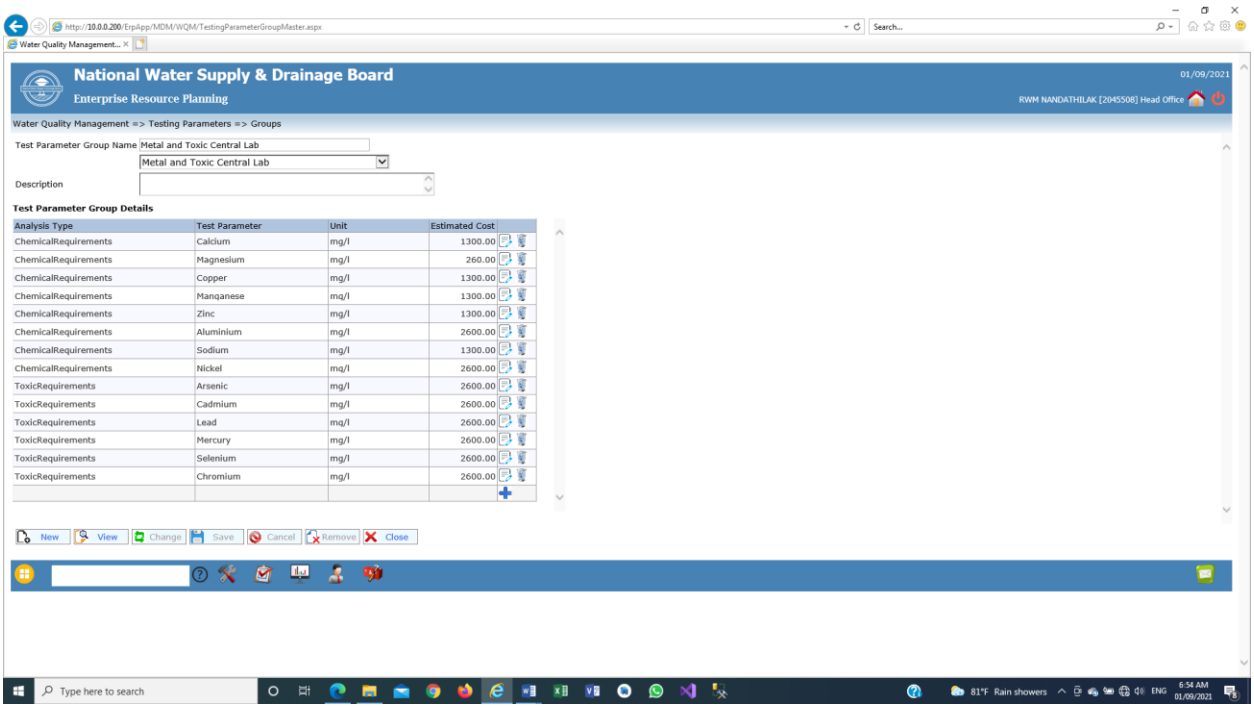

Figure B.13: Testing Parameter Group Management

Transaction Data Management

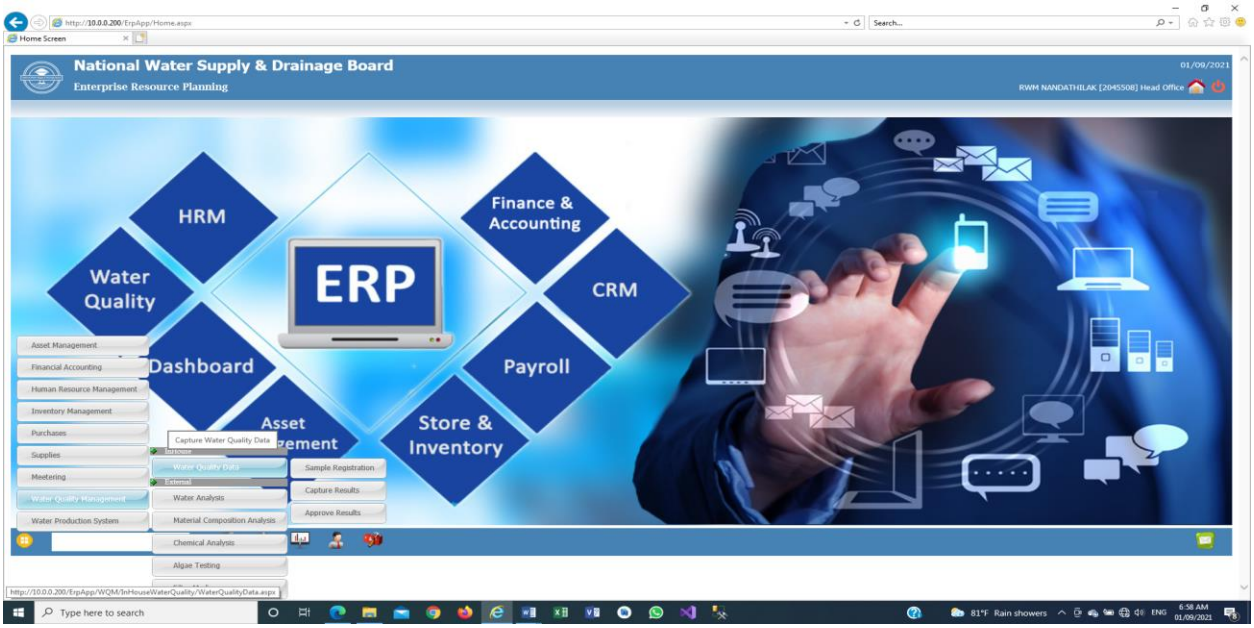

Figure B.14: Transaction Data Management Menu

Sample testing process conducted by laboratories island wide. Their test results are required to captured to the system using the menu options shown in the figure B.14 Each menu option used to Register, Capture Results and Approve Result are the relevant transaction data to the system.

When Samples are received to the laboratory, they have to register in the system with the required data. System shall generate the sample no and continue as unique no for the laboratory. This process incorporated screen is shown in figure B.15.

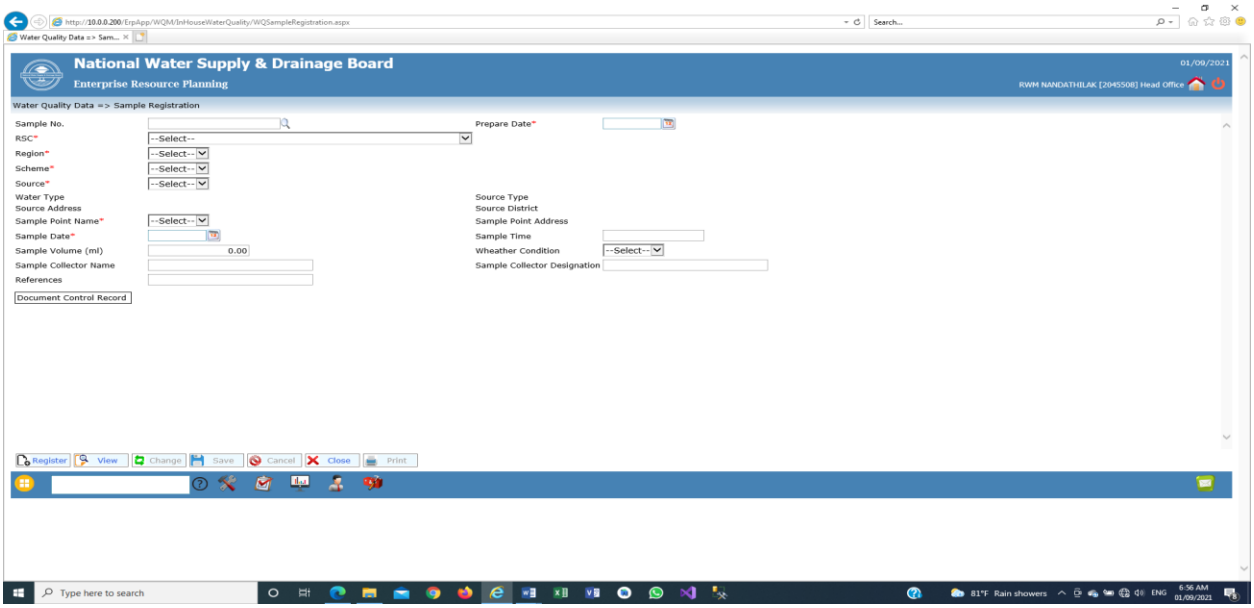

Figure B.15: Sample Registration Form

This screen facilitates to view existing sample details by entering sample no or searching through the separate search screen by entering the input criteria and viewing. This search provide user to find the sample no and retrieve from the database. This screen is shown in figure B.16 with the search window.

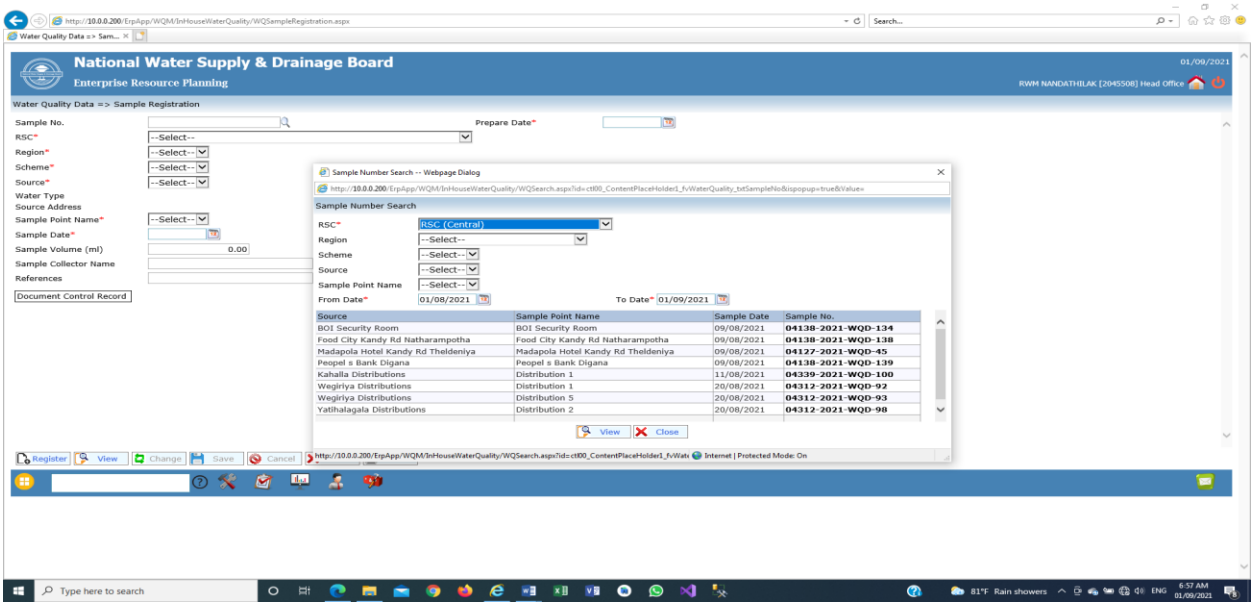

Figure B.16: Sample Registration View with Search Option

After completing the sample testing at laboratory, chemist should input the test results by inputting sample no directly or search and retrieve the relevant sample no using sample no search screen. This process is shown in the figure B.17.

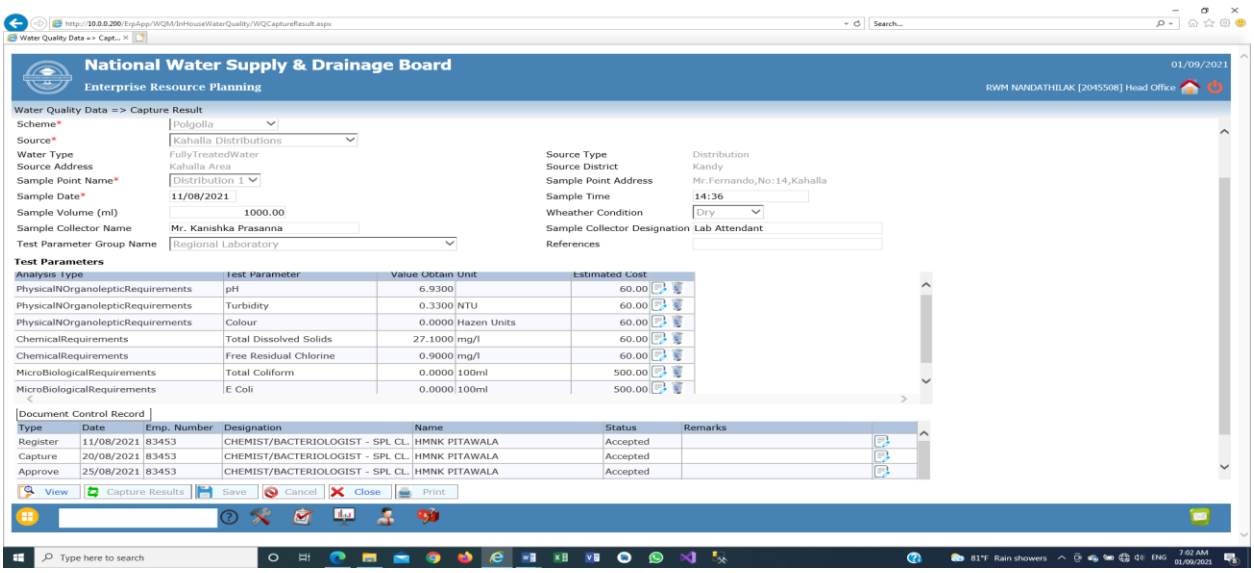

Figure B.17: Enter Test Results for Selected Sample Registration No.

Final Stage of the test results to be approved for confirmation of the test result. Head of the laboratory should input the sample no and view the result entered sample or using sample no search screen to find the sample for approval. This process was incorporated in figure B.18.

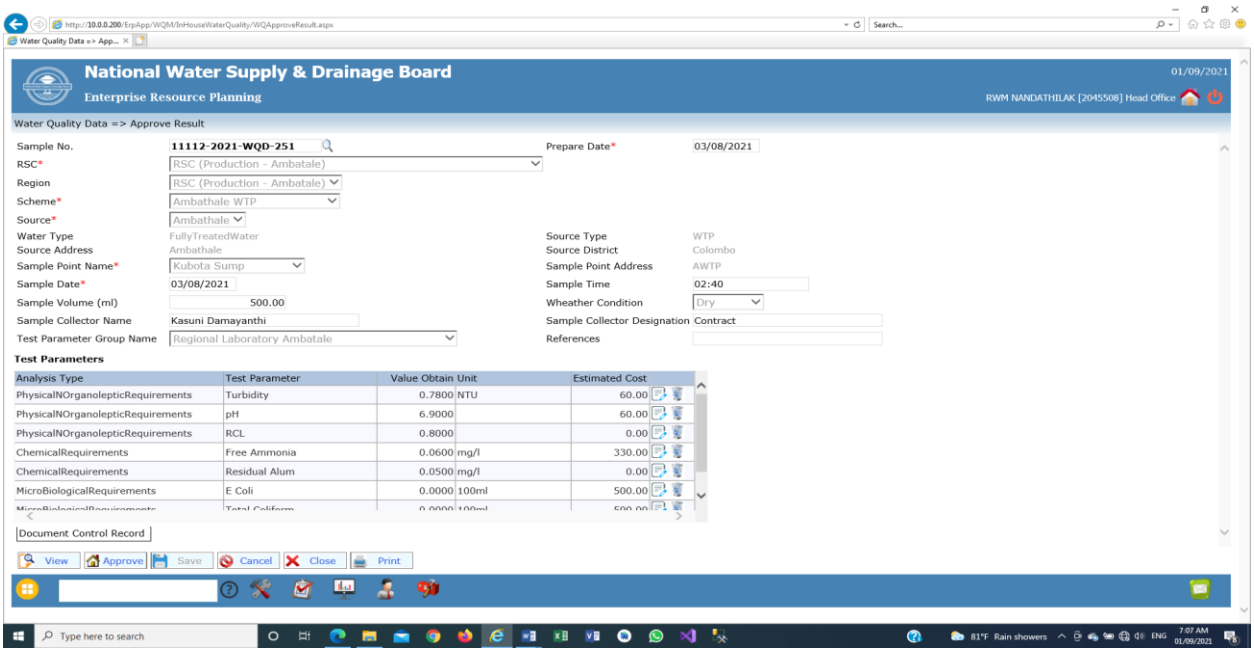

Figure B.18: Approve the Test Results Enter by Chemist Using Sample No.

Dashboard

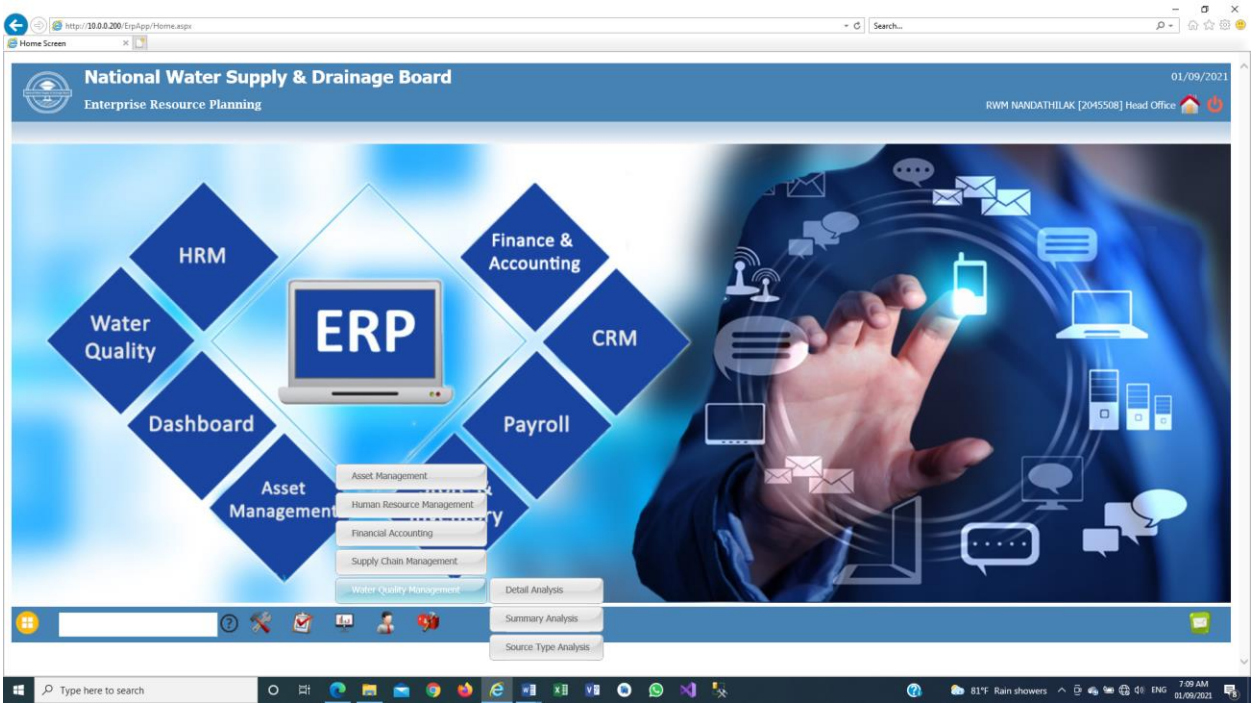

Figure B.19: Dashboards for Water Quality Management System

This concept was introduced to the NWSDB to operate paperless system to manage water quality of the water production and distribution. These dashboards are processed based on the user given criteria which is filtering the requirement needed by the end-user shown in figure B.19

Detail Analysis

This dashboard based on the water quality test results recorded by each laboratory in NWSDB. Users have a facility to filter required information according to the criteria built by their input values. Input RSC as “RSC North”, From Date as 01/05/2021 and To Date as 31/05/2021 other options are kept as ‘No Selection’. After completing the input criteria, system process the data and display the dashboard. Input fields labelled as “*” indicated required field other are selectable. This concept applied to all dashboards in the system. The results shown in figure B.20.

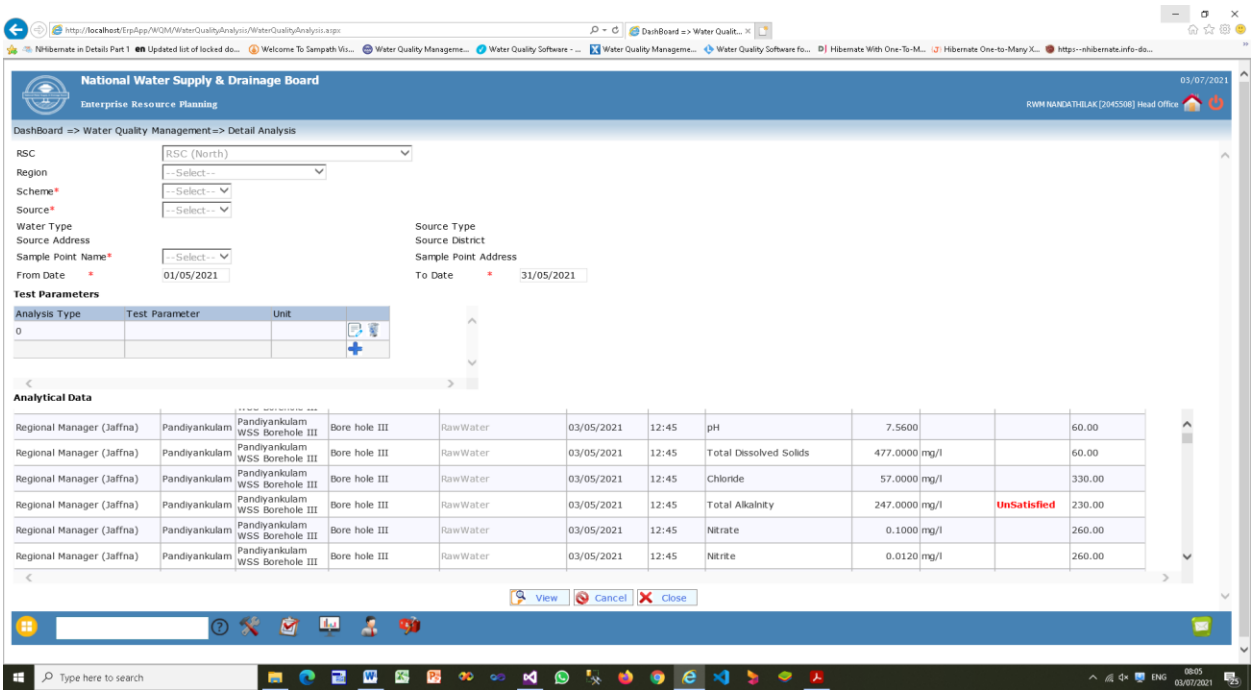

Figure B.20: Detail Analysis Dashboard

Summary Analysis

In this dashboard shows analytical data and the graphical view of the analysis. All inputs are in same standard define in detail analysis dashboard. Analytical data shown in figure B.21 and graphical view shown in figure B.22.

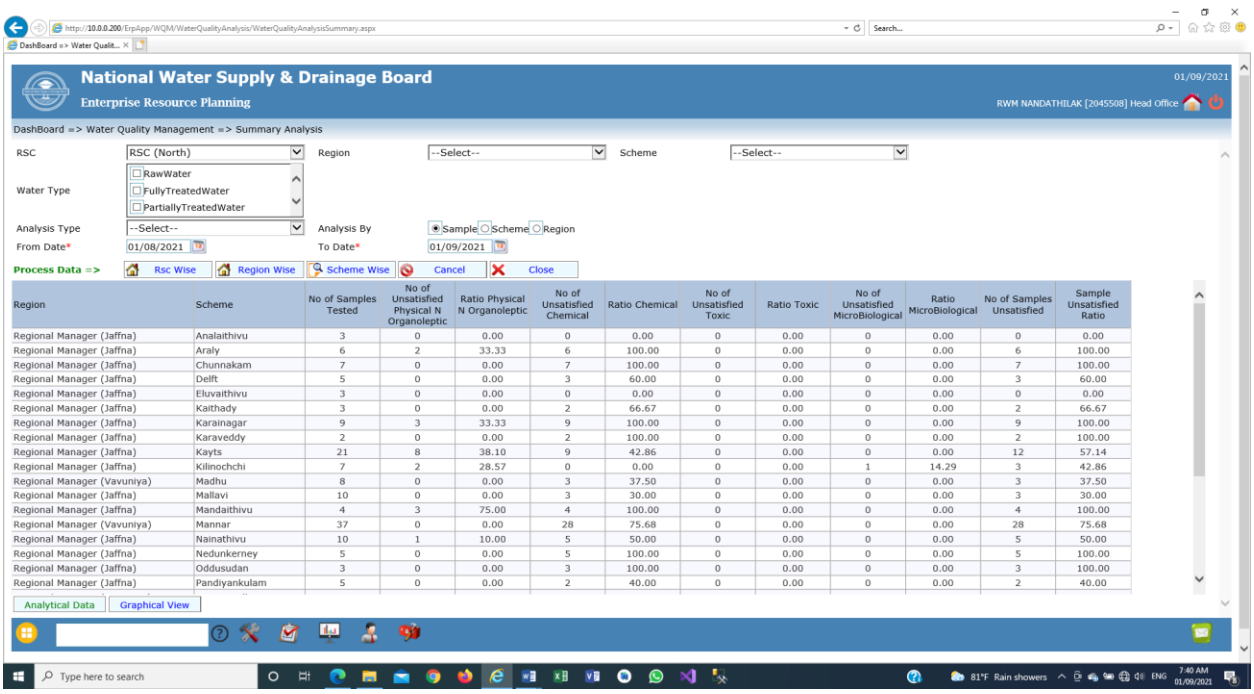

Figure B.21: Summary Analysis Analytical Data

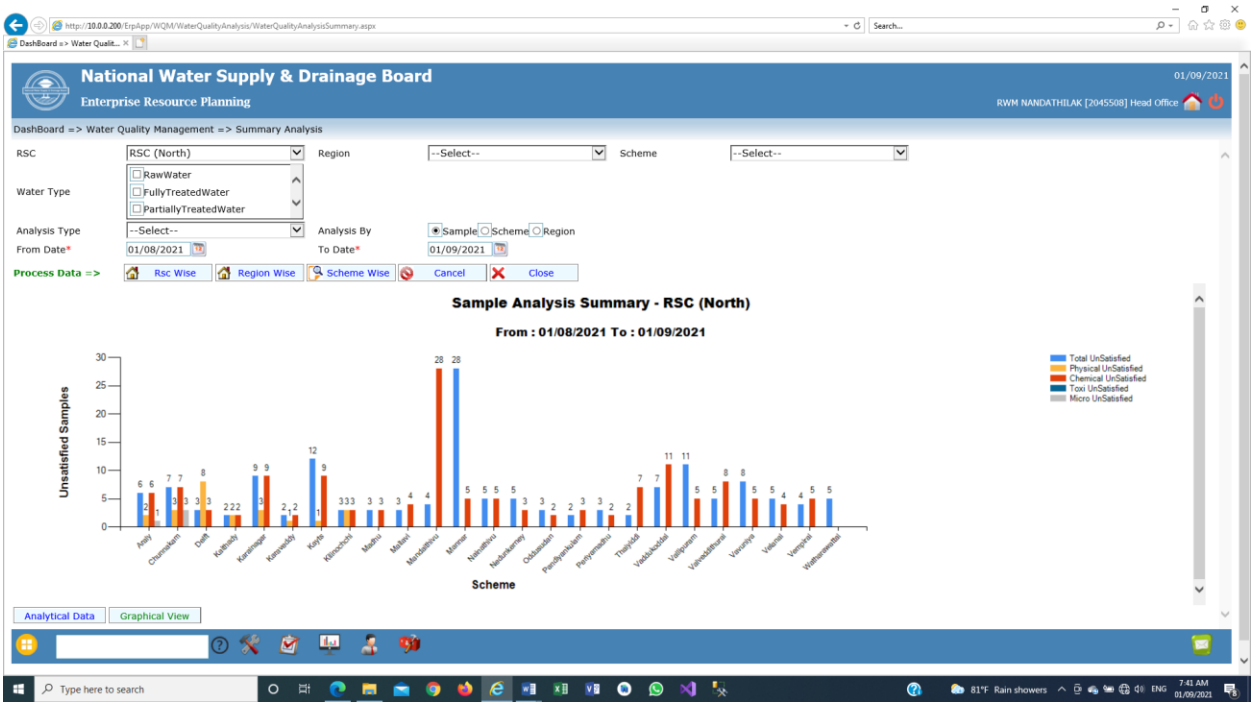

Figure B.22: Summary Analysis Graphical View

Source Type Analysis

In this dashboard provide user to analyse water sources based on the type. This dashboard shows analytical data in figure B.23 and graphical view in B.24.

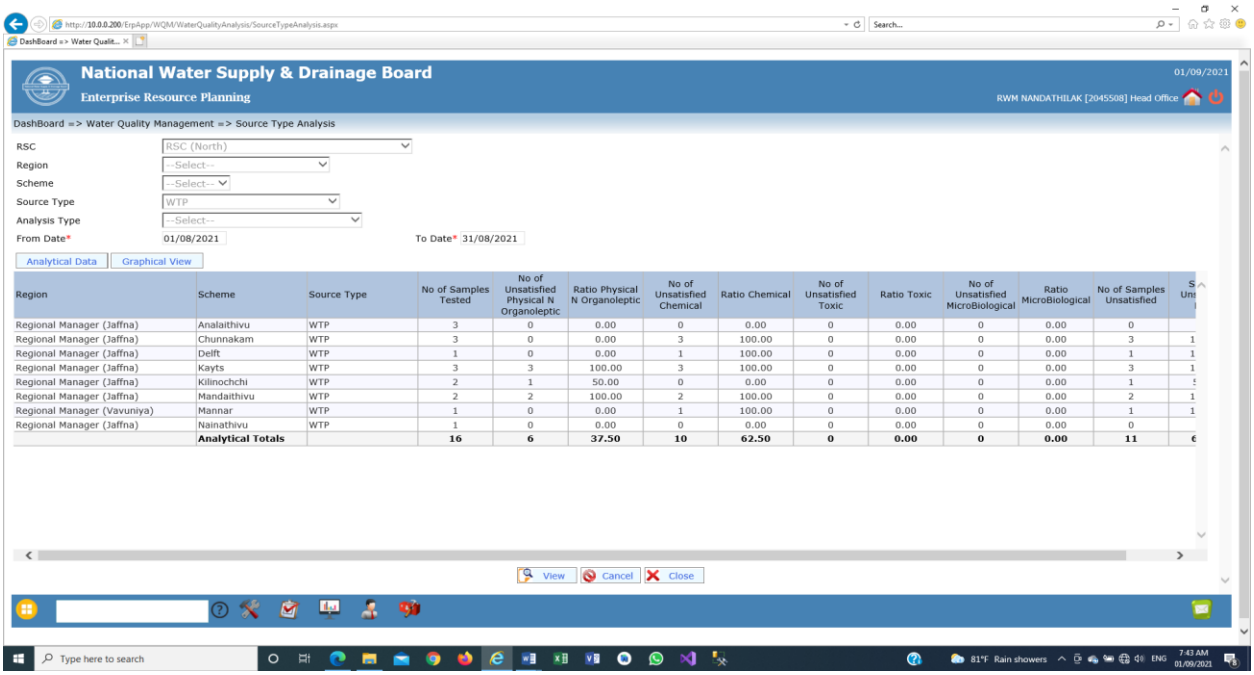

Figure B.23: Source Type Analysis Analytical Data

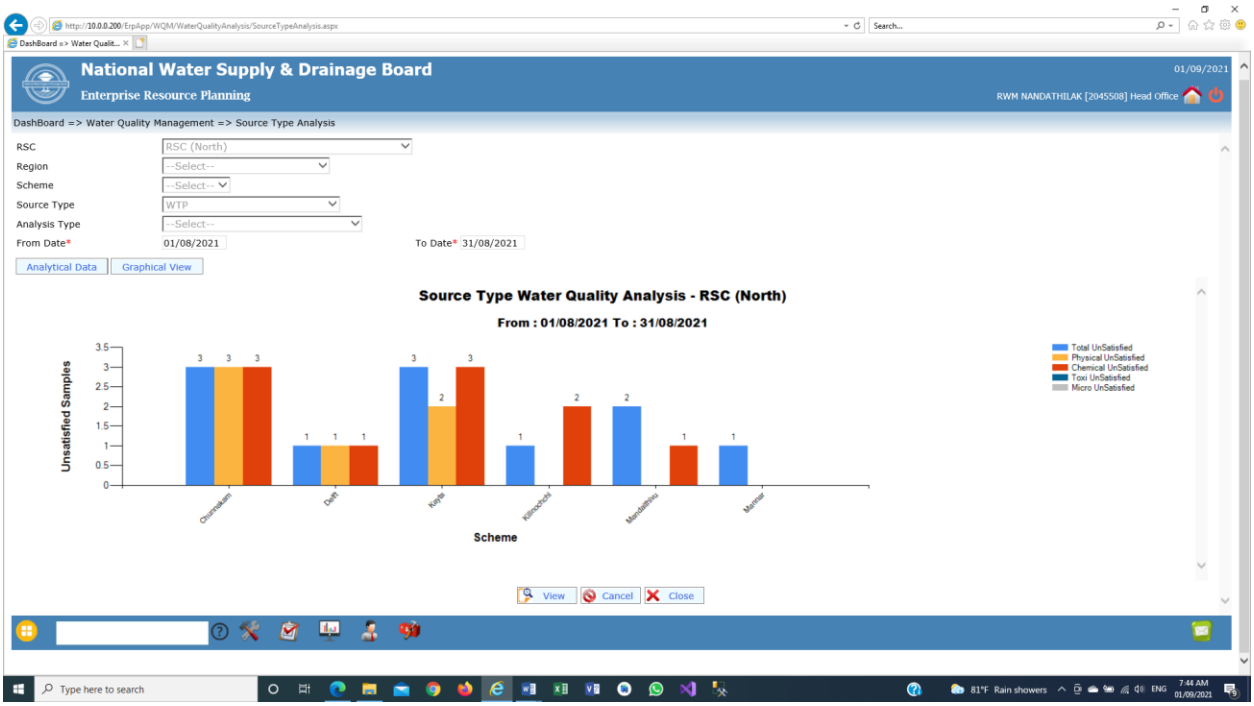

Figure B.24: Source Type Analysis Graphical View

Appendix C – Management Reports

Reports

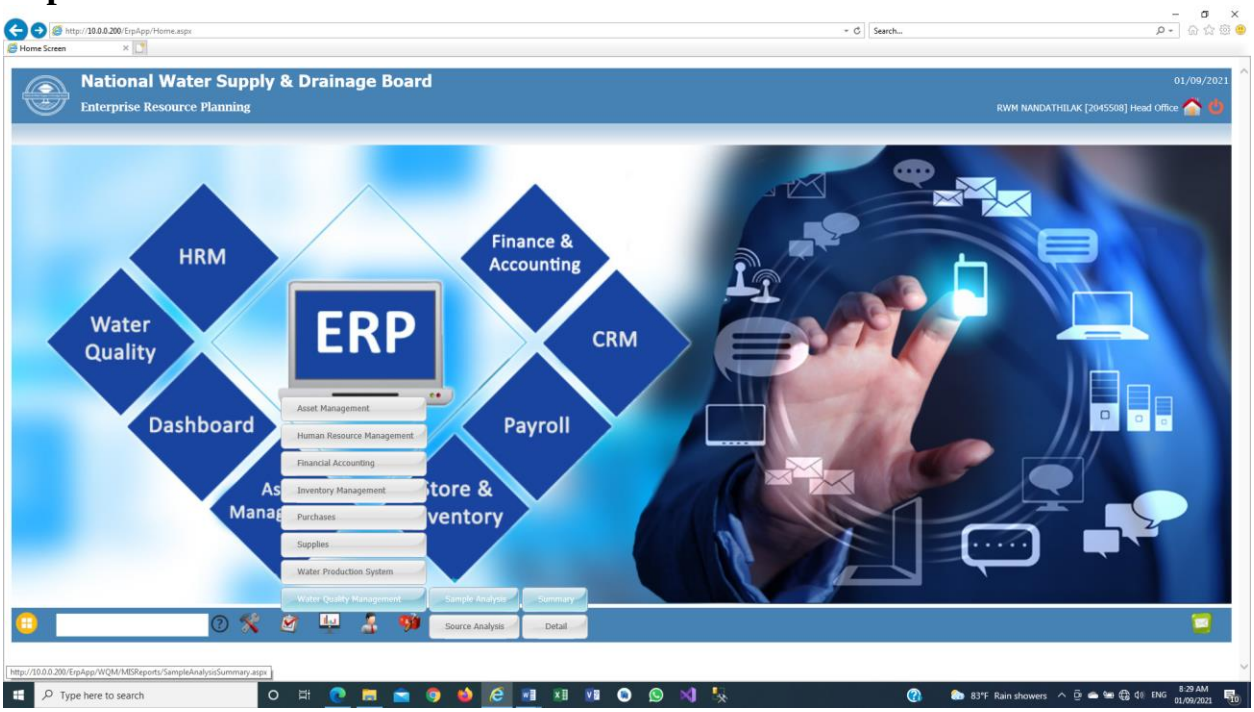

Figure C.1: Reports for Water Quality Management System

Management reports are developed in two ways in the system. Dashboards and the MIS Reports. Most of the dashboards are described in user manual. Management required reports are shown in figure C.1 and requirement are as follows;

- Water Quality Monitoring Summary report required to presented at progress review meeting
- Island wide monitoring and the information reported to the ministry by this report
- Remedial action taken based on the water quality of the source compared with previous month

In my project identified important report for water quality analysis summary define as follows. Input RSC as “RSC North”, From Date as 01/08/2021 and To Date as 31/08/2021 other options are kept as ‘No Selection’. After completing the input criteria, system process the data and display on the popup screen in pdf format. User can have a facility to print report in pdf format. The output and the input screen shown in figure C.2.

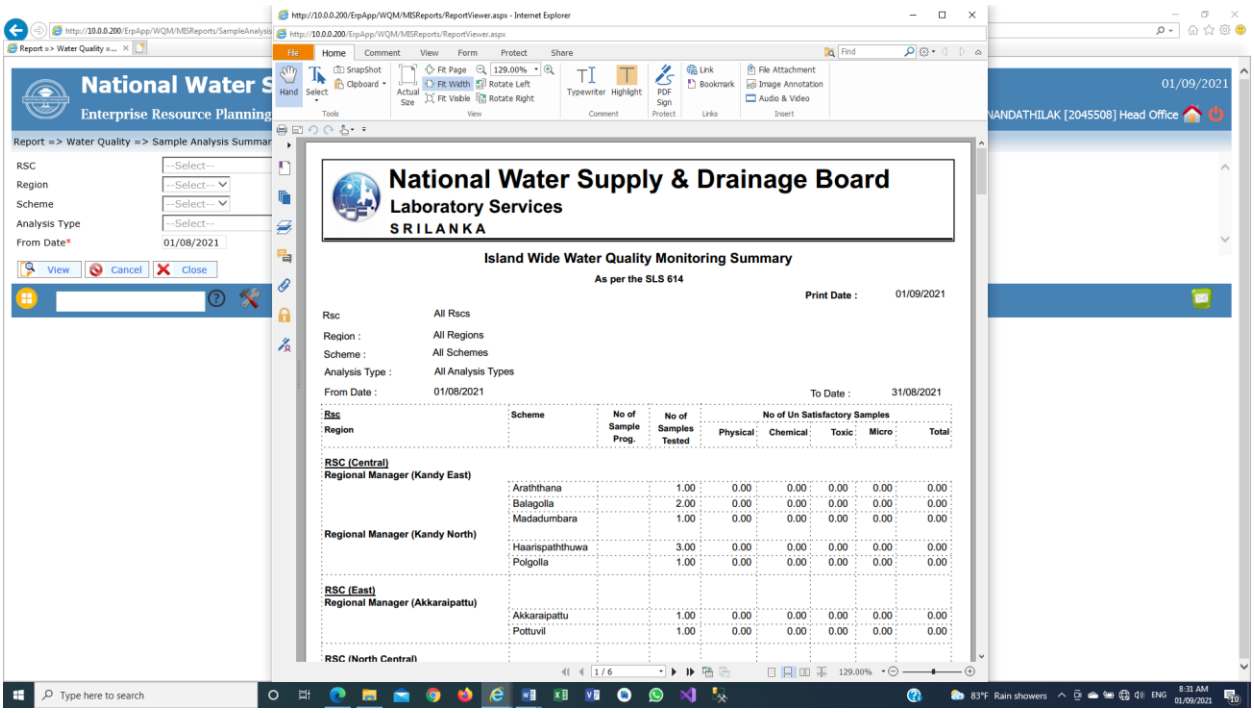

Figure C.2: Water Quality Monitoring Summary