

# Formulation and Utilization of an Assessment Tool in Optimizing Groundwater Resource Management through Integrated Water Resource Management (IWRM): A Case of Guagua, Pampanga

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**Abstract:** The sustainability and quality of groundwater in the Philippines are under threat due to natural factors and human activities, leading to health risks and limited access to water, particularly in areas such as in Guagua, Pampanga. Thus, the central objective of this study is to develop an assessment tool for optimizing groundwater resources through Integrated Water Resource Management (IWRM) in Guagua, Pampanga. To address the aforementioned issues, an IWRM participatory approach involving decision-makers and stakeholders was utilized in this study. Specifically, the assessment tool aimed to describe the current state of groundwater management, identify extant problems, and propose potential solutions based on IWRM principles. In doing so, the research evaluated the perceptions of the residents regarding the quality and quantity of water supply, water management practices, and their relationship to water consumption. Furthermore, it investigated the local government's policies and plans for securing water quality and quantity, and assessed the groundwater management practices through the perspective of consumers, planners, and lawmakers. Findings from this research will provide valuable information to the community and contribute to future research on water resource management. Hence, the development of an assessment tool for optimizing groundwater resources through IWRM is crucial for the long-term sustainability of groundwater in Guagua, Pampanga and the health and well-being of its inhabitants.

**Key Words:** — *Groundwater Depletion, Groundwater Contamination, Water Supply, Water Quality, Water Quantity, Water Management.*

## I. INTRODUCTION

### 1.1 Overview

Water is a vital resource that plays a significant role in several aspects of human life, including socioeconomic development, healthy ecosystems, and human survival [1]. Moreover, water is essential for agriculture, industry, energy production, and domestic use [2].

The availability of freshwater worldwide is limited to only 2.5%, with the majority of it being inaccessible since it is in polar ice caps and glaciers [3].

The Philippine Environment Monitor's report on Natural Resources stated that water is an essential natural resource that is crucial for the Philippines' economic advancement [4]. Nevertheless, a study [5] noted that surface waters and groundwater are the two main sources of freshwaters in the Philippines. However, Filipinos mainly depend on groundwater due to its accessibility and minimal treatment requirements. Unfortunately, the rising demand for freshwater, fueled by accelerated population growth, threatens the nation's groundwater supplies. The rapid growth of population and urbanization are only some of the reasons why the quality and quantity of water fluctuate over time, resulting in the depletion of its finite source [6].

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The excessive use of groundwater has been recognized as a significant issue that disrupts the natural water cycle and aggravates the impacts of environmental challenges such as climate change, pollution on water, and soil subsidence [7]. In many developing countries, adapting to the effects caused by climate change and contamination on resources of water is not the only reason policymakers invest in building water infrastructure. Other factors also motivate policymakers and planners to allocate more resources toward producing water infrastructure [8].

To effectively tackle the multifaceted challenges of managing integrated water resources, recent studies indicate that governance systems need to facilitate coordination across various levels and promote decision-making processes that are participatory, adaptive, and collaborative in nature. These approaches should bridge scientific, stakeholder, and community perspectives to promote effective management of water resources [9]. Many countries identified water scarcity as a growing concern, where there may still be enough water to meet the needs of rural communities, households, industries, and the environment [10]. However, due to a lack of economic resources, users may be hesitant to use these resources [11].

### *1.2 History and Current Water Management Situation in Guagua, Pampanga*

A study [12] stated that Pampanga is overly dependent on groundwater and has neglected its surface water along river systems. Guagua, Pampanga, for instance, has a land area predominantly devoted to agricultural purposes such as rice, sugar, fishponds, vegetables, orchards, and other cash crops. Therefore, the Municipality of Guagua, Pampanga, is highly reliant on the supply of water from irrigation and water districts that extract water from groundwater resources [13].

Based on the most recent statistics from the Philippine Statistics Authority's 2022 Census of Population and Housing, the population of Guagua, Pampanga has increased since the 2015 census. In the five-year period between 2015 and 2020, the population has grown by around 10.2% [14]. The population increase has resulted in a corresponding increase in the water consumption of the locality. Subsequently, the increasing population and overuse of groundwater resources, as emphasized in the study [15], can lead to water scarcity, amplifying poverty issues and water resource complications. Including the growing groundwater demand due to population growth, has put an enormous strain on resource use, resulting in lower water levels, land subsidence, water contamination, and increased salinization.

In the study [16], the NWRB has determined the possible range of the saltwater encroachment region, which covers a coastal zone that is approximately 20 to 30 kilometers wide, including certain provinces like Pampanga, and specifically in the Municipalities of Guagua and Sasmuan. In addition, the unguarded use of groundwater can cause a drastic effect on everyone. A case in point is the ground floor level of several old buildings in Guagua, Pampanga had sunk by 2 to 3 meters over a period of several decades.

Apart from this, the compaction of soil can lead to flooding in areas where groundwater is depleted. A study by the NWRB in collaboration with Japan International Cooperation Agency (JICA) identified several municipalities and cities in Tarlac, Bulacan, Nueva Ecija, and Pampanga are at risk due to water usage conditions, with the Municipality of Guagua being highlighted as one of the 11 areas with the highest risk. Additionally, Guagua has been ranked ninth in Region III since 2008 for being at risk in terms of groundwater resources. The risk will persist unless sustainable water management measures are implemented [17].

Furthermore, environmental issues of considerable magnitude have arisen in different areas of the Philippines including arsenic pollution of groundwater. Some research has explored the possibility that ground subsidence may be a contributing factor to the rise in arsenic levels [18]. The town of Guagua saw the first reported incidents of health issues related to arsenic, as identified by the Pampanga Regional Department of Health in 2014 [19].

It was suggested by the study [20] that proper water management practices, such as monitoring and regulating groundwater extraction, can help to ensure sustainable access to water resources for all, including the poor and vulnerable communities in Guagua, Pampanga. In addition, it is vital to balance the increasing demand for water resources with the need to protect and conserve at the same time, for future generations [2].

### *1.3 Significance and Relevance of Water Management and IWRM*

A study [21] stated in response to increasing danger and emergencies, many countries' water sectors have taken action by implementing latest mechanisms, simultaneous planning for water supply, or construction of new infrastructures. The government of the Philippines has continuously emphasized the significance of all-inclusive development, use, preservation, and safeguarding of water resources. The local government unit

in the Philippines has also established sub-national policies and legislative related to IWRM issues with the sub-national water resources policy [22].

The management of water resources is considered a long-time administration. It requires the contribution from the government, public and private organizations at all levels possible, participation if the charitable groups and individuals are also needed [23]. Supplies of water are in critical demand and the supply for the coming years is unpredictable, resulting in difficulties in preparation and management [24]. One way to deal the uncertainty with water supply is the IWRM model [25].

The research [26] indicates that IWRM is a method that fosters the synchronized growth and regulation of water, land, and associated resources to optimize the effective, just, and sustainable development and management of the world's finite water resources while addressing conflicting demands. Furthermore, the publication outlines the principles and practices of IWRM. The findings imply that IWRM is a crucial strategy for water management in the Philippines, and the government has been revising the water policy and regulatory framework to establish IWRM as a basis for sustainable development. In a study [27] one general framework that was emphasized by IWRM is the adaptation of the Dublin Principle (1992) that has the following principles:

*Principal No. 1* - Fresh water is considered a finite and critical resource to support living, improvement, and the environment.

*Principal No. 2* - Participation of users, planners, and policymakers at all levels is a must in terms of water development and management.

*Principal No. 3* - Women have the primary responsibility in the provision, administration, and security of water.

*Principal No. 4* - Water is acknowledged as an economic asset since it has cost and value among its competing applications.

While as per the information from the study [28], the Philippines' water supply and resources are managed and regulated by various government divisions, such as the River Basin Control Office (RBCO) under the Department of Environment and Natural Resources (DENR). The RBCO is responsible for overseeing and monitoring water-related programs and projects across the country, as well as managing the different uses of water and other natural resources from river basins to coastal seas. Moreover, another division that plays a vital role in water resource management in the Philippines is the National Water Resources Board (NWRB).

According to a study [29], the NWRB has adopted the principles of Integrated Water Resources Management (IWRM), is a participatory approach that facilitates the integrated development and management of water, land, and related resources within hydrological boundaries. The main goal of IWRM is to optimize economic and social welfare while ensuring the viability of critical ecosystems in an equitable manner. To be successful, IWRM requires group and technical awareness, as well as localized implementation.

The overall objective of this study is to formulate an assessment tool based on the principles of IWRM. And specifically aims (1) to describe the current state of the groundwater management of the municipality of Guagua, Pampanga, using the formulated assessment tool, (2) to identify the problems regarding the management practices of the surrounding groundwater resource in Guagua, Pampanga by analyzing the findings based on the formulated assessment tool, and (3) to present possible solutions to groundwater resource management challenges in accordance with IWRM aims.

## II. LITERATURE REVIEW

### 2.1 SDG: Sustainable Water Management

The United Nations Sustainable Development released an article on "Water and Sanitation" [30], covering the Sustainable Development Goal (SDG) on water supply Goal 6, that aims to guarantee an accessible clean water and sanitation for all. The goal includes targets such as increasing competence in water-use, implementing Integrated Water Resources Management (IWRM), and water-related ecosystems by protecting and restoring it. The SDG on water supply is critical for sustainable development, as water is vital for socio-economic growth, healthy ecosystems, and human survival.

Furthermore, the 2030 Agenda recognizes the significance of water resources to sustainable development and the improvements in drinking water, sanitation, and hygiene's contribution to progress in other fields, such as health, education, and poverty reduction [30].

### 2.2 Water Management Situation at National and Subnational Levels

The Philippines is experiencing significant strain on its water delivery and supply systems due to population expansion, economic development, and rising living standards [31]. As a result, there is a need to strike a balance between economic expansion and preserving the ecosystem to prevent surpassing the water supply capabilities. The country's economic

advancement relies heavily on water, as it is an essential natural resource [32].

The Philippine Clean Water Act pertains to water quality management in all water bodies in the country, primarily focusing on pollution abatement and control originating from land-based sources (ASEAN IWRM). A more integrated approach to water management is essential, and the traditional disjointed approach is no longer feasible [33]. It is also crucial to balance the increasing demand for water resources with the need to protect and conserve them for future generations [2].

Groundwater sources in the whole region Central Luzon highlighting Pampanga have seen a significant decline in quality due to indiscriminate domestic, agricultural, and industrial use [12]. Proper water management practices, including monitoring and regulating groundwater extraction can help in ensuring sustainable access of water resources for everyone, including the deprived and vulnerable communities in Guagua, Pampanga [20].

### **2.3 Implementation of IWRM**

An effective approach to addressing water-related issues in the Philippines is through the implementation of Integrated Water Resource Management (IWRM) [34]. The Philippine government has already initiated revisions to the water policy and regulatory framework in 2006 to promote sustainable development through the adoption of IWRM, as mentioned in an article from MDPI. Water management is defined by the study [35] as the control and flow of water resources to optimize their sustainable use while limiting harm to people and property. Managing dams and levees can decrease the possibility of flooding-related damage, while methods of irrigation water management can maximize the use of agriculture's limited water resources.

IWRM is distinctive from other water management approaches because it involves stakeholders from multiple sectors, depend on water balance and hydrological modeling tailored to a policy or planning context, and integrates hydrology with other environmental sciences [36]. In developing IWRM, scholars have made a significant progress through conceptualizing modeling methodologies, and reporting case studies. However, lack of documented knowledge was still experienced especially about the demonstration of workflow and the role of contextual factors in defining this workflow and the practices to employ. To support the implementation of IWRM modeling on a micro level, practice-oriented guidance is needed [37].

The water resources management must acknowledge the interconnected nature of hydrological resources [38]. IWRM is now accepted as an alternative to the previous top-down, sector-by-sector management approach. It recognizes the interdependence of various uses of water resources. The government or any management system should integrate local management interventions with broader basin management behavior and encourage communities to participate in governance and management [39].

A study [3] underline the importance of transparent information while making decisions on the management of water. Natural scientists, social scientists, engineers, and economists all need to participate in the decision-making process for freshwater ecosystems. Supporting this collaboration involves the use of tools that promote communication across disciplines. According to research [40], IWRM is a mechanism that renders easier coordination of the production and management of water, land, and associated services in order to maximize the resultant economic and social welfare in an equitable way. It also helps preserve vital ecosystems. In the study [41], it encourages the decentralization of water resources management to the local level by strengthening citizen participation in the decision-making process. All stakeholders must be included for this management strategy to be effective, and innovative methods must be employed [42]. Researchers and water resource managers from all across the world have embraced and tested the IWRM strategy [43]. Finally, a study [44] highlights that integrated management is a collaborative and coordinated endeavor that demands a global and sustainable perspective. Nowadays, this concept is widely utilized to address problems with water resources.

### **2.4 Challenges and Opportunities in Integrated Water Resource Management in the Philippines**

Management of water resources is a significant concern for the government of the Philippines, and there have been efforts to develop policies and laws related to Integrated Water Resource Management (IWRM) at the local government level. The founding of local offices and adherence to national laws and policies, revenue generation, resource mobilization, service delivery standards, and the promotion of IWRM elements through programs are some of the initiatives undertaken to address this issue [3]. However, despite these efforts, there is no comprehensive information on the progress and attainment of objectives of these sub-national policies. The level of implementation at the sub-national level is unknown, resulting

to difficulty in assessing the effectiveness of these initiatives [45].

One of the challenges in analyzing groundwater-based studies in the Philippines is the lack of institutions to offer data and information on the community's groundwater [46]. This challenge complicates the development of effective water resource management policies and laws, as there is a lack of data to inform decision-making processes. In Guagua, Pampanga, despite the government's efforts to establish regulations and implementation norms to improve the sanitation of liquid and solid discharges, water management remains fragmented, resulting in increased pollution and overexploitation of groundwater [47]. These threats contain permanent consequences on quality of water, accessibility, and future regeneration. Therefore, an integrated and synchronized approach to water resource management is necessary to address these issues [48].

### *2.5 Challenges and Impacts of Groundwater Depletion on Water Quality and Quantity*

Due to rapid urbanization, an increasing demand for water resources experienced, and as an outcome, many underground water sources are becoming depleted [49]. The over-extraction of groundwater is one of the causes of depletion, and some impounding water sources have already dried up due to unregulated groundwater extraction [16]. Groundwater scarcity occurs when water is being extracted at a rate faster than it can recharge, and excessive pumping of water from below the surface contributes to the problem [50]. Water usage and consumption also contribute to the depletion of freshwater resources that can lead to water scarcity and conflicts over water availability, access, and distribution [51].

Water scarcity is currently one of the most significant global challenges, and it is projected to become even more severe in the future due to climate change [52]. Agricultural production is primarily constrained by water availability and accessibility, making it crucial to address this issue in water-stressed areas. Aside from water scarcity, salinization is a significant global environmental issue that alters the natural water resources chemical composition such as lakes, rivers, and groundwater [53]. Salinization contributes to the degradation of agricultural and domestic water quality, the biodiversity loss, fertility of soil, and the downfall of agricultural and fishery industries, while causing serious health problems.

Excessive groundwater extraction not only contributes to groundwater scarcity and salinization but also causes land

subsidence, a significant challenge in the Philippines [54]. The lowering of the land surface by several centimeters to more than a decimeter per year is caused by over-extraction of groundwater, leading to problems such as seawater intrusion and sinking of the land surface. The most common human activity that results in land subsidence is the removal of subsurface water that causes the soil to collapse, compact, and sink [55].

Moreover, water contamination with naturally existing substances such as arsenic is a potential threat to water resources [56]. The contamination of water with arsenic can occur even at high levels, making it difficult to detect as it does not change the taste, smell, color, or appearance of the water. This situation can affect the source of water and accumulate other problems in the near future. Excessive salt in water can also contribute to the mismanagement of over-extraction of underground water, leading to health issues such as hypertension or high blood pressure that increase the risk of stroke [47].

## III. METHODOLOGY

### *3.1 Phase 1 – Introduction*

#### *3.1.1 Research Design*

The researchers utilized mixed methods since it collects, analyzes, and strategically integrates quantitative and qualitative study and techniques in a single study to better comprehend a research problem [57]. Mixed methods may be used for a rigorous description and interpretation of the data, to make quantitative results more comprehensible, or to grasp the broader relevance of small-sample qualitative findings [58]. A methodology was employed by formulating and utilizing assessment tool.

#### *3.1.2 Research Locale & Respondent Sampling*

The utilization of the formulated assessment tool took place in Guagua, Pampanga. These involve each of the town's 31 barangays. Based on the information [59], the population of Guagua, Pampanga as of 2020 is 128,893. Upon solving using Cochran's Formula the sample size needed for the survey questionnaire resulted to 385 individuals.

To countercheck, the sample size was also determined using the projected population in Guagua, Pampanga in 2023 and Raosoft Sample Size Calculator.

To project the population of Guagua, Pampanga in the year 2023, the annual growth rate of 1.98% [59] was considered. The

projected population for 2023 is 136,702. Upon computing using Cochran's Formulas the sample size also resulted to 385. Meanwhile, using Raosoft Sample Size Calculator contains a margin of error equal to 5%, a confidence level of 95% and a 50% response distribution, the resulting sample size of the study was 384.

Since the obtained values from Cochran's Formula and Raosoft Sample Size Calculator were relatively close, therefore, to identify the sample size, largest value governs. The sample size of the study was 385.

Stratified random sampling method was utilized to identify the 385 respondents of the study. The number of respondents to be chosen in each barangay is identified based on the portion that it occupies in the total population. The division of a population into smaller subgroups known as strata is an essential component of the sampling strategy known as stratified random sampling [60].

On the other hand, for the interview part of the assessment tool, the researchers asked the consent of 20 participants to be part of the study. Numerous publications, book chapters, and articles encourage guidance and suggest that 5 to 50 participants are adequate [61]. Convenience sampling was used for identifying the participants. A study [62] mentioned that convenience sampling, also known as accidental sampling or grab sampling, is a method of selecting a sample based on convenience and accessibility. Researchers chose participants who are readily available or easily accessible in the study area.

### 3.1.3 Research Instrument

In line with the Integrated Water Resources Management Principles and with its basis, the Dublin Principles, an assessment tool was obtained.

In formulating the first part: survey questionnaire, three categories were specified. It also utilized related literature in constructing the statements. The table below shows the statements and their respective citations.

Table.1. Basis of the first part of the Assessment tool

Statements	Citation
<b>Water Quantity</b>	Natural fresh water constantly does not have taste and odor, otherwise, it indicates contamination. The development of these two parameters in water can either happen from natural or artificial way [63]. A study [64] added that gasoline taste water could be a result of contamination of water from a leakage of underground storage tanks.
<b>A1</b>	
<b>A2</b>	Taste and odor in water used for drinking could be considered as a sign of contamination and malfunction either during water treatment or distribution. Thus, it

	could be an indication of the existence of substances that might pose a potential risk to health [65].
<b>A3</b>	Cloudiness in water is caused by acting material present in the water; some of these are clay and other organic matter that can serve as a space for dangerous germs preventing them from disinfection process [66].
<b>A4</b>	The increase in the incidence of illnesses including cholera, diarrhea, dysentery, hepatitis A, typhoid, and polio has been associated with water pollution and poor sanitation. People are exposed to preventable health hazards when water and sanitation facilities are insufficient, inoperable, or poorly maintained [65].
<b>A5</b>	Along with water quality, client satisfaction with tap water is an essential, but neglected, factor. This issue could be related to water operators' investments in improving water quality [67].
<b>Water Quantity</b>	A drawback of the MDGs monitoring was a lack of attention to water safety, which became an important component of the objective job for water supply and sanitation when the Sustainable Development Goals (SDGs) were designed [68].
<b>B1</b>	
<b>B2</b>	Low pressure of the water may result from a variety of issues, like pipe corrosion, scale leaks, and even gravity. With older pipes, corrosion is common, where metal reacts with the oxygen content of the flowing water it may build up and then restricts the flow of water [69].
<b>B3</b>	Over-extraction can diminish water supply, deplete groundwater, and cause land subsidence then contamination of wells by salt water intrusion in coastal areas. IWRM can help to prevent over-extraction by taking a holistic approach to water management [29].
<b>B4</b>	One of the descriptions for the global water crisis is having limited access to clean water; it can also alternatively be called a governance crisis [70].
<b>B5</b>	There are 12 possible reasons for sudden increases in water bills and two of them are; first, bad water wasting habits affiliated either to the home utilities or recreational activities, and second seasonal changes that result in increased water consumption [71].
<b>Water Management</b>	Access to trusted drinking water is a privilege as a fundamental human right and a way to improve living standards. At a basic level, consuming safe water has a major role in importing developmental challenges such as human health, food, and industrial growth [72].
<b>C1</b>	
<b>C2</b>	A reliable source of water is vital to guarantee the safety of everyone consuming it. The use of a water pump to access water, especially in places far from civilization, will help them to meet their water needs [73].
<b>C3</b>	The proper use of water reduces and lowers the issues associated with water locking. Consciousness about the consumption of water will create awareness, which can lead to proper management of water for everyone [74].
<b>C4</b>	Water is a basic necessity of life, and without it, life seems inconceivable. In consuming water, it is strictly consumed properly. The consumers used water that they only needed [75].
<b>C5</b>	Managing water, such as reusing it, is increasingly practiced throughout the world. It is meant to help the

	environment, and the water cycle, and sustain the water resources [76].
C6	Conservation of water is a beneficial way to save water and avoid water losses. Successful implementation of parameters to save water is effective management of water resources [77].
C7	Storing water has been a long practice in society in response to large climatic variability. Meeting this demand for storing water is a sufficient plan that needs by society [78].
C8	Water demand globally is a serious challenge for both water authorities and consumers. Achieving sustains the demand and supply of water is a major step in dealing with water scarcity. In line with this, managing water in households has a big impact on everyday practices to save water [79].
C9	Equipping consumers with proper information about water management is a useful way to save water. Information that is needed to inform everyone on the impact of water management practices is necessary [20].
C10	Involvement of consumers in water management and ensuring participation in different programs and planning can help lessen the threat of a water shortage. Engaging in the program related to developing water resources will give security to future generations [80].

In formulating the second part: the interview, the IWRM principles (Dublin Principles - 1992) were highlighted.

Table.2. Basis of the second part of the assessment tool

Dublin Principles (1992)	Interview Questions
Principle No. 1	Q1, Q2
Principle No. 2	Q3, Q4, Q5
Principle No. 3	Q6
Principle No. 4	Q7

To test the validity of the assessment tool, face validity was used. The term "face validity" is interchangeable with "content validity". It involves experts using their knowledge and experience to quickly evaluate an entire tool or instrument. This evaluation is based on their expert opinion and expertise [81]. The validation was performed by an expert in water management, a statistician, and a psychometrician in order to confirm the quality and eliminate any partiality or enmity from the procedures.

In order to test the reliability of the formulated assessment tool, Cronbach's Alpha was performed. This determined the measure of internal consistency and scale reliability by assessing how closely a group of items are related to one another [82]. The researchers utilized 30 individuals who will administer the survey questionnaire. According to a study [83], a pilot test for measuring reliability using Cronbach's alpha

required at least 30 participants as the sample given the scale items exhibit a strong correlation with one another. This set of samples came from the different subset of the population of Guagua, Pampanga.

Table.3. Case Processing Summary using Cronbach's Alpha

Case Processing Summary			
		N	%
Cases	Valid	30	100.0
	Excluded <sup>a</sup>	0	.0
	Total	30	100.0

Table 3 shows the case processing summary of Cronbach's Alpha. It denotes that there are 30 valid cases and there are no exceptions.

Table.4. Reliability Statistics using Cronbach's Alpha

Reliability Statistics	
Cronbach's Alpha	N of Items
.784	20

Based on Table 4, Cronbach's Alpha has a value of 0.784; therefore, the survey questionnaire of the assessment tool is reliable. Research [84] stated that when the Cronbach's Alpha is greater than 0.7, it is considered reliable.

Thus, the formulated assessment tool was valid and reliable.

### 3.2 Phase 2 – Data Collection

The study conducted the application of the assessment tool. A survey questionnaire was administered. The researchers also conducted interviews to those selected individuals who are acknowledged as consumers, planners, and lawmakers. Dialogues with the interviewees were recorded and then analyzed, correlating their responses to the aim of this study. All of the preceding information aids in reaching the study's objectives.

### 3.3 Phase 3 – Data Analysis and Evaluation

The study implemented the use of the Four Point Likert Scale. The use of this scale allows the researchers to include four extreme options without a neutral choice [85]. An instrument was used to obtain the perceptions of the people in the vicinity of the study. In this way the respondents are forced to form an evaluation and get the specific response. The following were the ratings used: 4 – frequently observed, 3 – occasionally observed, 2 – rarely observed, 1 – not observed. Weighted data were gathered and the Likert Scale Interpretation below was used.

Table.5. Interpretation for the weighted mean values

Weighted Average	Interpretation
3.25 – 4.00	Frequently observed
2.50 – 3.24	Occasionally observed
1.75 – 2.49	Rarely observed
1.00 – 1.74	Not observed

To assess the findings, Relative Importance Index was used. The rankings produced were then used to categorize the responses into three levels: high, medium, or low.

Table.6. Relative Importance Index Interpretation

RII Values	Remarks
RII<50%	Low Level
50%<RII<70%	Medium Level
(RII>70%)	High Level

Thematic analysis is a method of analyzing qualitative data of the study, the interview. Usually, it refers to a collection of texts, such as an interview or a transcript [86].

To evaluate the situations about groundwater resources and its management in Guagua, Pampanga, the findings from the utilization of the assessment tool (survey and interview) were assessed. IWRM principles were used in assessing the current challenges faced then possible solutions were made. The solutions aided the efficacy of the community’s water management as well as its citizens.

#### IV. RESULTS AND DISCUSSION

##### 4.1 Mean Rating from the Survey

Table.7. Average Mean per Water Quality Question

WATER QUALITY QUESTIONS		MEAN RATING
A1	Chlorine taste, gasoline taste, metallic taste, and other undesirable tastes of water are observed in the water supply.	1.88
A2	An unpleasant odor is observed from the water supply.	1.94
A3	Water is contaminated due to cloudiness and discoloration in the water supply.	1.97
A4	Skin reaction, diarrhea, and other negative impacts on health were observed after drinking/using water sources.	1.44
A5	The consumer is not satisfied with the quality of the water.	1.84

Table 7 indicates the mean rating for water quality questions. It shows that A3 ranked the highest mean rating of the five questions. The least mean rating from the five questions is A4.

Table.8. Average Mean per Water Quantity Question

WATER QUANTITY QUESTIONS		MEAN RATING
B1	Day/s without water supply is experienced in the area, especially during summer.	2.25
B2	Discharge of water from the source is relatively slow during the morning since there is a high demand for supply (workers and students are preparing) compared to the rest of the day	2.82
B3	The excessive use of water is observed by consumers during weekends since it is usually the “wash day or general cleaning day” and all members of the household are present at home	3.03
B4	There is limited access to water.	1.86
B5	Sudden increase in water bills is often experienced.	2.78

In table 8, there are three water supply problems highlighted by ranging above average scores acknowledged as “Occasionally observed”. The highest mean score among the three is B3, followed by B5 then B2, while least among the listed mean are B1 and B4.

Table.9. Average Mean per Water Management Question

WATER MANAGEMENT QUESTIONS		MEAN RATING
C1	Water is directly consumed since it is safe and trusted coming from the water sources.	1.92
C2	A water pump is used in the household as an alternative water source.	1.98
C3	Water is utilized properly by consuming only the amount of water needed for the activity.	3.51
C4	Water is only consumed if necessary	3.42
C5	Reusing of water is exercised.	2.48
C6	Discipline is practiced to save water and avoid losses.	3.32
C7	Water is stored in case of water supply interruption.	2.20
C8	Strategies for managing your water are being developed and practiced in your household.	2.74
C9	Everyone is equipped with the necessary water management information.	3.31
C10	Everyone is engaged with water resources planning and programs.	1.75

Based on the table 9, respondents from Guagua, Pampanga, have practice-well of proper water management, as shown by the large of number of "frequently observed" responses for question C3, C4, C6, and C9. However, C1, C2, C5, C7, and C10 show the majority of the respondents were "rarely observed".

##### 4.2 Relative Importance Index Method

Table.10. RII Values, Remarks and Rank per question under Water Quality

MUNICIPALITY OF GUAGUA				
WATER QUALITY QUESTIONS		RII	REMARK	RANK
A1	Chlorine taste, gasoline taste, metallic taste, and other undesirable tastes of water are observed in the water supply	46.95%	LOW	3
A2	An unpleasant odor is observed from the water supply.	48.44%	LOW	2
A3	Water is contaminated due to cloudiness and discoloration in the water supply.	49.29%	LOW	1
A4	Skin reaction, diarrhea, and other negative impacts on health were observed after drinking/using water sources.	35.97%	LOW	5
A5	The consumer is not satisfied with the quality of the water.	46.10%	LOW	4



The results showed that A3 has the highest RII, making it the most important criterion. However, it was still labeled as low rating. According to a study [87] most consumers do not notice water discoloration, indicating the water is contaminated, for the reason of visual appearance. On the other hand, A4 has the least importance and was also given a low rating. The low significance observation of negative health impact increased as they see it as an issue [88].

Table.11. RII Values, Remarks and Rank per question under Water Quantity

MUNICIPALITY OF GUAGUA				
WATER QUANTITY QUESTIONS		RII	REMARK	RANK
B1	Day/s without water supply is experienced in the area, especially during summer.	56.36%	MEDIUM	3
B2	Discharge of water from the source is relatively slow during the morning since there is a high demand for supply (workers and students are preparing) compared to the rest of the day	70.58%	HIGH	2
B3	The excessive use of water is observed by consumers during weekends since it is usually the "wash day or general cleaning day" and all members of the household are present at home	75.71%	HIGH	1
B4	There is limited access to water.	46.56%	LOW	5
B5	Sudden increase in water bills is often experienced.	69.55%	MEDIUM	4

Based on the data presented in Table 11, the highest risk was indicated under B3 that referred to excessive water use during weekends, whereas most water consumption occurs on weekends considering water is used more on houses [89]. The said issue was widely reported by respondents, particularly those from Brgy. Pulung Masle, San Pedro, as well as Brgy. San Juan Nepomuceno with a RII of 75.71%, the risk has a high ranking and significance.

Table.12. RII Values, Remarks and Rank per question under Water Management

MUNICIPALITY OF GUAGUA				
WATER MANAGEMENT QUESTIONS		RII	REMARK	RANK
C1	Water is directly consumed since it is safe and trusted coming from the water sources	47.92%	LOW	9
C2	A water pump is used in the household as an alternative water source.	49.42%	LOW	8
C3	Water is utilized properly by consuming only the amount of water needed for the activity.	87.86%	HIGH	1
C4	Water is only consumed if necessary	85.58%	HIGH	2
C5	Reusing of water is exercised.	61.95%	MEDIUM	6
C6	Discipline is practiced to save water and avoid losses.	82.92%	HIGH	3
C7	Water is stored in case of water supply interruption.	54.94%	MEDIUM	7
C8	Strategies for managing your water are being developed and practiced in your household.	68.51%	MEDIUM	5
C9	Everyone is equipped with the necessary water management information.	82.35%	HIGH	4
C10	Everyone is engaged with water resources planning and programs.	43.64%	LOW	10

Table 12 depicts that C3 was rated the most significant component in water management, with a high RII score of 87.86%. The utilization of water was increasingly observed in response to the issue on water sources [90]. On the other hand, C10 had the lowest rating with an RII of 43.64%. The limited participation of the executives in the development of water management discourages the residents from participating in different programs regarding proper management of water [91].

### 4.3 Thematic Analysis

Thematic Analysis is the approach used by the researchers to examine the information gathered from the participants.

There are twenty (20) consenting individuals for the interview: ten (10) consumers, five (5) planners, and five (5) lawmakers.

Table.13. Themes based from the findings of the interviews

Theme 1: Groundwater Availability and Accessibility	
<b>Consumers</b>	<p><b>Sub-theme 1.1 Difference in Location and how it Affects Water Supply</b></p> <p>Half of the participants said that they are not aware about the concern regarding the Groundwater becoming a limited source. A participant (CP3) even said that it was unlimited and they did not encounter a problem about this since the water source is located nearby.</p> <p>On the other hand, a participant (CP4) said that he is aware of the problem regarding the Groundwater resources since based on his experience, the soil that needs to dig for deepwells is much lower than before and it even differs depending on the location. Based on the study [92], due to excessive pumping the groundwater table can be lowered, that will prevent wells from accessing groundwater.</p> <p><b>Sub-theme 1.2 Ordinance Regarding Installation of Water Source</b></p> <p>A participant (CP6) showed mindfulness regarding Groundwater resources since he recalled that the water district, that supplies water for most of the consumers, banned the digging of deepwells. The deepwells that were used to be owned by each household are no longer allowed. Land subsidence is defined as the sinking of land brought on by the compaction of sensitive aquifer systems, can be worsened by digging deeper wells for groundwater extraction [93].</p>
<b>Planners</b>	<p><b>Sub-theme 1.1 Water Supply</b></p> <p>The theme significantly highlighted that each barangay in Guagua, Pampanga has a water supply as claimed by all the participant planners (PP). However, there are still problems with the supply of water during peak hours according to the planners.</p> <p>Thus, as stated by the study [50], this raises questions about the sustainability of the water supply, management during</p>

	<p>high demand, and the need for collaboration between stakeholders to provide innovative solutions that aim to manage the water supply efficiently and ensure it is safe for consumption.</p> <p><b>Sub-theme 1.2 Unequal Distribution of Water Supply in Guagua, Pampanga</b></p> <p>Though it is claimed that most households have sufficient water supply in some areas of Guagua, Pampanga, the opposite is experienced in other barangays when it comes to their accessibility to water as claimed by Participant-Planner 3 (PP3) and 5 (PP5). They considered groundwater supply as lacking or limited resources.</p> <p>Remarks were made by the study [94], that inequality in water distribution can have severe effects on communities due to a lack of access to a reliable, safely managed source of water and a lack of access to safely managed household sanitation facilities.</p> <p><b>Sub-theme 1.3 Hand pumps as an alternative water source</b></p> <p>The theme highlights the resilience of communities in addressing water scarcity issues in Guagua, Pampanga, especially in the indigent community of Brgy. San Agustin as mentioned by Participant-Planner 5 (PP5). It indicates that some barangays have found ways to alleviate water scarcity, such as using pumps as the main source of water for areas that do not reach the water district.</p> <p>As stated in the book [95], hand pumps can be an effective solution to alleviate the communities that are unable to be supplied by the water districts. However, poor planning and neglecting physical limitations can cause failures in water supply systems, e.g. improper construction, lack of maintenance, and inadequate water resource.</p> <p><b>Sub-theme 1.4 Potability of Water Supply</b></p> <p>The statements described the differing perspectives and knowledge among planner participants on the safety and quality of drinking water in Guagua, Pampanga. It highlighted the municipality's proactive approach to ensure safe drinking water through water testing and wide surveys per barangay. The comments of Planner Participant 4 (PP4) emphasized the unsafe drinking water coming from the area of Guagua, Pampanga due to contamination of arsenic as mentioned by the Provincial Health Government in a seminar held by the Capitol of Pampanga.</p> <p>The study [18] was carried out to measure the levels of arsenic in 101 wells located in Guagua, Pampanga, and the results showed a spatiotemporal variation of groundwater arsenic.</p> <p>Moreover, Participant-Planners also mentioned the importance of knowledge and information-sharing among stakeholders, specifically in relation to safe drinking water.</p>	<p>further limits the water supply. The negative effects of urbanization and tourism include an increase in the demand for pure drinking water that exceeds the supply system's capacity, resulting in water shortages [96].</p> <p>It was also added by the study [97] that precipitation takes various paths on land, with some evaporating back into the atmosphere, some seeping into the ground, and the rest becoming surface water that flows through rivers and streams into oceans and lakes.</p> <p>However, urban development and the accompanying impervious surfaces disrupt this natural process, resulting in a decrease in the amount of water that percolates into the soil. This impacts the availability of clean, pure water for humans, wildlife, and aquatic life by increasing the quantity of surface water with diminished quality.</p> <p>In addition to the rapid disappearance of agricultural farms, cities are endangering the livelihoods of farmers and fishermen by causing water pollution and shifting water resources to urban areas [98].</p> <p><b>Sub-theme 1.2 Effects of Climate Change to Water Supply</b></p> <p>Another two participants (LP3 &amp; LP5) described how climate affects the water supply specifically during extremely hot weather; they mentioned that they consumed a larger volume of water because of too much heat. Despite their answer, LP3 also added that there are no visible problems with their water supply as their NAWASA is functioning well, and that they also have water pumps as an alternative.</p> <p>LP4 on the other hand, did not know which agency or office could answer, and added that it may be a person from the water district.</p>
<p><b>Lawmakers</b></p>	<p><b>Sub-theme 1.1 Conversion of Farmland to Fishponds and Subdivision</b></p> <p>Two of the participants (LP1 &amp; LP2) pointed out that the conversion of farmland to fishponds and subdivisions</p>	<p align="center"><b>Theme 2: Factors that Affect Groundwater Resources</b></p> <p><b>Consumers</b></p> <p><b>Sub-theme 2.1 Population</b></p> <p>To fulfill the rising water demand brought on by population growth, groundwater resources are being progressively exploited [99]. The participants (CP 1, 7, and 8) described the flow of water to be slower when there are many consumers using it.</p> <p>The water coming from the irrigation is also discussed by a participant (CP 3). Since there are many farmers that will utilize the water, the supply is not enough. It was stated that only the farmers who will receive the first batch of water will benefit. At present, 70% of groundwater withdrawals worldwide, and even more in dry and semi-dry areas, are utilized in agriculture to produce food, fibers, cattle, and industrial crops, and an estimated 38% of the land that is fitted for irrigation is served by this resource [100].</p> <p><b>Sub-theme 2.2 Climate Change</b></p> <p>Awareness about Climate change is visible among the participants (CP 7, 8, and 9). Due to too much heat, participants said that they consumed plenty of water than usual leading to more demand. Water supply is not sufficient since rain is also not observed often. The</p>

<p>hydrological cycle is one of the many ways that climate change affects groundwater systems, and it can modify how much groundwater recharges [101].</p> <p><b>Sub-theme 2.3 Installation of Deepwells</b></p> <p>Participants described that the presence of deepwells have an impact on the water resources. It is mentioned that the lowering of the water table occurs because of high demand for water. Hence, installations of deepwells need to be dug lower to have a supply of water.</p> <p>A participant (CP5) shared his own experience about the situation; water was interrupted because it can no longer supply water. After checking it, the length of the pipe needed to be used was triple compared to the first pipe they used.</p> <p>Hence, it is believed that monitoring deepwells is very important since it causes depletion of groundwater resources. For the participant (CP4), one of the solutions to help in groundwater management, all the residents must limit their pumps and be a consumer of NAWASA instead.</p> <p>Consumer participant four (CP4) also expressed his knowledge about deepwells and its consequences to the groundwater resources. Limiting of the resources will not be experienced since there are no longer fishermen that use deepwells for their fishponds.</p> <p>The groundwater table can be lowered by excessive groundwater extraction. Water must be drawn or pumped from a well that extends below the water table in order to obtain groundwater. The inability of the wells to access the groundwater when the groundwater level drops too much, demonstrates the constant need to deepen the well or possibly drill a new one. This suggests that groundwater would be unavailable if current wells were used, emphasizing how important it is to adjust to changes in the groundwater table level that might be a raising concern regarding the resources [102].</p> <p><b>Sub-theme 2.4 Conversion of Surface Water to Commercial Buildings</b></p> <p>Surface water is another source that can supply the demands of water but it is not being optimized. As mentioned by the participant (CP6), surface water is being converted to buildings resulting for the fishermen to be dependent on groundwater. According to study [103] surface water resources are seriously affected by urbanization, one of the main causes of their conversion to land. This impact is measured in terms of surface water loss. Future urban growth scenarios predict rising surface water losses that will have negative impacts on people and the environment.</p> <p>Additionally, surface water importance is also emphasized by another participant (CP4) as another source of water. Gather water from seas then perform desalination. Through pipes, every part of the Philippines can have a supply. Desalination is a method that is becoming more and more popular for obtaining fresh water for home and industrial use. It is a process that entails the removal of salts, as well</p>	<p>as other minerals and pollutants, from wastewater effluent, brackish water, and saltwater [104].</p> <p><b>Sub-theme 2.5 Harmful Chemicals</b></p> <p>Since Guagua is surrounded by surface water, most of its fishponds operate on it, along with the groundwater. But as described by the fisherman (CP6), the water that originated from the ground has a problem when it comes to quality. No matter what treatment is performed to solve the problem, there is still no effect.</p> <p>From his perspective, this has something to do with the chemicals that are being thrown everywhere. The water was described as oily or smells like gasoline.</p> <p>From the point of view of another participant (CP10), discipline when it comes to throwing of garbage, especially those containing chemicals, must be observed since it affects the quality of water.</p> <p>Polluting substances that occur naturally exist in rocks and sediments. As groundwater percolates through sediments, metals like iron and manganese are dissolved, and these metals may later be found in the water in large proportions. Industrial discharges, urban activities, agriculture, groundwater pumping, and waste disposal can all have an effect on groundwater quality. Leaking fuel tanks or spills of harmful chemicals or gasoline could introduce pollutants into the groundwater that could contaminate the aquifer. The water table can get contaminated by pesticides and fertilizers used on lawns and crops [105].</p> <p><b>Sub-theme 2.6 Cutting Down of Trees</b></p> <p>One way to recharge the groundwater is through rain by the process of water cycle. The hydrological cycle requires trees to be able to function and the participants are aware of this significance. In a process known as transpiration, through pores in their leaves, trees extract water from the earth and release it as vapor into the atmosphere that can have an impact on rainfall and global temperatures [106]. A participant (CP2) suggested that the cutting down of trees should be imposed. Although the groundwater has a continuous flow, factors like trees and rain affect its recharge.</p> <p>As stated by the study [107] in order to sustain groundwater and streams during periods of low precipitation forests are frequently referred to as "sponges" that collect rainwater and release it gradually. Previously, this theory of the sponge and similar concepts guided policies aimed to protect and restore forests.</p> <p><b>Planners</b></p> <p><b>Sub-theme 2.1 Climate and Facilities</b></p> <p>The theme highlights that the hot climate and lack of facilities have resulted in a limited groundwater supply in Guagua, Pampanga as stated by Participant-Planner 1 (PP1) and supported by Participant-Planner 5 (PP5).</p> <p>Climate change and inadequate infrastructure can contribute to water scarcity and quality issues [108]. Addressing this issue requires a comprehensive approach that includes community education on water conservation</p>
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	<p>practices, investment in infrastructure, and considering social equity and justice in planning and implementing solutions. Ultimately, the goal is to ensure that all communities have access to sufficient and safe water supply despite the challenges posed by the hot climate and lack of facilities</p> <p><b>Sub-theme 2.2 Rising Population and Increasing Demand</b></p> <p>Participant-Planner 3 (PP3) pointed out the challenges faced in Guagua, Pampanga due to limited groundwater resources caused by the high volume of consumers and population growth.</p> <p>In the study [109] the Philippines is experiencing a water crisis because the population is multiplying quickly, and inadequate governance has resulted in a failure to establish essential water supply infrastructure.</p>		<p>a deep well since they grew up drinking water from that water source.</p>
<b>Lawmakers</b>	<p><b>Sub-theme 2.1 Water Contamination</b></p> <p>Awareness about the quality of groundwater is visible to the majority of the participants as they mentioned some physical changes like the water changing color and becoming slippery. They talked about septic tanks and the volcanic mudflow from the eruption of Mt. Pinatubo contaminated both deepwells and surface water.</p> <p>Septic tanks are usually near our deepwells, and according to our participants, as our septic tanks used to be made of gravel beddings, they can infiltrate the deepwells and contaminate them. If a septic system is located in close proximity to a well, groundwater from the septic drain field may infiltrate and contaminate the water entering the deepwell [110].</p> <p>It was also stated by the study [111] that volcanic eruption can cause an increase in ortho-phosphate and temperature in streams that further limits the availability of clean and safe water for human usage.</p> <p>Participant LP4 spoke that they do not know who can answer, but they did mention the arsenic content of the water that cannot be disclosed to the public yet.</p>	<b>Planners</b>	<p><b>Sub-theme 3.1 Community-Based Programs and Conservation Efforts</b></p> <p>The statements highlighted a discussion where participants emphasized the importance of community involvement in improving water supply and quality of life in Barangay communities. Participant-Planner 3 (PP3) and 4 (PP4) pointed to the success stories of Brgy. San Agustin and Brgy. San Matias as examples of how effective community engagement can lead to successful water management initiatives. These initiatives require planning and coordination between different stakeholders, including local government units, water service providers, and community organizations, to ensure sustainable and equitable water management practices. Ultimately, the discussion emphasized the need for collaboration and the development of effective solutions to address water supply challenges and improve the quality of life for the community.</p> <p>As stated in the study [112] to improve water supply, there is a need for collaboration between barangays, municipalities, and water districts. Barangays can work with municipalities and water districts to identify areas with poor water supply coverage and prioritize them for public and private investments.</p> <p><b>Sub-theme 3.2 Resident Participation in Water Management</b></p> <p>The statements suggested that community participation is important in addressing water supply challenges in barangays, and highlighted the initiatives taken by some Barangays where residents played an active role. The planners emphasized the need for collaboration between different stakeholders and noted that community participation alone cannot solve all the water supply challenges.</p> <p><b>Sub-theme 3.3: Municipal and Barangay-Level Programs</b></p> <p>Two participant planners shared recent activities in Guagua, Pampanga. PP2 discussed the municipality's survey of its barangays, while PP4 mentioned a seminar on safe drinking water that was attended by all the municipal barangays, yet other participant planners mentioned that no initiative or programs as such are being conducted by the municipality. These initiatives show that the government and community organizations are taking steps to address the water supply issues in the area. However, proper dissemination of information and programs in the municipality must be addressed.</p>
<b>Theme 3: Programs and Strategies on Water Supply</b>			
<b>Consumers</b>	<p><b>Sub-theme 3.1 Establishing Alternative Water Source</b></p> <p>In the point of view of a participant (CP2), having a personal deepwell is a better option than choosing the water district that supplies most of the consumers in the community, since it will be a cheaper choice. The aforementioned participant owns a business that consumes a lot of water, a carwash shop.</p> <p>Meanwhile, because of unresolved problems regarding the irrigation system, participant CP3 said that most farmers decided to have their own deepwells as well to support their needs in watering their crops.</p> <p><b>Sub-theme 3.2 Aiming for Better Quality of Water</b></p> <p>Consumer (CP4) is not satisfied with the quality of water that the water district, the main supplier of water in the community, offers and he also added that he prefers having</p>	<b>Lawmakers</b>	<p>Participants also showed awareness about projects and proposals that tackles water management, such as the controlling of procurement of water from deep wells for fish pond usage (LP1), using surface water as a new septage target (LP1), as well as using simple strategies to save water such as the usage of water supply from water district only</p>

	<p>for drinking and cooking (LP3), and water from water pump for other household chores.</p> <p>Lastly, the water scheduling was implemented for farmers with some difficulties, as some people were unsatisfied with the limitations of their water supply. According to LP5, there were instances where some people blocked the water source of others in order to gain more benefits with their water flow.</p>
<p><b>Theme 4: Cooperation and Collaboration between the Community, Government, and Third Party</b></p>	
<b>Consumers</b>	<p><b>Sub-theme 4.1 Ordinance About Maintaining Surface water</b></p> <p>As mentioned earlier, surface water can be utilized as a water source, hence, it is important to take care of it. The participant expressed ways to manage surface water properly that mainly focuses on keeping the bodies of water clean and that the government should make policies regarding it.</p> <p><b>Sub-theme 4.2 Construction of Dams</b></p> <p>Participants (CP8 &amp; CP9) suggested the building of dams as a way to conserve water. Dams must be considered especially those near the mountains. In the article [113] a dam is a structure placed over a river or streams to stop the flow of water by obstructing it with rock, dirt, or concrete. Dams are often constructed to store water in a reservoir for later use in a number of ways, including irrigation and municipal water supply.</p> <p><b>Sub-theme 4.3 Irrigation System</b></p> <p>Disappointment was evident to participant CP3 regarding the poor irrigation system in the area. Lack of proper implementation and slow actions are one of the seen problems. Meetings happen frequently, but the solutions are not visible.</p> <p>Participants (CP4) said that farmers are hoping for rain to come since the government does not have a solution to the irrigation system. Rain plays a big role in the system; it even causes the system to overflow sometimes. Rain now is very seldom, hence, the planting of crops became affected. No rainwater means more groundwater needed, and to be able to get it, diesel is needed. As a result, farmers opted not to plant since they lost a lot of money.</p> <p>Groundwater recharge is interdependently impacted by variations in precipitation, evapotranspiration, and runoff, in addition to changes in the hydrological cycle and the likely instigation of basic climate change elements. It is probable that higher rainfall intensity will cause less recharge and more runoff. Less groundwater recharge with high demand of water leads to a drop in the groundwater table [114].</p>
<b>Planners</b>	<p><b>Sub-theme 4.1 Dependence on Water District</b></p> <p>The respondents in the discussion believed that the water district has jurisdiction over the water resources and management in the Municipality of Guagua, Pampanga.</p>

	<p>They expressed their dependence on Prime Water that is responsible for providing water supply to the area. The discussion highlighted the importance of understanding the role of water districts and the need for sustainable water management practices to ensure a sufficient and safe water supply for the community.</p> <p>Study [115] stated that dependence on water districts can have negative effects on water supply and management in the Philippines. Furthermore, dependence on water districts can limit resident participation in water management and reduce their ability to ensure equitable access to water and sanitation services.</p> <p><b>Sub-theme 4.2 Communication Between the Municipality and its Barangays</b></p> <p>The statements suggested that respondents in the municipality of Guagua, Pampanga expressed concerns about water-related problems but felt that the authorities were not taking the initiatives despite efforts made by the barangays to raise the issues. The lack of communication and information sharing between the authorities and the barangays was also highlighted as a contributing factor to the problem.</p>
<b>Lawmakers</b>	<p>Participants are well-knowledgeable about possible solutions to water scarcity. They talked about cooperation between agencies related to the issue (LP1), teaching and applying the correct process of saving water (LP3), and reaching out to other government agencies (e.g., NIA) to come up with more solutions such as building a new source of irrigation (LP5).</p>
<p><b>Theme 5: Development of Water Management</b></p>	
<b>Consumers</b>	<p><b>Sub-theme 5.1 Saving and Reusing of Water</b></p> <p>Majority of the participants (CP1, CP5, CP6, CP7, CP9, and CP10) believed that saving water is important to help conserve natural resources. Simple acts that can be done in daily lives are mentioned: turn off the faucet when the bucket is full, reusing water used from laundry, avoid using showers since it causes a great loss of water and when utilizing supply of water, slow flow must be exercised to avoid losses.</p> <p><b>Sub-theme 5.2 Collecting and Using of Rainwater</b></p> <p>Participant CP8 mentioned that rainwater can be used as a source of water if the supply is not enough for the consumers. As mentioned by the study [116] the process of enhancing surface runoff or natural infiltration of rainfall into the earth using various man made techniques is known as rainwater harvesting.</p> <p><b>Sub-theme 5.3 Fixing Water Pipe Leaks</b></p> <p>Leakage from broken water pipes causes water to be wasted and as a result two participants (CP2 and CP8) stated that checking and repairing the pipes are beneficial. If the water gauge or meter is rotating even though no faucet was used at the moment, it might be an indication of broken pipes.</p>

	<p><b>Sub-theme 5.4 Solving Problems Regarding Water Waste</b></p> <p>Most of the participants said that their daily negative practices cause the water to be wasted. It is highlighted that waste is coming from continuous flow of water when it is used for daily activities. Participants suggested proper management and the use of right equipment for specific tasks as keys to avoid water loss.</p>
<b>Planners</b>	<p><b>Sub-theme 5.2 Testing and Monitoring of Water Quality</b></p> <p>The participant planners highlighted the lack of participation of the water district in water testing in some areas of Guagua, though there are initiatives of each barangay in monitoring the water quality in their area. There are also efforts by water districts to test the quality of pumps and lines in the municipality of Guagua, Pampanga. It also emphasized the importance of collaboration between barangays and the water district to ensure a safe and sufficient water supply for the community.</p> <p><b>Sub-theme 5.3 Prime Water Plans, Projects, and Improvements</b></p> <p>The planners' responses regarding Prime Water's plans and projects for solving water-related issues in each barangay of Guagua raise the question of timing for the rest of the community, while some barangays may have access to solutions, other areas may still be experiencing water problems. This highlighted the need for timely and equitable distribution of resources and solutions to all areas in the community.</p>
<b>Lawmakers</b>	<p>For the development of water and its management, the participants pointed out a policy from a feasibility study wherein the process of removing septage from septic tanks and treating it to discharge safely in the environment (LP1). The partially decomposed feces in a septic tank are referred to as septage. Regular desludging and treatment of the septage collected from septic tanks is a solution [117].</p> <p>They also added the aforementioned factors about building septic tanks from gravel bedding to concrete slab to avoid contamination of deepwells (LP1). LP3 on the other hand, talked about a simpler way of water management, such as teaching the community about the processes of how to properly save water, adding that they remind the community quarterly. Lastly, LP5 mentioned the scheduling of the aforementioned water.</p>
<b>Theme 6: Involvement of Women in Water Management</b>	
<b>Consumers</b>	<p>Most of the participants (CP2, CP5, CP6, CP7, CP8, and CP9) agreed that women are the one responsible for the management of water since usually they are the head of household management of household, wherein they handle the budget making them knowledgeable about expenses with water consumption. They are responsible for telling the importance of water and how they should conserve it. They will also remind everyone how the management of water affects their bill in water. It was even stated by a</p>

	<p>participant (CP7) that not all men care about the water consumed.</p> <p>In the management of water, women are crucial. Most frequently, they are the household's water collectors, users, and managers. Because of these responsibilities, women have enough knowledge about water resources, including the quality and dependability, limits, and suitable storage techniques. They are essential to the success of policies and programs aimed at developing water resources. It is commonly acknowledged that a significant factor contributing to the high failure rate of water supply and sanitation facilities is the exclusion of women from the planning process. International programs like the United Nations Conference on Environment and Development (UNCED) and the International Drinking Water Supply and Sanitation Decade have been crucial in advancing the position of women in water management [118].</p>
<b>Planners</b>	<p>The respondents highlighted the importance of women's role in water management and their knowledge of water conservation. Women are the primary users of water in households, responsible for managing water bills, and are more likely to have concerns about water. The planners observed that women are more likely to initiate water conservation and act to conserve water.</p>
<b>Lawmakers</b>	<p>Most of the participants' statements center on the topic of gender, gender equality, and women's involvement in making policies. The first statement emphasized the role of women in promoting gender awareness and advocacy by mentioning the Gender and Development Program (GAD), but also included the subjective viewpoint that women are becoming more powerful than men. The second statement highlighted the significance of women's participation in attaining gender equality. The third statement emphasized that women are frequently the primary recipients of social programs like Tulong Panghanapbuhay sa Ating Disadvantaged/Displaced Workers (TUPAD), and Pantawid Pamilyang Pilipino Program (4Ps), that are designed to alleviate destitution. The fourth statement stressed out the need for equal opportunities for women in a variety of disciplines, including agriculture and program development, as well as their potential to have a significant impact.</p> <p>As stated by the study [119] the fifth goal of the SDG involved gender equality as one of the most basic human rights. Promoting gender equality is essential for all aspects of a healthy society, including reducing poverty and promoting girls' and boys' health, education, protection, and well-being [120]. Millennium Development Goals Achievement Fund (MDG-F) added that to achieve gender equality, it is essential to establish a community where men and women share authority and influence in equal measure.</p>
<b>Theme 7: Water as a Need and Asset</b>	
<b>Consumers</b>	<p>All of the participants agreed that water is the most important thing in our life because, basically without it, life on earth will not survive. Humans cannot survive without</p>

	<p>water. Water is even more important than food, or air, as without it we are nothing.</p> <p>Based on the article [74] water is essential for all living things, and it serves several important roles in the human body, including transporting and dissolving vitamins and minerals, regulating body temperature, facilitating the work of the kidneys and other organs, protecting the body from injury, and acting as a cushion. In addition to all of these, water plays a crucial role in carrying out numerous crucial processes, including circulation, excretion, and 80–90% of our blood and 75% of our muscles are created during reproduction over water. Life cannot exist without water.</p>
<b>Planners</b>	<p><b>Sub-theme 7.1 Vital Importance of Water for Human Survival</b></p> <p>The remarks stated by all participants emphasized the recognition of the vital role of water and its importance to human life as a necessity.</p> <p><b>Sub-theme 7.2 Protecting Water as a Valuable Resource</b></p> <p>The theme highlighted the significance of water conservation and management to ensure that this resource is preserved for future generations. Moreover, the statement is that some participants consider water as wealth and should be protected and valued. In the study [121] water is a valuable resource that needs to be protected, was emphasized.</p> <p><b>Sub-theme 7.3 Water's Value Compared to Electricity</b></p> <p>The comparison made by the three participant planners emphasized the crucial role that water plays in our lives. Without electricity, we may experience inconvenience and disruption in our daily activities, but without water, we cannot survive. It is crucial to recognize the value of water as a resource and to prioritize its conservation and management to ensure that we have a sustainable supply for future generations. Moreover, according to the study [122] water is more important than electricity in human survival because it is a vital resource for all known forms of life, including humans.</p>
<b>Lawmakers</b>	<p>The statements revolved around water, its importance as a necessity for human survival, and its function as a resource for individuals, families, and communities. LP1 mentioned that water is essential to life, especially in extreme weather, and its scarcity can have dire consequences. Study [123] claimed that between 60 and 75 percent of the weight of the human body is made up of water. Dehydration can occur with as little as a 4% loss of bodily water, and a 15% loss can be deadly. Similarly, a person can survive one month without sustenance, but only three days without water. This dependence on water is fundamental to all forms of existence.</p> <p>LP2 highlighted the need to protect water as an irreplaceable resource and the significance of pure water for health and hygiene. LP3 stressed the broader impact of water waste and the potential for water scarcity to become a national or international issue. LP4's statement focused on the non-negotiable nature of water's fundamental</p>

<p>function as a necessity, framing it as a need rather than a want. LP5 recognized that water is both a source of nutrients for agriculture and a source of drinking water for people, highlighting its significance as an economic and social asset.</p> <p>When water resources are scarce and ineffectively managed, ecosystems and humanity suffer. When water supplies become depleted, people cannot consume it, bathe in it, or use it to irrigate their crops, which may lead to economic deterioration, hence, effective and efficient water management is necessary [124].</p>
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The findings on Table 13 depict the different perspective and stand of the respondents regarding groundwater resources and its management.

#### 4.4 Proposed Solutions

The following are the identified problems regarding Groundwater Resources based on the findings of the assessment tool. Proposed Solutions for these concerns were made by the researchers.

Table.14. Challenges faced by Groundwater Resources and possible keys to overcome the situation

	<b>Problems Regarding Groundwater Resources</b>	<b>Proposed Possible Solutions</b>
<b>W A T E R  Q U A L I T Y</b>	Unpleasant smell of water	Low-cost sanitation programs and long-term investments in hygiene promotion must be prioritized.
	Water is contaminated due to: <ul style="list-style-type: none"> <li>• Arsenic</li> <li>• Septic tank leakage</li> <li>• Volcanic Mudflow</li> </ul>	Private and public entities work together to develop concrete plans to address the most pressing water quality issues. Funding of water quality facilities plays a significant role. Additionally, public awareness regarding safe water drinking must be taken seriously. Public health is an utmost priority.
	Clothes and tiles turning yellowish in color after continuous contact with water.	Replacement and maintenance of facilities and equipment like water/pump lines must be observed.
	Lack of water quality testing on some barangays of Guagua, Pampanga.	Monitoring the water quality coming from the source by conducting regular testing and ensuring it passes the standards set for safe drinking.

W A T E R  Q U A N T I T Y	<p>Slow flow of water during:</p> <ul style="list-style-type: none"> <li>• Morning and night in some areas</li> <li>• Weekends</li> <li>• Hot weather</li> <li>• High volume of consumers</li> </ul>	<p>Proper management of water must be exercised to avoid losses. There are several solutions that will help with the supply of groundwater such as artificial recharge and groundwater banking.</p> <p>Improvement and addition of equipment and facilities to provide for a larger volume of consumers. Utilizing surface water as an alternative water source must also be developed.</p>	A N A G E M E N T	<p>Lack of actions of the Water District (main supplier/source of water) on community's concerns</p>	<p><b>For the Consumers:</b> Urging the government to respond to the concerns regarding the services they offer.</p>
	<p>Lack of water supply at the area where Indigent People of Guagua, Pampanga are located.</p>	<p>Providing and improving facilities to be able to supply all areas.</p>			<p><b>For the Planners:</b> Customers should be informed and educated with regard to their rights, responsibilities, and utility service standards.</p>
	<p>Installation of personal deepwells</p>	<p>Deepwells or water pumps installed by consumers should be subject to mandatory registration to ensure accurate monitoring.</p>			<p><b>For the Lawmakers:</b> The collection of data on groundwater fluctuations, water level trends, and water quality is crucial for comprehending aquifer conditions and behavior. The government should continue to fund groundwater monitoring data acquisition.</p>
	<p>Limited water supply from irrigation systems</p>	<p>As the largest water consumer, agriculture should increase water use efficiency by modifying cropping patterns, relining canals, and redesigning irrigation facilities to utilize return flows.</p>		<p>Lack of public awareness or information about safe drinking water</p>	<p><b>For the Consumers:</b> Public awareness should focus on the connections between land use, development practices, aquifer recharge, and groundwater quality and quantity. Particular attention should be made to the manner in which particular practices have direct effects on groundwater resources.</p>
	<p>Over extraction of water causes ground subsidence</p>	<p>The development of surface water sources through the construction of dams and reservoirs should be pursued in order to reduce the community's reliance on groundwater resources.</p>			<p><b>For the Planners</b> Welfare of everyone must always be taken into consideration. Hence, performing seminars and creating advocacy about safe drinking water should be at the utmost priority.</p>
	<p>Surface water conversion to residential buildings</p>	<p>Monitoring the conversion of surface waters and land coverage (such as the construction of buildings) is necessary to identify available areas for rainfall to replenish aquifers.</p>			<p><b>For the Lawmakers</b> Partner agencies and LGUs should be endowed with the necessary skills and resources to effectively implement the Clean Water Act's laws and regulations.</p>
W A T E R  M	<p>Lack of local government programs regarding water conservation and management</p>	<p><b>For the Consumers:</b> Residential and agricultural water conservation practices can significantly contribute to overall water efficiency improvement initiatives.</p>	<p>Negative practices of consumers on water management that cause water to be wasted and contaminated.</p>	<p><b>For the Consumers:</b> Increasing the use of alternative water supplies, such as recycled water, stormwater, rainwater, and greywater, can improve water supply reliability, free up water for environmental use, and reduce the amount of treated effluent discharged into water bodies.</p>	
		<p><b>For the Planners:</b> Public awareness should focus on the connections between land use, development practices, aquifer recharge, and groundwater quality and quantity. Particular attention should be made to the manner in which particular practices have direct effects on groundwater resources.</p>		<p><b>For the Planners:</b> Produce barangay level and community level programs to prioritize the involvement of all residents in developing water management.</p>	
		<p><b>For the Lawmakers:</b> Water extraction tracking mechanisms must account for unregistered and illegal users, as well as those with unauthorized or excessive water consumption. To achieve this, metering should be implemented for deepwells, water bores, and pumps, as well as areas with high water consumption.</p>		<p><b>For the Lawmakers:</b> As mandated by the Local Government Code of 1991, LGUs should expedite the carrying out of the Ecological Solid Waste Management Act of 2000 to protect water resources through effective solid waste management.</p>	



The proposed solutions are made in accordance with the principle of IWRM. Participatory approach is taken into account to achieve water development and management.

## V. CONCLUSIONS

Improper water management is one of the main global crises and since 2015 the United Nations is making ways to address the elevating problems through the adaptation of Sustainable Development Goals. In line with this goal, the study formulated and utilized a tool that could help the community of Guagua, Pampanga in managing the water in the said area.

Findings from the survey, interviews, and other information gathered, the researchers have concluded that the management of water in the area of Guagua, Pampanga must be improved, associating with water quantity and water quality, as data indicated that more than half of the factors that pose challenges to the community's water supply (water quantity) are frequently observed, and one of the stated alarming results from the interview is the concern regarding land subsidence. Concurrently, it was also discovered through the interview that water quality disturbances may constitute health dangers; the possible presence of heavy minerals was mentioned in the interview, specifically with arsenic contamination.

The community also responded both in the survey and interview that there is lacking in initiating programs that the residents can participate in, regarding water management.

The researchers able to arrive at these conclusions by utilizing the IWRM principle-based developed assessment tool. The study emphasizes the importance of effective groundwater management practices and the need for cooperation between various stakeholders to manage groundwater resources sustainably. Researchers' findings provide a framework for future research and proposed possible solutions to address the challenges of groundwater depletion in Guagua, Pampanga, and other similar communities.

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