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INVESTIGATING THE POTENTIAL OF LIQUEFACTION ISSUE OF SOME IRAQI DAMS DURING EARTHQUAKES

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Master`s Thesis

Supervisor

Assoc. Prof. Dr. Sepanta NAİMİ

Istanbul, 2022

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The thesis titled INVESTIGATING THE POTENTIAL OF LIQUEFACTION ISSUE OF SOME IRAQI DAMS DURING EARTHQUAKES prepared by LAITH MOHAMMED MAHMOOD MAHMOOD and submitted on 22/12/2022 has been **accepted unanimously** for the degree of Master of Science in Civil Engineering.

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I hereby declare that this thesis meets all format and submission requirements of a Master`s Thesis.

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I hereby declare that all information presented in this graduation project has been obtained in full accordance with academic rules and ethical conduct. I also declare all unoriginal materials and conclusions have been cited in the text and all references mentioned in the Reference List have been cited in the text, and vice versa as required by the abovementioned rules and conduct.

Laith Mohammed Mahmood MAHMOOD

Signature

DEDICATION

I would like to dedicate my thesis to my lovely father and my dear mother, who have continuously shown their love, support, help, and enthusiasm to me while I have pursued my research. The staff at Altinbas University, my supervisor, and all civil engineering doctors are also thanked for their assistance, guidance, and invaluable expertise they provided in this study. In addition, my supervisor gave me a ton of support and direction for my study analysis and survey.

I also want to express my gratitude to everyone at Altinbas University who offered me time and assistance so I could conduct my research and complete my thesis analysis.

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ABSTRACT

INVESTIGATING THE POTENTIAL OF LIQUEFACTION ISSUE OF SOME IRAQI DAMS DURING EARTHQUAKES

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This research is executed to investigate the critical role of soil properties in influencing the liquefaction phenomenon due to earthquakes. Also, this study highlights active methods that can help project managers construct dams that have higher stability and significant robustness. A case study is considered of the Karakaya Dam. Four research approaches were implemented, including one secondary data collection approach and three research methods to collect primary data collection, including extrapolation, linear regression, and interviews. Datasets were collected of Azami, Ortalama, and Asgari. The Euphrates River discharge rate was assessed from the Turkish Ministry of Environment and Forestry. The results indicated that the annual temperature in the future of zones and regions around the Karakaya Dam, including Azami, Ortalama, and Asgari, would witness a moderate increase of about 3 to 6 degrees Celsius next decade. The Euphrates River discharge rate at the Karakaya Dam would witness a significant increase from (100-350 m3) to (2,590-2,640 m3) in 2029, explaining that temperature and discharge rate may influence the occurrence of liquefaction problems. Soil temperature under the Karakaya Dam and chemical elements would not variate significantly next decade. The pH

number will variate widely from 4.14 to 9.74 in 2029. The most significant chemical molecule concentration in the soil under the Karakaya Dam is the phosphite anion, corresponding to a minimum and maximum concentration of 1 and 2 µg/m2, respectively. Data analysis on earthquakes around the Karakaya Dam was not implemented as earthquake opportunities cannot be numerically predicted.

Keywords: Dam, Modern Construction Techniques, Project Manager, Stability, Mechanical Performance.

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ABBREVIATIONS

AI	:	Artificial intelligence
ANNs	:	Artificial Neural Networks
BIM	:	Building Information Modeling
CPM	:	Critical Path Method
EGFVA	:	Explicit Galerkin Finite Volume Approach
EFEA	:	Explicit Finite Element Analysis
FEA	:	Finite Element Analysis
HPC	:	High-Performance Concrete
InSAR	:	Interferometric Synthetic Aperture Radar
LROA	:	Linear Regression Optimization Algorithm
ML	:	Machine Learning
PLAXIS	:	Plane Strain and Axial Symmetry
PERT	:	Program Evaluation and Review Technique
R&D	:	Research and Development
UAV	:	Unmanned Aerial Vehicles
UHPC	:	Ultra-High-Performance Concrete

LIST OF SYMBOLS

pH	:	Soil Potential Hydrogen Number
T_{Soil}	:	Soil Temperature
ºC	:	Degree Celsius
Cu	:	Copper
NO_2	:	Nitrogen Dioxide
PO_3	:	Phosphite Anion
NH_4^+	:	Ammonium Ion
NH_3	:	Ammonia

1. INTRODUCTION

1.1 RESEARCH BACKGROUND

The construction sector has been significantly expanding due to remarkable urbanization development and the migration of citizens from rural to urban areas [1]–[9]. Massive facilities like bridges, tunnels, dams, and skyscrapers were built in these zones. However, the construction of these facilities should consider some building criteria and codes that enable their robustness and workability when subjected to difficult circumstances or natural accidents [10]–[13]. For example, Japan, which is considered a greatly seismically active country, utilizes some criteria and building approaches that can redistribute the forces in the building and alleviate the dangerous impacts of seismic events [14]. Figure 1.1 presents some examples of novel methods implemented to mitigate the earthquake influences and redistribute forces in the building to avoid an overall collapse. Furthermore, researchers reported the utilization of moment-resisting frames, diaphragms, cross braces, and shear walls to control the momentum and shear forces when seismic activities occur [15]–[17]. Moreover, scholars remarked on the significance of using a tuned mass (pendulum) damper in which a mass is suspended in the center of the building and controls the frequency of the building when earthquakes cause significant vibrations [18], [19]. The tuned mass damper tries to resist these vibrations by mitigating the motion and returning the building to its original state, thus, improving its stability. Through extensive Research and Development (R&D) work, scholars and engineers have designed and prepared state-of-the-art software tools that can estimate and assess the dangerous impacts of natural disasters, namely earthquakes on several large urban facilities, such as bridges, tunnels, dams, and skyscrapers. One example of these software tools is the Plane Strain and Axial Symmetry (PLAXIS) software package [20]. This software can apply Finite Element Analysis (FEA) to predict the failure characteristics, deformations, water flow, stability, and robustness of large structures when they are subjected to severe geological accidents, such as earthquakes [21].

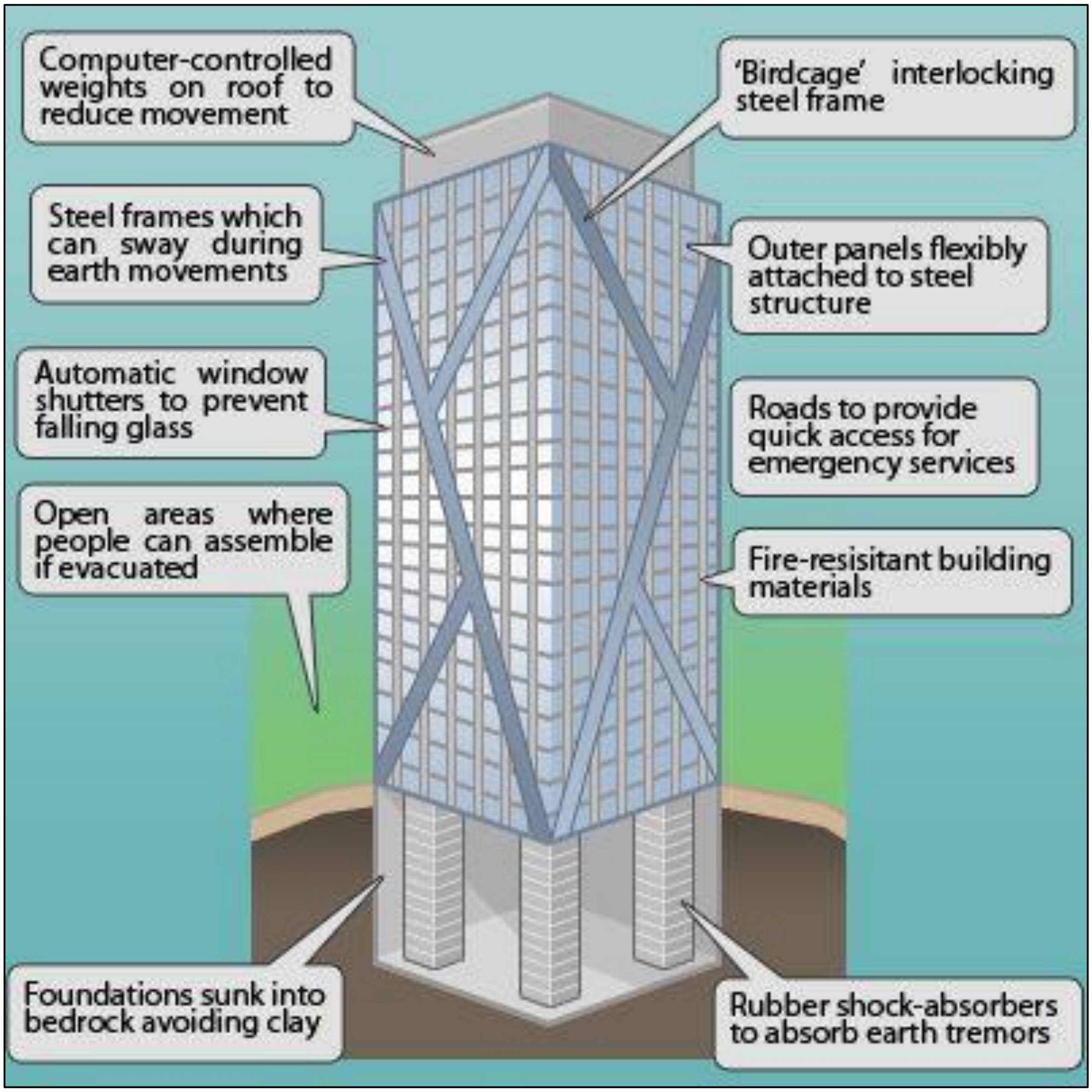

Figure 1.1: Several methods to mitigate the destructive seismic impacts of buildings [22].

1.2 PROBLEM STATEMENT

Over the last decades, large-scale construction projects have been established to meet the elevated infrastructure requirements associated with the increase in the global population. One of the critical large-scale construction projects is the dams. Dams are concrete barriers built to save water and act as reservoirs. They raise the water level to be used later for electrical power generation via hydropower energy, besides their essential role in providing water for regions around the and increasing countries' water security [23]. Nevertheless, dams may be subjected to dangerous natural disasters and accidents that affect their structural stability and performance [24]. One example of these nature accidents is earthquakes. In general, the time at which earthquakes take place cannot be predicted. They occur abruptly without giving a chance for responsible authorities and people to act or save themselves from severe impacts and damage. Therefore, large-scale facilities and structural objects should be strengthened and carefully built to enable significant effectiveness and protection against severe natural accidents. When earthquakes strike large-scale structures, they may cause significant damage and devastation to properties and buildings around them. If earthquakes hit dams, a large volume of water may spread in all directions and damage facilities around the dam. In this context, smart protection strategies and intelligent building techniques should be implemented. An example of negative earthquake impacts on dams is the soil liquefaction problem. This phenomenon occurs when an earthquake shakes the dam's foundation intensively, affecting its soil and sediment characteristics on the base and breaking their robust connection and bonds, converting these particles into liquid [25]. Figure 1.2 represents the modeling and numerical analysis of Phu Vinh dam using geotechnical software tools.

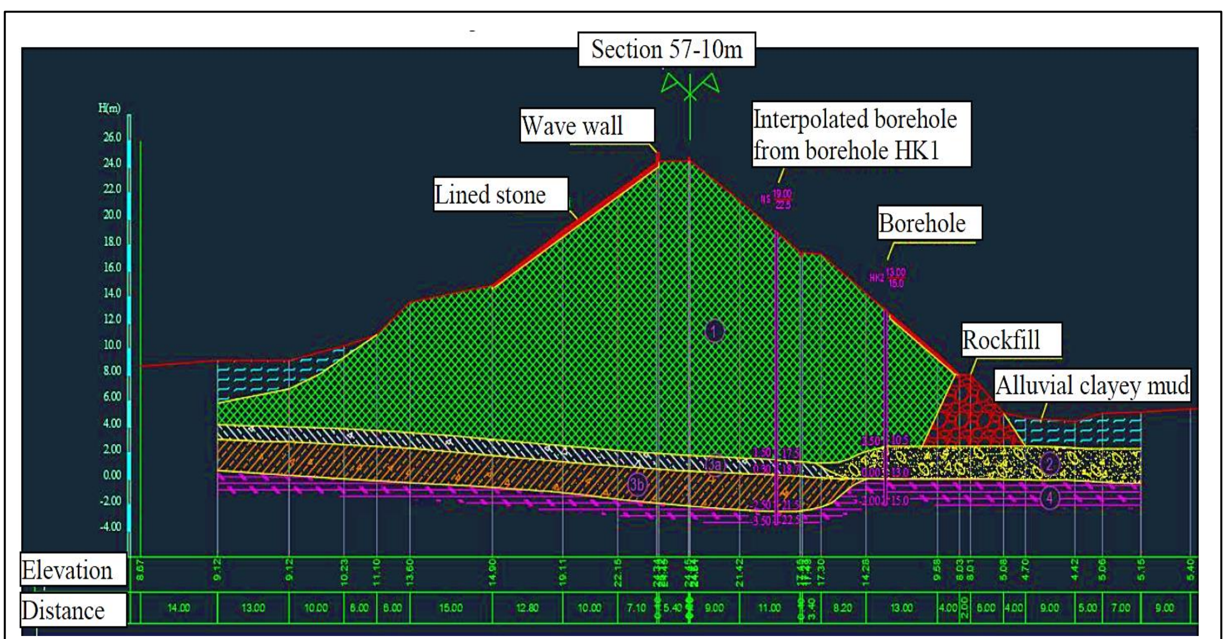

Figure 1.2: The modeling and numerical analysis of Phu Vinh dam using geotechnical software tools [25].

Therefore, the overall devastation of the dam structure can take place. In this work, numerical modelling, analysis, and simulations are executed on an Iraqi dam (case study) via the PLAXIS software package to identify and determine the critical contributions and significant benefits of intelligent techniques and smart approaches that can be adopted to boost the dam structure's effectiveness, performance, stability, and robustness when severe earthquakes occur. These software tools can estimate the seepage and liquefaction problems in dams, as indicated in Figure 1.3.

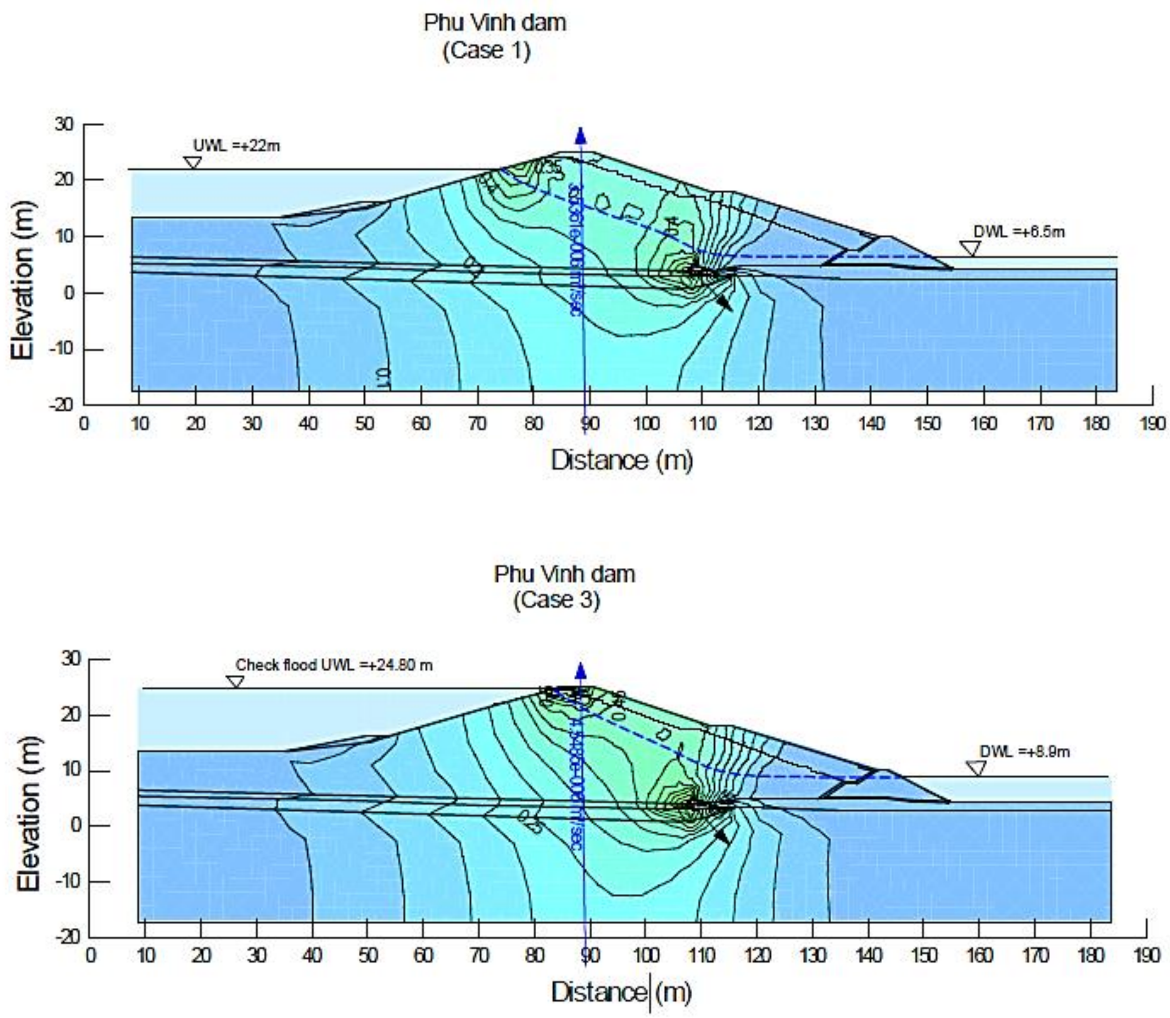

Figure 1.3: The numerical assessment of seepage and liquefaction of the Phu Vinh dam using geotechnical software packages [25].

1.3 RESEARCH SIGNIFICANCE

This work comes with a set of distinct relevances. Firstly, this research will describe critical concepts and terminologies related to dams and dangerous accidents that affect their structural stability, including destructive earthquakes, soil liquefaction phenomenon, and dam structure effectiveness, robustness, and performance to resist these dangerous incidents. The second relevance of this work is to determine critical obstacles and challenges related to dams when subjected to severe earthquakes that influence their structural stability and performance. The third research relevance is associated with identifying innovative dam construction techniques and intelligent approaches to improve the performance and effectiveness of dams. These data are collected using a comprehensive literature review through which secondary data are gathered from several recent peer-reviewed articles and research publications. Furthermore, the theoretical research relevances lie in the following:

i. To enrich the literature review with state-of-the-art methods and intelligent techniques that can be implemented to protect dam structures from being affected by dangerous earthquakes.
ii. To address the problem of soil liquefaction phenomenon and explore its significant impacts on the dam structures.
iii. To highlight a group of key solutions and intelligent approaches that can be applied to protect dam structures and help them resist earthquakes and provide higher dams' robustness against soil liquefaction phenomenon.
iv. To conduct numerical analysis, modelling, and simulations via the PLAXIS software package to validate the critical contributions and beneficial impacts of intelligent techniques and smart methods in boosting dam structure effectiveness, performance, stability, and robustness when severe earthquakes occur.
v. To execute further Research and Development (R&D) work related to the employment of intelligent methods and state-of-the-art techniques that can foster dam structural reliability, performance, and robustness to the soil liquefaction phenomenon and earthquakes.

The practical significance of this research can be classified into the following articles:

i. The need for intelligent methods and innovative approaches to implement on the Iraqi dams and protect their structures from severe earthquake impacts.
ii. The requirement for higher-performance Iraqi dams that can resist the soil liquefaction phenomenon and provide higher robustness and reliability against different severe effects of earthquakes.
iii. The necessity to provide innovative guidelines and instructions for civil engineers, project managers, architects, and designers who construct dams to enhance their performance, reliability, robustness, and resistance to dangerous earthquake accidents.

1.4 RESEARCH MAJOR AIM AND MINOR OBJECTIVES

The research's major aim is to explore and examine critical methods and smart techniques that can be implemented for Iraqi dams to improve their structure reliability, robustness, and resistance to destructive earthquakes. In addition, a group of minor objectives are followed to execute the thesis's major target, which is presented in the following paragraphs:

a. To shed light on major limitations and challenges of the dams and their structural characteristics when subjected to dangerous earthquake impacts.
b. To identify state-of-the-art practices and strategic methods that can be adopted and applied to protect Iraqi dams from the soil liquefaction phenomenon when damaging earthquakes occur.
c. To select a case study of an Iraqi dam that requires modifications and smart stability methods to protect it from critical earthquake impacts.
d. To apply numerical analysis and simulation work using the PLAXIS software package to assess and evaluate the critical role of intelligent dam construction approaches in fostering the structural resistance and durability to severe earthquakes that may cause the soil liquefaction phenomenon.
e. To validate, verify, modify, and adjust the research findings according to a panel of dam experts and soil liquefaction professionals' points of view.

1.5 RESEARCH QUESTIONS

The work is conducted to examine smart practices and effective approaches that can alleviate the severe impacts of severe earthquakes on Iraqi dams and prevent the soil liquefaction phenomenon that can result in an overall structural failure. The research's numerical analysis will offer some answers to the research questions, which are presented in the following articles:

i. What are the main difficulties and challenges of dams when they are subjected to critical earthquakes?

ii. Could the utilization of intelligent dam construction techniques resolve these limitations?

iii. What are smart approaches and state-of-the-art methods that can be adopted and implemented to alleviate dams' soil liquefaction phenomenon?

iv. Can the employment of effective dam materials and construction strategies provide better structural stability during severe earthquakes?

1.6 RESEARCH HYPOTHESES

This research is conducted to examine the liquefaction phenomenon of soil when dangerous earthquakes take place, causing critical problems to the structure of Iraqi dams. The research hypothesis will be validated or invalidated according to the simulation findings of this research (using the PLAXIS software package). These hypotheses are presented in the following paragraphs:

i. Null Hypothesis, H_o – which assumes that: "Severe earthquakes do not cause harmful impacts on the Iraqi dam's structure and do not cause soil liquefaction phenomenon."

ii. Alternative Hypothesis, H_a – which assumes that "Severe earthquakes cause harmful impacts on the Iraqi dam's structure and the opportunity of soil liquefaction problem can significantly increase."

iii. Sub Hypothesis, $H_{a,1}$ – which assumes that: "Using smart techniques for Iraqi dams' structures plays a critical role in alleviating the harmful impacts of dangerous earthquakes."

iv. Sub Hypothesis, $H_{a,2}$ – which assumes that: “Implementing intelligent methods of construction for Iraqi dams is remarkably crucial to maintain better structural stability and reliability during severe, large-scale accidents, including earthquakes.”

v. Sub Hypothesis, $H_{a,3}$ – which assumes that “Utilizing state-of-the-art approaches in building dams is essential to prevent the occurrence of soil liquefaction phenomenon during dangerous earthquakes.”

1.7 THESIS STATEMENT

The title of this study is “Investigating the Potential of Liquefaction Issue of Some Iraqi Dams During Earthquakes.” This research is executed to investigate and assess the liquefaction phenomenon of soil when earthquakes occur, resulting in Iraqi dams’ overall structure failure. It will shed light on critical solutions and intelligent methods that can resolve this phenomenon and alleviate the consequences of soil liquefaction during earthquakes.

1.8 THESIS ORGANIZATION

The layout of this thesis includes five chapters. These chapters will cover several topics and key ideas associated with the soil liquefaction phenomenon of Iraqi dams and critical strategies that can be implemented to resolve this issue during severe earthquakes. The thesis layout can be summarized through the following articles:

i. Chapter One, with the title of INTRODUCTION, describes significant data associated with the study background, problem statement, study significance, research questions, hypotheses, and the research’s major and minor objectives.

ii. Chapter Two, which has the title of LITERATURE REVIEW, discusses critical aspects and important concepts related to the liquefaction phenomenon of several large-scale dams worldwide. In addition, chapter two identifies vital strategies and practical approaches that can be applied and followed to resolve this issue during severe earthquakes. The information in chapter two is collected from publications from PhD and master dissertations and web research engines, including ScienceDirect, ResearchGate, Google Scholar, and Academia. Additionally, several conference proceedings are used to gather databases on the soil liquefaction phenomenon and intelligent methods to resolve and alleviate this critical problem.

iii. Chapter Three has the title RESEARCH METHODOLOGY. It illustrates the major approach and methods conducted and followed in executing this study. Also, chapter three explains critical study variables and parameters tested and investigated via the PLAXIS software package. The numerical analysis, modelling, and simulations of the Iraqi dam is crucial to understanding the soil liquefaction phenomenon and identifying significant methods and smart techniques to improve the Iraqi dam's performance and resistance to severe earthquakes.

iv. Chapter Four has the title RESULTS AND DISCUSSIONS. This chapter presents major thesis findings associated with the numerical analysis and simulations executed by the PLAXIS software package to predict critical improvements and key methods to enhance the Iraqi dam structure in resisting severe earthquakes that may cause soil liquefaction phenomenon. Furthermore, chapter four describes the research discussions that relate the research's major outputs to other scholars' findings.

v. Chapter Five, which has the title CONCLUSIONS AND RECOMMENDATIONS, indicates the main study's conclusions associated with the research's numerical findings from the PLAXIS software package. Further, chapter five illustrates a set of recommendations and key suggestions related to future work to provide critical ideas for scientists and engineers to carry out further improvements on enhancing the dam's construction performance and resistivity to soil liquefaction phenomenon caused by dangerous earthquakes.

2. LITERATURE REVIEW

2.1 AIM AND INTRODUCTION

This chapter discusses previous studies conducted on investigating the potential liquefaction issue of some Turkish dams during earthquakes, where it displays the main development steps and stages of development for the construction of dams, reviews modeling of dam construction against earthquakes in Turkey, and dam construction in Turkey and its impact on economic.

2.2 THE MAIN DEVELOPMENT STEPS AND STAGES OF DEVELOPMENT FOR THE CONSTRUCTION OF DAMS

[26] studied the risks resulting from dam liquefaction and the impact of soil liquefaction on construction projects, where the damage and risks related to dams were studied by identifying liquefaction as a basic problem affecting the behavior of soil movement, and the necessary methods were identified in the process of estimating and estimating the load affecting the soil to avoid the occurrence of collapses Dirt in the site and earthquakes in general. The results of the study showed that the liquefaction processes in the site affect the soils of the dense silt through their exposure to fibrous interactions, which made them vulnerable to liquefaction, which may cause soil subsidence and the formation of the dam's collapse. Based on the practical results, it was concluded that the clear differences in the deterministic and limited sway are partially linked to each other, depending on the statistical analysis processes and tests. The study indicated that soil liquefaction processes affecting dams are one of the most important factors affecting the formation of soil and dam liquefaction, making them subject to decomposition and ensuring that they do not change over time, which leads to some changes in the resistance of construction and soil, in addition to its impact on the quality of construction.

Referring to [27], the authors mentioned that earth dams are considered a basic bridge for measuring the seismic coefficient and estimating the safety factor to ensure that there are no collapses and slips in the dams, by calculating and measuring the seismic coefficient and the weight of the slip, in order to determine the amount of the effect of seismic vibrations on the existing buildings. Through the computational results reached by the researcher, it was noted that the estimation of the seismic coefficient greatly affects the behavior of the soil and slopes based on approved standard design codes, such as the design criteria set by the Japanese Committee for Large Dams. The conclusions, researcher concluded that the study lacked a consistent approach in testing the seismic coefficient, which led to a weakness in the strength and resistance of the soil due to seismic collapses, which calls for the adoption of analytical methods that contribute to the process of determining the coefficient of soil slippage to ensure the flexibility of dams, and thus contributes Improving 3D modeling of dams during construction, operation and maintenance processes.

The study conducted by [28] on the construction of dams and their role in managing and controlling water from floods in order to exploit it for human use in drinking and enter it on a large and large scale in industry, given that hydroelectric energy generates approximately 50% of electricity production, while dams generate Approximately 19% of the production and generation of electricity in all countries of the world. The researcher found that building dams contribute significantly to improving the infrastructure of countries and developing economic development by creating job opportunities and ensuring a good rate of electricity consumption. The study stated that to ensure the achievement of the objectives assigned to the liquefaction of dams, it is necessary to provide basic elements that raise the rate of dam resistance, namely: financial value, participatory decision-making, and achieving sustainability.

In the same vein, [29] mentioned the stages of designing and building dams through preparing and developing the economic feasibility of the project, improving the modeling processes at each stage of dam construction, and to ensure that there are no collapses, losses or demolition in the construction, LEAN technology approved worldwide was used that contributes to construction management and development infrastructure. The goal is to achieve significant levels of highly sustainable buildings by reducing construction costs, reducing inventory, building just in time, comprehensive scheduling of building components, improving public safety standards, and improving overall productivity.

Figure 2.1 shows the critical considerations that should be taken into account during the construction

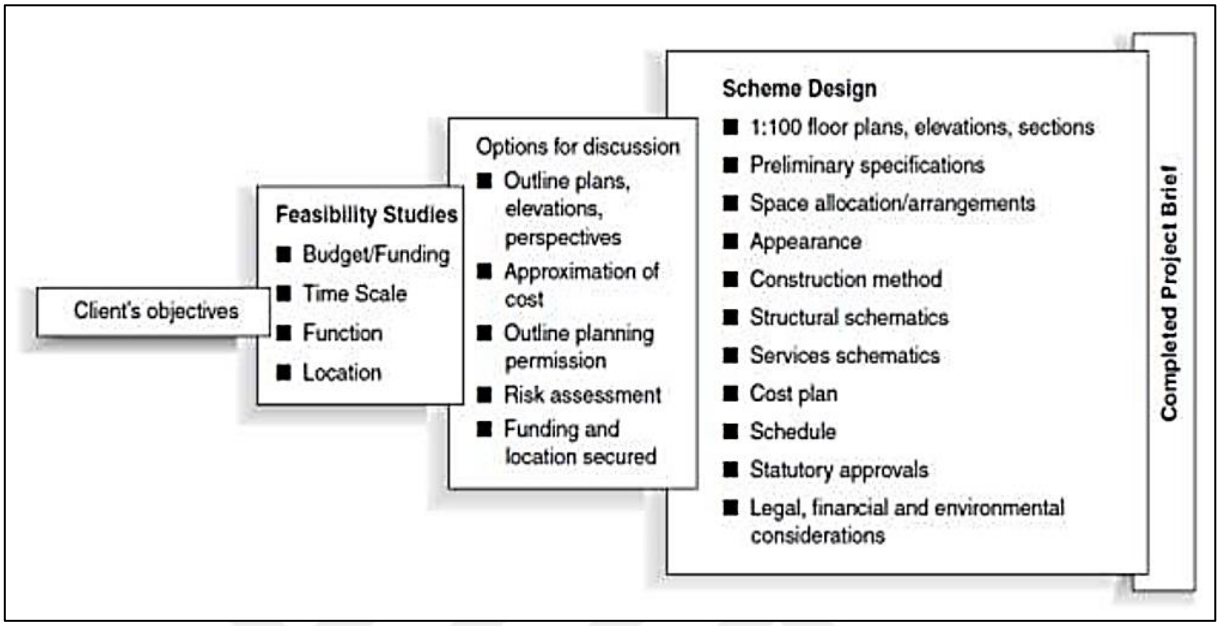

Figure 2.1: Critical considerations that should be taken into account during the construction [29].

The results showed that following and applying the technical specifications clauses contribute significantly to improving the quality of dam design and construction and reducing the risks and damages that may result due to poor understanding and management of dam project design. Figure 2.2 illustrates the major construction activities and design phases through the project lifecycle development.

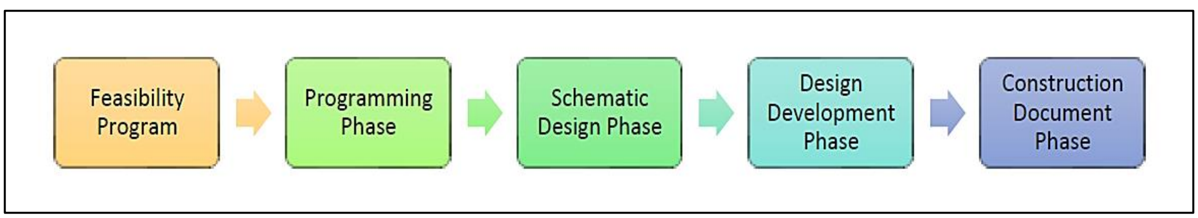

Figure 2.2: Major construction activities design phases through the project lifecycle [29].

Figure 2.3 represents the decline in the evolution of different construction companies between 2009 and 2016.

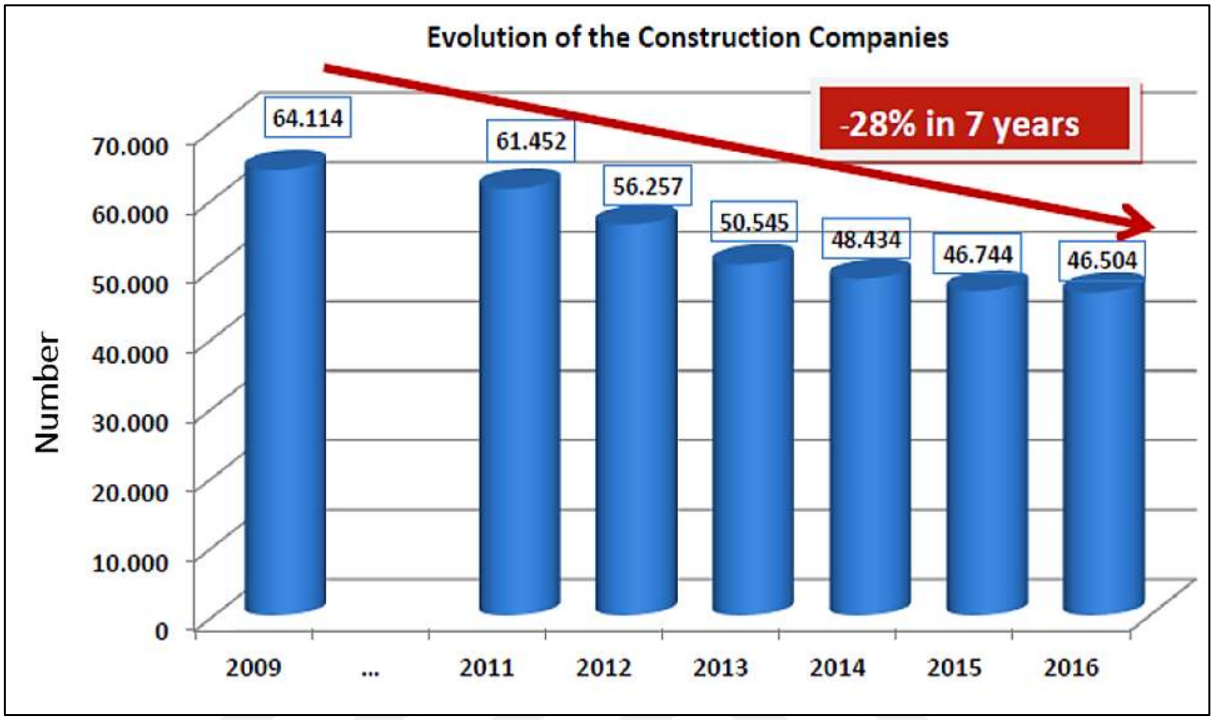

Figure 2.3: The decline in the evolution of different construction companies [29].

With reference to [30], the authors studied the alternatives that contribute to improving water resources and achieving adequate development by conducting various studies on dams in several countries of the world as a case study in the research, where the researcher conducted a quantitative survey of approximately 125 dams, to study and evaluate the performance of dams and its impact on the economic, environmental and social terms, which is one of the most important indicators of the effective sustainability of construction projects in general, in addition to monitoring planning and design work to ensure facilitation of the decision-making process in the construction, operation and maintenance of dams.

[31] mentioned that dam construction is one of the most important industries that today compete with major industries due to its great role in controlling and managing water resources, improving soil levels and protecting it from collapse and liquefaction. This research came to assess and control dam construction management through the application of modern algorithms, including the Critical Path Method (CPM) and the Program Evaluation and Review Technique (PERT), which have a major role in planning and controlling dam construction projects. Figure 2.4 indicates the number of days to achieve activities related to the dam project.

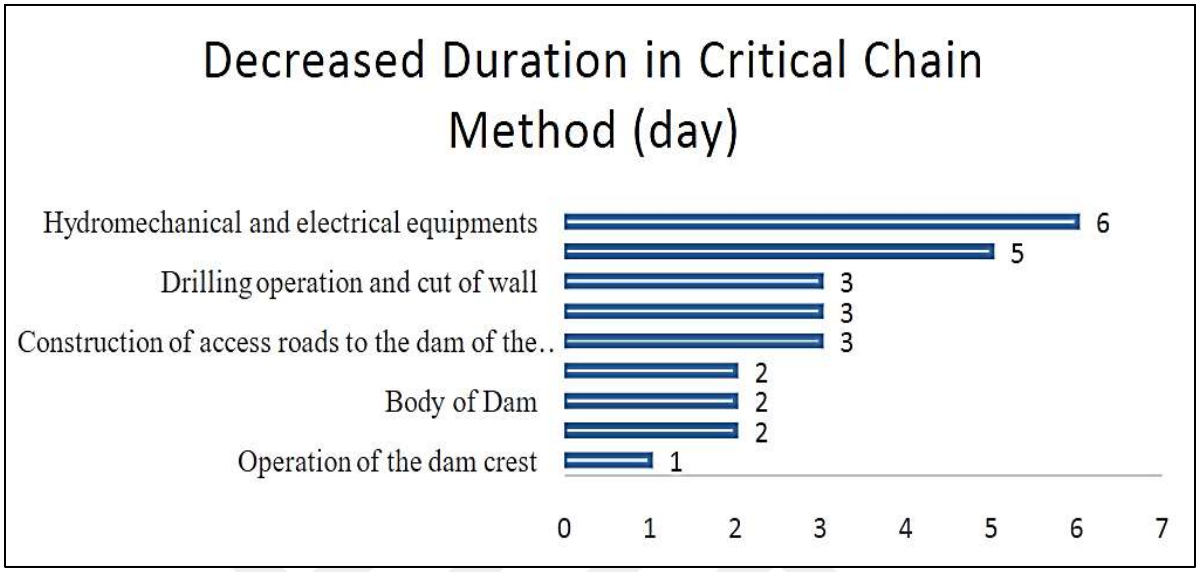

Figure 2.4: The number of days to achieve activities related to the dam project [31].

The research found that building dams have a clear impact on industrial projects in the long run by raising development, increasing job opportunities, and improving sustainable development standards. In the same vein, [32] stated that building dams contribute to achieving public gains and achieving environmental protection by reducing expected damage and risks by controlling the comprehensive and integrated management processes of water resources when building dams, which leads to facilitating the evaluation process of dam-building projects and achieving economic feasibility, high through the improvement and development of quality and effective sustainability. This study showed the importance of evaluating and addressing the challenges that dam construction projects and future maintenance may face through the implementation of the Asian Development Bank's water strategy in 2005. The research was based on the study of the Asian Development Bank, which included 65 projects affiliated with dam-building projects by following a set of strategies Building a database related to large dam-building projects and preparing reports that assess environmental impacts.

[33] conducted a case study in Turkey of soil capable of liquefaction and studied the main factors that affected the nature of the soil, and led to the destruction and collapse of the soil, especially the clay soil, which is one of the types of soil with low hardness and plasticity. Laboratory tests

were conducted on-site for a set of soil samples, through which the upper and lower limits of the soil layers were estimated and estimated based on fixed criteria, taken from a depth of 0.004 meters up to 1.6 meters, where it was concluded that the estimation of the strength of the soil undergoing liquefaction is one of the necessary factors that Affect the levelling of the building in general. The study was based on presenting the practical results through the application of the PLAXIS program and the UBC3D-PLM model, with the aim of evaluating the liquefaction and liquefaction of the soil caused by earthquakes. According to field observations and analytical readings, it was concluded that the foundation was close to collapse compared to the bearing capacity, especially in the case of soils subject to liquefaction, which resulted in some errors as a result of the poor possibility of modeling water flow during dynamic analysis processes and the large force resulting from earthquakes, which led to the occurrence of A clear discrepancy in the estimation of the degrees of stability and stability of the construction.

2.3 MODELING OF DAM CONSTRUCTION AGAINST EARTHQUAKES IN TURKEY

According to [34], modeling of dams in seismic areas was studied through the mechanical modeling method, with the aim of finding the permissible displacement when building an earthen dam, where the Guadeloupe Dam was adopted as a case study.

Figure 2.5 represents a 2D modeling and analysis of the dam investigated in their work.

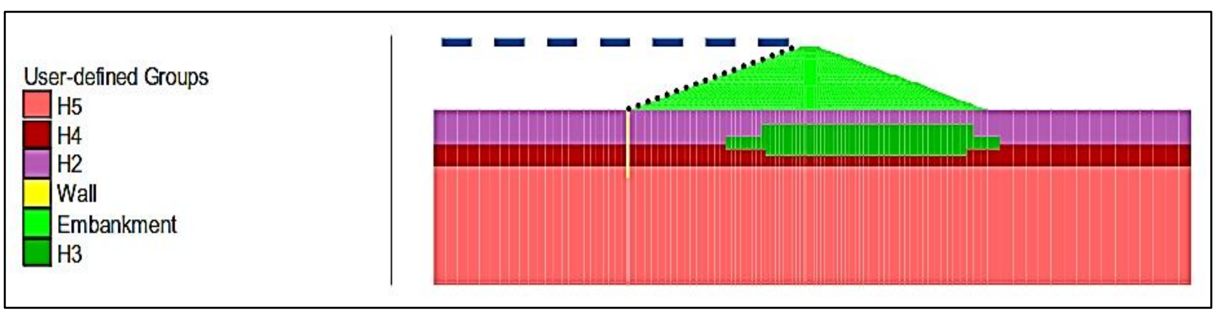

Figure 2.5: A 2D modeling and analysis of the dam investigated in the work of [34].

The hydraulics of the earth dam and the mechanical balancing in order to adjust and determine the amount of displacement and the permissible speed and then perform the dynamic and hydraulic calculations during the modeling process in order to evaluate the performance of the dam while raising the pressure affecting the dam.

Figure 2.6 represents the pore pressure in the model before the earthquake calculation (in kPa).

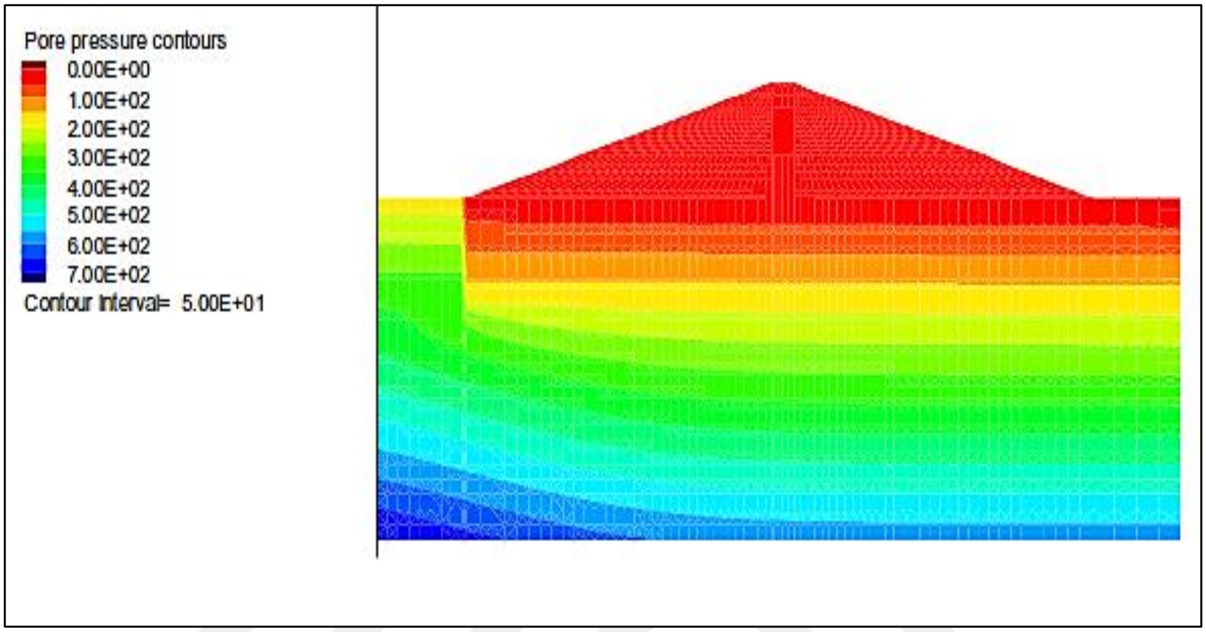

Figure 2.6: Pore pressure in the model before the earthquake calculation (in kPa) [34].

Furthermore, the geotechnical analysis provided research findings associated with the pore pressure in the model after the earthquake calculation (in kPa). The modeling results in Figure 2.7 present this information.

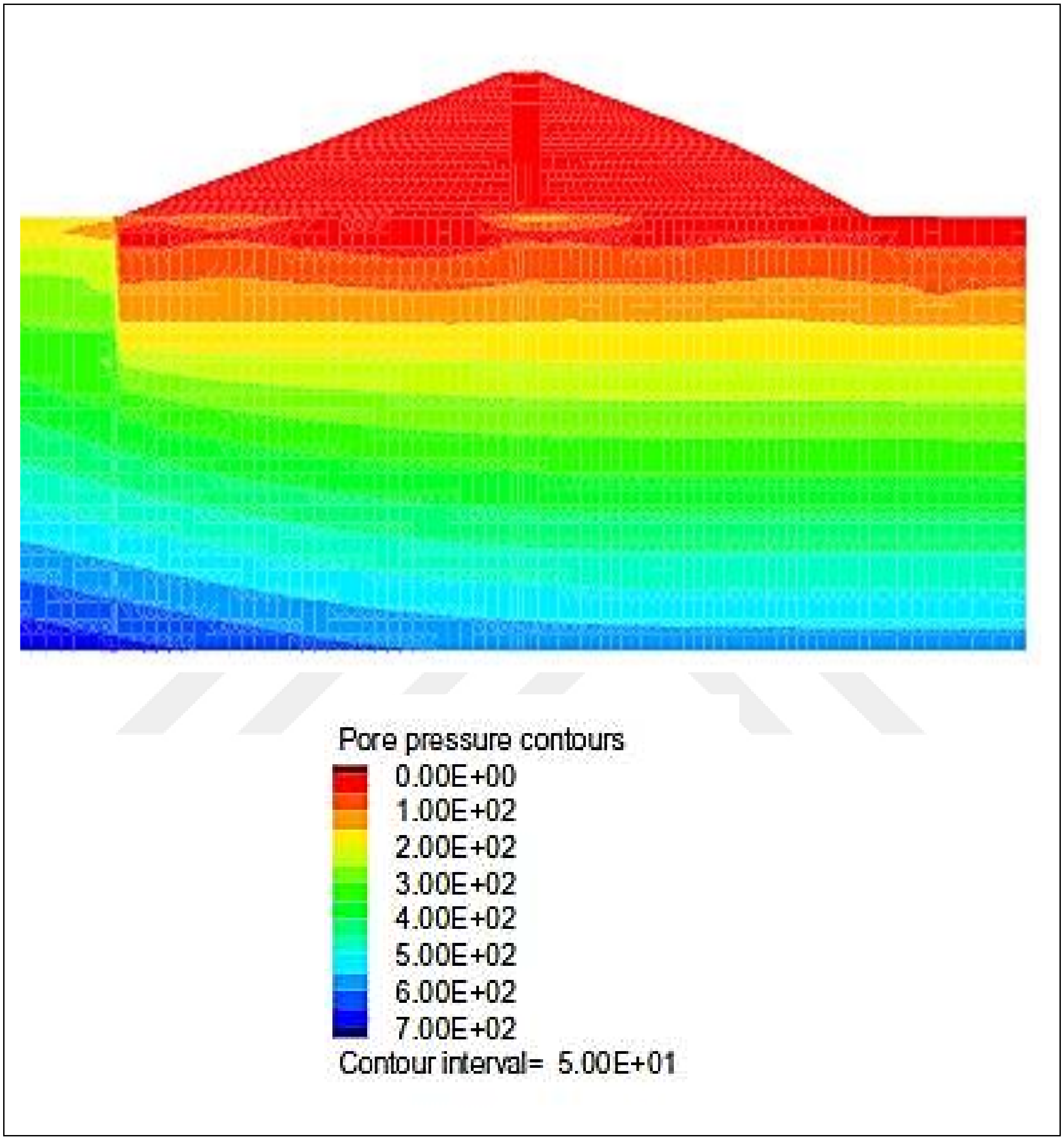

Figure 2.7: The pore pressure in the model after the earthquake calculation (in kPa).

Besides, Figure 2.8 represents dam horizontal displacement analysis related to the end of the earthquake (in meters)

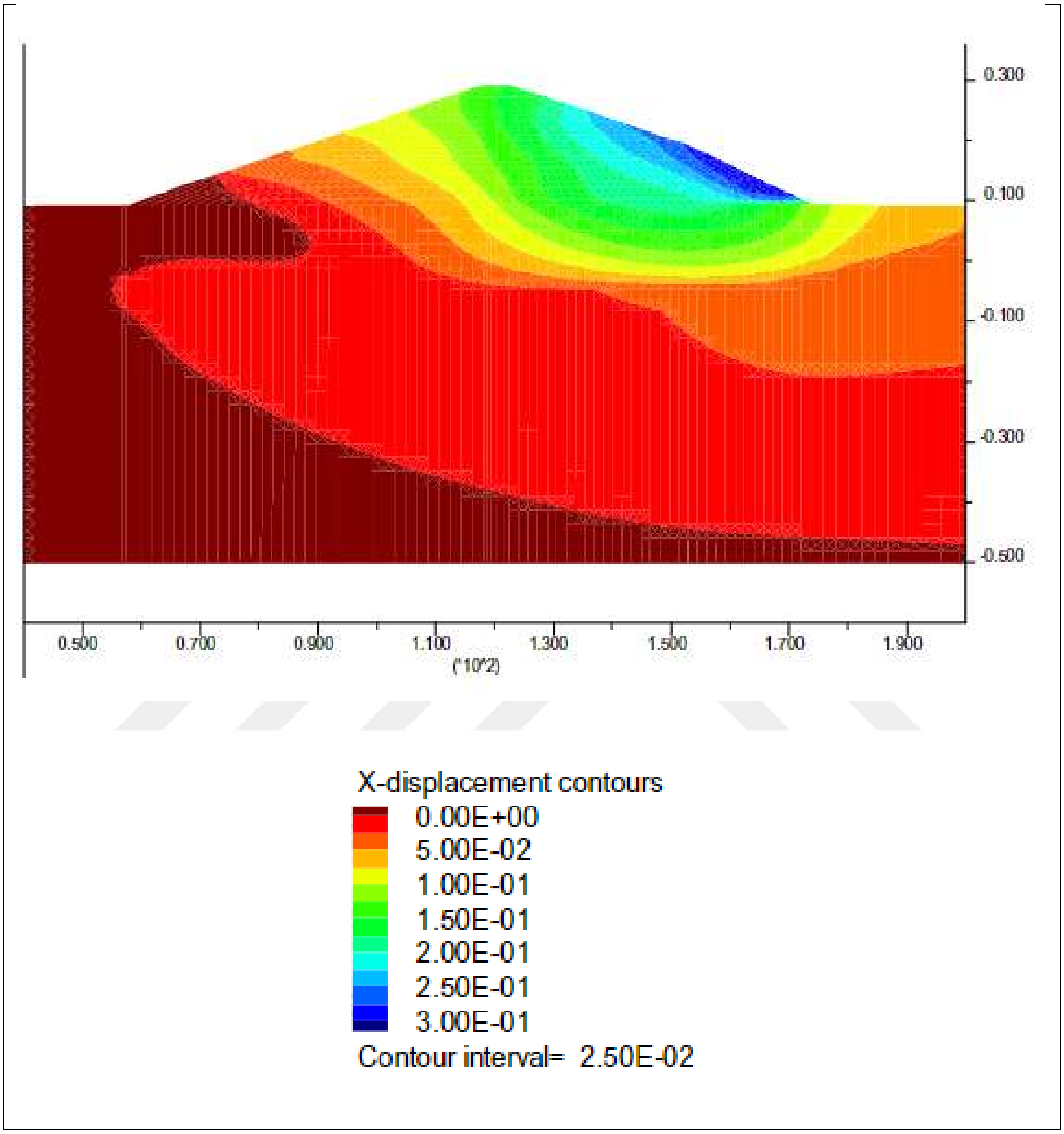

Figure 2.8: Dam horizontal displacement analysis related to the end of the earthquake (in meters) [34].

The study came out with the necessity of conducting preliminary calculations when designing dams when applying the modeling process through doing tests in the laboratory or site that led to the hypotheses developed with great accuracy in order to obtain data to determine the amount of deformation and collapse in dams at a certain stress level, and the need to make feedback and calibrate the modeling to determine the behavior of the dam and its resistance to earthquakes.

[35] studied the evaluation of the performance of dams and the amount of tolerance obtained from seismic loading and the evaluation of the role of earthquake engineering in reducing the risks of earthquakes and their impact on the liquefaction of dams. And note the impact of the geographical location of the dam on the amount of seismic loading. The research relied on the selection of ten dams based on the highest peak height of more than 20 meters, and modeling was carried out when the stress situation is high and compared with numerical analysis techniques to obtain more accurate results. In the same vein, [36] applied a quantitative survey to study and evaluate the impact of earthquakes on dams in order to ensure the stability and stability of the dam, with cost management during the design and implementation phase. And ensuring that the dams are not liquefied during earthquakes, as the dam was modeled through the program to determine the permissible seismic scale to avoid the hydrodynamic effects on the dam, through the results of the study, the performance of the dams was evaluated through the FLAC program and its effective role in the analysis of the field of vibrations occurring in the dams.

[37] pointed out the importance of applying safety standards in the engineering of dams against earthquakes to ensure the stability of the dam and the absence of collapse in the structure of the dam model and to reduce seismic risks. The researcher conducted quantitative analyzes about the total risks affecting the stability of bridge dams located within the seismic zones. The study concluded that it is necessary to design and prepare a special safety program for dams classified under the framework of critical dams to assess problems and defects by following international specifications and standards.

[38] discussed the method of modeling dams under the influence of seismic analysis and conducting a study using the simulation system to assess the response of concrete gravity dams, which is one of the most important models of structures for civil engineering projects due to its high capacity to store large quantities of water and resist high pressure. The research adopted the investigation mechanism in evaluating the dynamic behavior of the dam through the application of various modeling techniques and programs, including the CADAM program, in order to measure the response of the dam and determine the amount of stability and stability.

2.4 DAM CONSTRUCTION IN TURKEY AND ITS IMPACT ON ECONOMIC

[39] pointed out that building dams are a necessary step that contributes to achieving water and energy requirements and the great ability to control and control floods, which leads to achieving sustainable development in its three dimensions: environmental, economic, and social, in addition to its role in managing water resources and mitigating climate change and global warming severe impacts to comply with the basic requirements of humans. And meet all the requirements and services related to water. Through this research, the mechanism of building dams was studied to ensure the provision of renewable energy at reasonable prices in a way that makes it sustainable economically, environmentally and socially, giving special focus on the climate change and global warming effects, which helps to achieve the economic development of the world. In the same vein, [40] pointed out the importance of dams in evaluating the economic and social elements by conducting a study on a dam project in the Laleli area and evaluating the extent of the dam's impact on the lives of the residents of the area. A questionnaire was designed and distributed to specialists and conducted investigative research by doing interviews with people and asking them questions. The results of the study came out that the number of people who will affect by the Laleli Dam project on their lifestyle amounted to about 2,273, and the construction of the dam project will contribute to reducing migration and encouraging the development of investment projects that Increase the rate of economic development of the country and improve the standard of living of individuals.

[41] conducted a study investigating critical construction methods to rebuild dams and increase their sustainability. They focused on Ilisu Dam in Turkey as a case study and assessed the degree of its impact from an environmental and social point of view. The study concluded that building the dam in an improper manner and without follow-up and management could have contributed to causing catastrophic effects. Their research analysis revealed that reconstructing different dams in Turkey could contribute to the development of sustainability principles and significant improvements, amendments, and evolution of the infrastructure facilities. Furthermore, through their research analysis, it was found that constructing dams and rebuilding and maintaining dam projects could achieve better enhancement in the infrastructure facilities and amenities. In the same vein, [42] conducted a study investigating and assessing the mechanical properties of dams

depending on analyzing a case study representing the Xiluodu Dam/ Reservoir built on the Xingguang village landslide. The water flow of this dam reaches the Jinsha River. It has been facing a critical problem mirrored by significant deformation levels that threatened the residents and citizens living around this zone. The authors used descending and ascending track Interferometric Synthetic Aperture Radar (InSAR) observations and utilized Unmanned Aerial Vehicles (UAV) to record some images that could characterize this issue to configure some effective solutions. Building on their numerical analysis of the data obtained from the dam, it was found that there were some important factors that could influence the stability and mechanical performance of the dam, including the higher steep bank slope cut and hard and soft anticline strata. In addition, the modeling and numerical analysis revealed that time-series plans and maps could be employed to prevent and monitor the failure associated with rocky slopes in the dam. Thus, significant enhancements in its structure could be observed. Figure 2.9 depicts a geological map of the dam region and other details related to the Xiluodu Dam's location. [24] guided a research work in which they explored and examined the critical impacts and severe effects of earthquakes on earth dams. They investigated a case study related to the Koyna gravity concrete earth dam. They developed an Explicit Galerkin Finite Volume Approach (EGFVA) through which assessments and estimations were carried out of damage paths in different dams' concrete structures, considering the principles of nonlinear behavior related to the concrete material. In addition, the EGFVA was compared with another technique, which is the Explicit Finite Element Analysis (EFEA), to validate and verify the efficiency and accuracy of their approach. Furthermore, they conducted an empirical work by which the concrete's nonlinear behavior was estimated and examined depending on the testing of two variant specimens that are posited under higher tension and pressure loading conditions. Also, they validated their research results by making a comparison with other scholars' outputs in the literature. Their study findings revealed that concrete dams could be dramatically affected due to earthquakes that can change soil characteristics and lead to severe damage to the dams' structure. Also, their proposed method, EGFVA, provided higher rates of performance, accuracy, and efficiency compared with other approaches, including EFEA. Additionally, it was found that their developed model, EGFVA, required roughly three folds lower time of processing data using the CPU compared with EFEA.

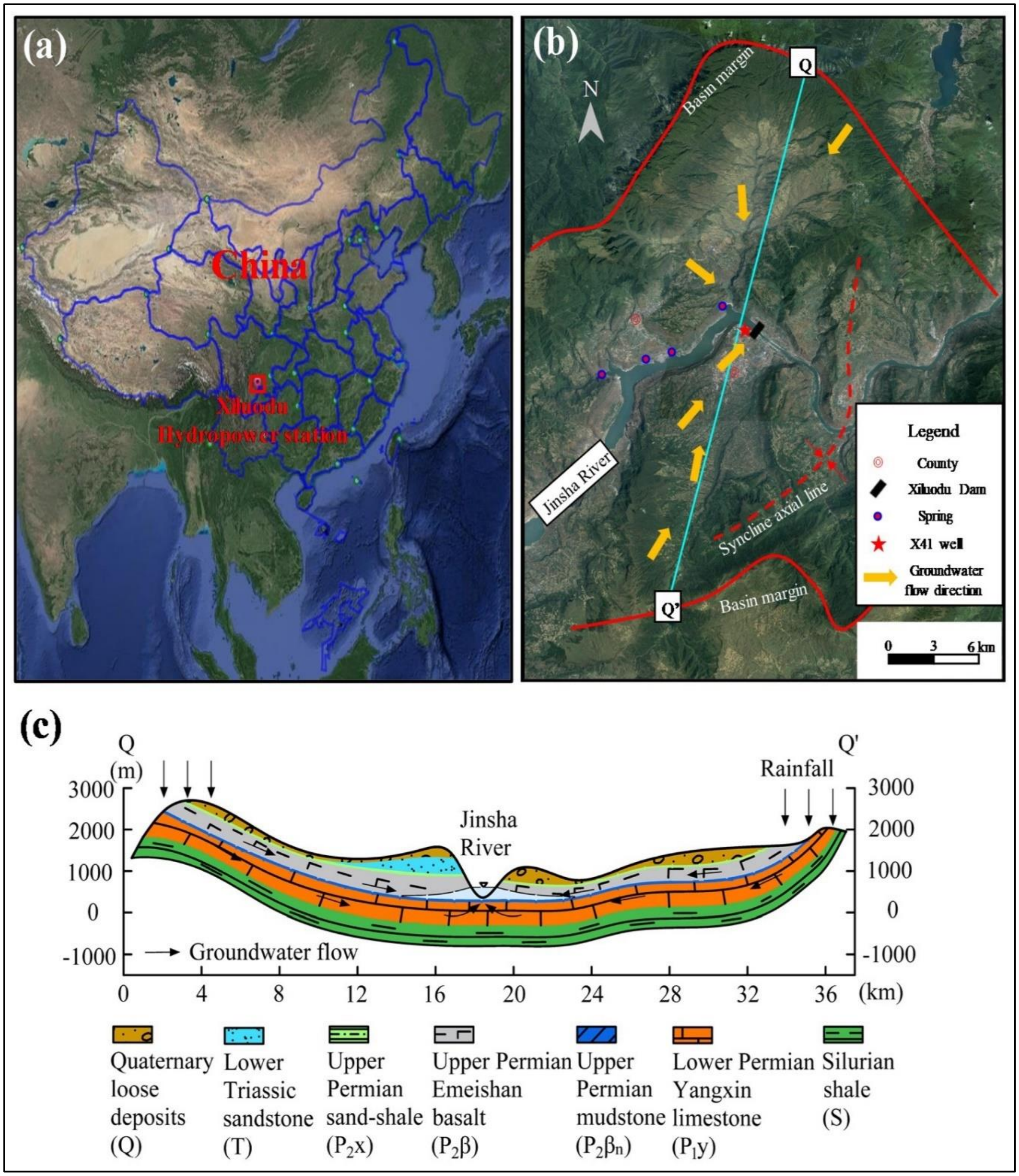

Figure 2.9: A geological map of the dam region. (a) The Xiluodu Dam's location. (a) A summary of the research (c) Yongsheng synclinal basin cross-section. (((a) and (b) are from the software OvitalMap).

[43] led a study examining and estimating critical consequences and harmful impacts of earthquakes when hitting concrete dams, leading to dangerous damage and failure. They followed a numerical analysis approach to achieve their study goal through which geotechnical analysis, 2D and 3D modeling, and numerical simulations were implemented. They used the Geo-Studio software package version 2018. They evaluated the seepage analysis and the slope stability related to a case study that represents Al-Adhaim Dam in Iraq. Their numerical results indicated that earthquake shaking could cause serious issues associated with seismic stability, static stability, and seepage. In addition, the numerical outputs revealed that earthquakes could result in imposing further short-term and hysteric loading in the two directions, leading to significant damage and overall failure of dams' structure because of soil liquefaction occurrence, higher pore water pressure values, piping variation, and settlement degradation. The authors also reported that such investigations would be beneficial and highly crucial as dams' structures are vulnerable to different types of failures during their operation, especially due to earthquakes, requiring deeper examination and assessment of their performance to increase their reliability and performance to serve a long lifespan. According to research guided by [44], Turkey is considered one of the countries that consume energy significantly, which makes it a large growing importer of energy, in order to cover the needs between supply and demand, so it is necessary to resort to dam construction projects for its great role in achieving the necessary and necessary requirements of energy and electricity. The study concluded that the total hydropower production in Turkey amounted to about 433,000 GWh/year, which is equivalent to 1% of the total energy globally. In general, building dams is one of the motives that lead to the sustainable building of clean energy, eliminating environmental damage and causes, and improving standards and indicators of economic development. [45] conducted the study on the Kayraktepe dam in Turkey with the aim of controlling the quantities of water that may lead to floods and following up and analyzing the results of the research based on evaluating the role of dams in energy generation and production and improving social, environmental and economic impacts. The researcher adopted the method of logical analysis based on the economic feasibility study of the project to ensure and facilitate the decision-making process by officials to achieve sustainable management in the long term in Turkey. [46] conducted research investigating seismic effects and severe earthquake loads that influence the stability of earth

dams. They explored a case study representing the Xiker Earth Dam, which was damaged by the Jiashi Earthquake event in 2020 in the Northwestern region of China. The authors carried out in situ and laboratory tests through which strata distribution properties were attained related to the dam foundation. They used drilling to obtain some specimens of soil to analyze their characteristics. In addition, their analysis provided data on the shear wave velocity related to the dam's soil layers, standard penetration, and particle size kind and distribution. Moreover, they estimated the sand liquefaction potential linked to variant layers. Also, they developed a relationship between sand liquefaction and dam fissures. Their research results revealed that the earthquake that occurred at the Xiker dam caused significant ground shaking and significant co-seismic deformation in and around the meizoseismal region. In addition, their study outputs confirmed that soil liquefaction took place between zero and three meters under the dam foundation. Also, soil liquefaction caused uneven settlement in the dam foundation, resulting in horizontal deformations related to the dam's back slope. These deformations were higher than that in the dam's fore-slope. Further, the numerical simulations indicated that maximum deformations recorded a value of approximately 7.45 cm in the dam's backslope and fore-slope, causing the dam to rotate in the downstream direction. Also, it was noted that large fissures were formulated at the dam's crest. [47] carried out research work exploring and identifying major influences and severe impacts of earthquakes and seismic activities in and around the dam area. They found that earthquakes could lead to several significant impacts on the dam's structural effectiveness, translated by significant weakness in the dam's robustness, severe effects on its structure stability, and mechanical performance. Therefore, it is remarkably important to consider various beneficial and advantageous building techniques that could improve the dam's seismic behavior. [48]–[52] conducted an analysis exploring the soil liquefaction phenomenon and classifying critical characteristics and observations of this problem. They reported that soil liquefaction issues could contribute to significant damage to the infrastructure and several facilities due to the remarkable losses in the soil's stiffness, strength, and valid mechanical properties. This phenomenon could cause buildings to topple over abruptly, sink, and tilt. Furthermore, [53]–[56] guided research works to identify some intelligent strategies and practical approaches that can be adopted to mitigate the soil liquefaction problem in construction. They found that employing kaolinite-clay, stone columns, nanomaterials, recycled materials, colloidal silica, bentonite, laponite, and short synthetic fibers could be applied and implemented to improve the soil's mechanical characteristics by enhancing its potential to resist the liquefaction problem when an earthquake occurs and making amendments in its structure.

2.5 LITERATURE REVIEW SUMMARY

Table 2.1 provides a summary of the literature review articles that were examined for this work.

Table 2.1: Literature review publications reviewed in this work.

#	Author(s)	Year	Paper Title	Major Contributions
1	Arnab Banerjee, D. K. Paul, and R. N. Dubey	2014	Modeling Issues in Seismic Analysis of Concrete Gravity Dam	Dam modeling was applied under the influence of seismic analysis. A study was conducted using the simulation system to evaluate the response of concrete gravity dams due to their high capacity to store large amounts of water and resistance to high pressure. The research adopted the CADAM program.
2	Avni Birinci, Nuray demir, and Koksal Karadas	2016	Evaluation of the Possible Socio – Economic Effects of Dam Projects on People Living on Agricultural Activities: The Case of Laleli Dam in Turkey	The results of the study showed that the number of people affected by the Laleli Dam project on their lifestyle amounted to about 2,273, and the construction of the dam project would contribute to reducing immigration and encouraging the development of investment projects that increase the rate. For the economic development of the country and the improvement of the standard of living of individuals.

Table 2.1: Literature review publications reviewed in this work. “tables continued”

3	Ayhan Demirbas¸and Recep Bakis	2003	Turkey Water Resources and Hydropower Potential	The study showed that the total hydropower production in Turkey was about 433,000 GWh/year, which is equivalent to 1% of the total energy globally. In general, dam construction is one of the drivers that lead to the sustainable construction of clean energy, the elimination of environmental damage and causes, and the improvement of economic development standards and indicators.
4	Dr. William F. Marcuson, III	2007	Seismic Design and Analysis of Embankment Dams: The State of Practice	Estimated seismic modulus greatly influences soil and slope behavior, based on approved standard design codes, such as Design Standards developed by the Japan Commission for Large Dams. Through the conclusions, it was noted that the study lacked a consistent approach in testing the seismic coefficient, which led to a weakness in the strength and resistance of the soil as a result of seismic collapses, which calls for the adoption of analytical methods.

Table 2.1: Literature review publications reviewed in this work. “tables continued”

5	Ebrahim Ghanizadeh and Mohammad Ghanizadeh	2017	Evaluation of Stability and Performance of Dam Foundations at Static State	The performance of the dams was evaluated through the FLAC program and its effective role in analyzing the field of vibrations that occur in the dams and ensuring that the dams are not liquefied during earthquakes.
6	Eric Antoineta, Hadrien Buffiereb, and Kristina Kovalcikova	2017	Time dependent earthquake modeling of an earth dam	According to the results, preliminary calculations must be made when designing dams when applying the modeling process through laboratory or site tests that have led to hypotheses with great accuracy to obtain data to determine the amount of deformation and collapse in dams at a given stress level.
7	Hasan Tosun	2021	Experience on Earthquake Safety of Large Embankment Dams Constructed in Turkey	The results showed the necessity of designing and preparing a safety program for dams classified as critical dams to assess problems and defects by following international specifications and standards.

Table 2.1: Literature review publications reviewed in this work. "tables continued"

8	Ikram Guettaya, Mohamed Ridha El Ouni, and Robb Eric S. Moss	2013	Verifying liquefaction remediation beneath an earth dam using SPT and CPT based methods	The results of the study showed that in-situ liquefaction processes affect the dense silt soil by subjecting it to fibrous interactions, making it susceptible to liquefaction that may cause soil subsidence and dam formation, and that the obvious differences in the inevitable and limited impact are partly related to each other.
9	Yifei Zhu, Xin Yao, Leihua Yao, Zhenkai Zhou, Kaiyu Ren, Lingjing Li, Chuangchuang Yao & Zhenkui Gu	2022	Identifying the Mechanism of Toppling Deformation by InSAR: A Case Study in Xiluodu Reservoir, Jinsha River	Building on their numerical analysis to the data obtained from the dam, it was found that there were some important factors that could influence the stability and mechanical performance of the dam, including the higher steep bank slope cut and hard and soft anticline strata. In addition, the modeling and numerical analysis revealed that time-series plans and maps could be employed to prevent and monitor the failure associated with rocky slopes in the dam. Thus, significant enhancements in its structure could be observed.

Table 2.1: Literature review publications reviewed in this work. "tables continued"

10	Isak Berneheim and Erik Forsgren	2016	Behavior of Swedish Concrete Buttress Dams at Sesmic Loading	Ten dams were selected based on the highest peak height of more than 20 meters. Modeling was done when the stress condition was high and compared with numerical analysis techniques to obtain more accurate results.
11	J. Quintero; S. Saldanha; M. Millen; A. Viana da Fonseca; S. Sargin; S. Oztoprak; and M. K. Kelesoglu	2019	Investigation into the Settlement of a Case Study Building on Liquefiable Soil in Adapazari, Turkey	Based on the results of the study, estimating the strength of the soil undergoing the liquefaction process is one of the necessary factors that affect the settlement of the building in general. The study was based on presenting the practical results by applying the PLAXIS software and the UBC3D-PLM model.
12	Jeremy Bird	2006	Dams and Development, A source of information, guidance, and weblinks related to planning and implementing dam projects	The research was based on the Asian Development Bank's study of several dam-building projects by following a set of strategies by building a database related to large dam-building projects and preparing reports assessing environmental impacts.

Table 2.1: Literature review publications reviewed in this work. “tables continued”

13	L. Hommes, J. Hoogesteger, and R. Boelens	2022	(Re)making hydrosocial territories: Materializing and contesting imaginaries and subjectivities through hydraulic infrastructure	Their research analysis revealed that reconstructing different dams in Turkey could contribute to the development of sustainability principles and significant improvements in the infrastructure. Furthermore, through their research analysis, it was found that constructing dams and rebuilding and maintaining dam projects could achieve better enhancement in the infrastructure facilities and amenities.
14	Mohammad Javad Khosravi	2019	The Economic Development of Dam Construction Projects by Applying a Critical Chain Project Management	The results of the study showed that building dams have a clear impact on industrial projects in the long term by raising development, increasing job opportunities and improving sustainable development standards.
15	Ö. Sever, Ş. Tiğrek, N. Şarlak	2012	Balancing energy and environmental concerns: the case of the Kayraktepe dam, Turkey	The study adopted a logical analysis method based on the economic feasibility study of the project to ensure and facilitate the decision-making process by officials to achieve long-term sustainable management in Turkey.

Table 2.1: Literature review publications reviewed in this work. “tables continued”

16	Boulange J., Hanasaki N., Yamazaki D., & Pokhrel Y.	2021	Role of dams in reducing global flood exposure under climate change	The results of the study showed that dam construction could contribute to several sustainable developments in its three dimensions: environmental, economic, and social, in addition to its role in managing water resources and mitigating climate change and global warming's severe impacts to comply with the basic requirements of humans. Also, dam construction could meet all the requirements and services related to water. Through this research, the mechanism of building dams was studied to ensure the provision of renewable energy at reasonable prices in a way that makes it sustainable economically, environmentally and socially, with it role in alleviating the climate change and global warming effects, which helps to achieve the economic development of the world.

Table 2.1: Literature review publications reviewed in this work. "tables continued"

17	S.-R. Sabbagh-Yazdi, A. Farhoud, A. Mohammadi, and E. Yazdinasabkarani.	2022	"Earthquake damage estimation of the Koyna concrete gravity dam using explicit GFVM model considering fluid–structure interaction	Their study findings revealed that concrete dams could be dramatically affected due to earthquakes that can change soil characteristics and lead to severe damage to the dams' structure. Also, their proposed method, EGFVA, provided higher rates of performance, accuracy, and efficiency compared with other approaches, including EFEA. Additionally, it was found that their developed model, EGFVA, required roughly three folds lower time of processing data using the CPU compared with EFEA.
18	Rubén Quiñones Martínez	2019	Design Management Phases in a Construction Irrigation Dam: Case Study	The results showed that following and applying the terms of the technical specifications contributes significantly to improving the quality of the design and construction of the dam and reducing the risks and damages that may result from misunderstanding and managing the design of the dam project.

Table 2.1: Literature review publications reviewed in this work. "tables continued"

19	World Commission on Dams	2001	Dams and development: A new framework for decision making Overview of the report by the World Commission on Dams	According to the results of the study, hydroelectric power generates nearly 50% of electricity production, while dams generate nearly 19% of electricity production and generation in all countries of the world. The construction of dams contributes significantly to improving the infrastructure of countries and developing economic development by creating job opportunities and ensuring a good rate of electricity consumption.
20	World Commission on Dams	2000	Dams and Development: A New Framework for Decision-Making	The results of the study showed the method of evaluating the performance of dams and their impact on the economic, environmental, and social aspects, in addition to monitoring the planning and design work to ensure the facilitation of the decision-making process in the construction, operation and maintenance of dams.

Table 2.1: Literature review publications reviewed in this work. “tables continued”

21	S. A. Aude, N. S. Mahmood, S. O. Sulaiman, H. H. Abdullah, and N. al Ansari.	2022	Slope Stability and Soil Liquefaction Analysis of Earth Dams with a Proposed Method of Geotextile Reinforcement	Their numerical results indicated that earthquake shaking could cause serious issues associated with seismic stability, static stability, and seepage. In addition, the numerical outputs revealed that earthquakes could result in imposing further short-term and hysteric loading in the two directions, leading to significant damage and overall failure of dams’ structure because of soil liquefaction occurrence, higher pore water pressure values, piping variation, and settlement degradation. The authors also reported that such investigations would be beneficial and highly crucial as dams’ structures are vulnerable to different types of failures during their operation, especially due to earthquakes, requiring deeper examination and assessment of their performance to increase their reliability and performance to serve a long lifespan.

Table 2.1: Literature review publications reviewed in this work. "tables continued"

22	P. Hong Le, S. Nishimura, T. Nishiyama, C. Fang, and T. Canh Nguyen.	2022	Seismic Deformation of Earth Dams: A State-of-the-art Review	They found that earthquakes could lead to several significant impacts on the dam's structural effectiveness, translated by significant weakness in the dam's robustness, severe effects on its structure stability, and mechanical performance. Therefore, it is remarkably important to consider various beneficial and advantageous building techniques that could improve the dam's seismic behavior.

2.6 CHAPTER SUMMARY

It can be inferred from a review of numerous research articles and recent academic publications that the investigation of the dam liquefaction problem has different negative impacts on the dam's stability and mechanical performance depending on the scale and size of the dam. Thus, scholars and researchers investigated and examined various intelligent methods, critical solutions, and practical approaches that could play an essential role in improving and enhancing the dam's robustness and promoting its structural effectiveness under different severe seismic consequences. In addition, the construction process of different small and large-scale dams could contribute to achieving sustainable environmental, social, and economic development indicators and reducing the accumulation of water that leads to floods and environmental and human disasters.

3. RESEARCH METHODOLOGY

3.1 CHAPTER GOAL

Chapter three illustrates critical aspects and important concepts related to the major research steps and practical study methodologies employed in this work to carry out the necessary analysis of the dam construction process and collect the vital primary data regarding the soil liquefaction problem impact on the dam's stability, robustness, and mechanical performance. In addition, this chapter describes major data analysis techniques adopted to analyze the information obtained from the primary data collection process.

3.2 RESEARCH METHOD

This study depends on one secondary data collection approach and three primary data collection methods. Through the employment of the secondary data collection technique, previous data are gathered and collected, existing in several peer-reviewed articles, master and PhD dissertations, conference proceedings, and other recent academic publications. The aim of the secondary data collection is to address the problem of soil liquefaction and classify its critical impacts and dangerous consequences that influence the dam's stability, structural seismic behavior, and mechanical performance under earthquake attacks. In addition, the secondary data collection is essential to highlight and determine innovative building techniques and modern construction methods and practices implemented by chief engineers, constriction professionals, and project managers to construct high-efficient dams that can resist seismic effects and offer significant levels of structural stability for the reservoirs.

Furthermore, two primary data collection processes are adopted to predict some mechanical properties and physical measures associated with the thesis case study, which represents the Karakaya dam that is located in Turkey. The first research technique comprises the utilization of extrapolation principles with the help of Excel software equations. The extrapolation method is vital to predicting the temperature and water flow discharge rate related to the Euphrates River at Karakaya next some years. The second method depends on the principles of Machine Learning (ML) to forecast the concentration of some elements and indices in the soil under the

Karakaya dam, which may influence the occurrence of soil liquefaction situation in the dam, including:

i. Soil Potential Hydrogen Number,
ii. Soil Temperature,
iii. Copper,
iv. Nitrogen Dioxide,
v. Phosphite Anion,
vi. Ammonium Ion,
vii. Ammonia.

Notwithstanding, relying alone on the secondary data collection would not provide sufficient and essential data for construction engineers and project managers regarding possible intelligent methods and practical techniques that can be adopted and applied to resolve the soil liquefaction problem in dams and provide robust construction and high-performance structural behavior in case dams may face seismic attacks in the future. Therefore, the researcher employed a third primary data collection procedure through which modern practices and state-of-the-art techniques can be identified and highlighted according to the points of view of some construction professionals and high-experienced project managers who worked with various large-scale construction of reservoirs and dams through their job history.

The opinions of those key specialists and experienced engineers would provide beneficial guidelines and a vital database for senior and junior engineers to help handle and resolve the soil liquefaction problem in dam projects. Finally, the results of the three research approaches will be verified, modified, and validated depending on the opinions and experiences of those persons. Hence, advantageous recommendations can be drawn to help project managers implement intelligent techniques and practical construction methods to provide high robustness and stability to dams that may face seismic attacks and earthquakes throughout their lifespan. Figure 3.1 represents the research methodology flowchart associated with this thesis.

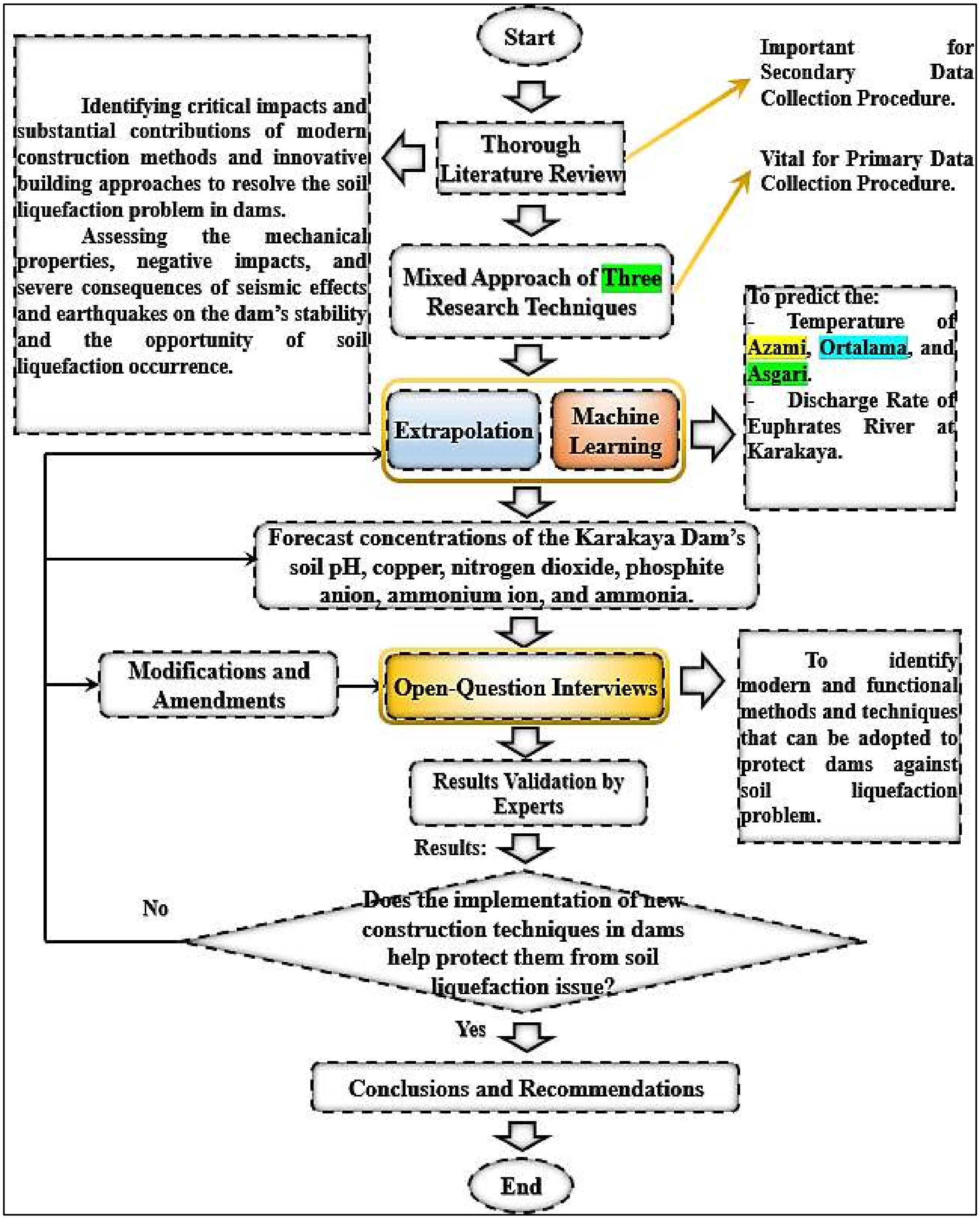

Figure 3.1: The research methodology flowchart.

The following paragraphs indicate more details on the three research approaches implemented in this work.

3.3 THE DATA COLLECTION APPROACHES

As mentioned in the research method, there are three critical research approaches adopted and implemented to collect the necessary primary data to address effective strategies and practical techniques that can help improve the robustness and strength of dams against earthquakes and severe seismic effects that would cause harmful impacts and adverse effects on their structures throughout their lifespan.

3.3.1 Extrapolation Research Approach

Extrapolation can be described as a statistical research procedure through which the trends of data in the future can be determined and forecasted according to some data existing currently. Excel software can be employed to draw a conclusion regarding the relationship between one variable with time and give a formula, which can be utilized to predict the future values of the same parameters next year. Extrapolation has significant advantages and benefits translated by its practicality for several broad engineering, medical, statistical, mathematical, and other applications. In addition, extrapolation can help scholars and engineers identify the behavior of some variables, whether they would increase, maintain constant, or decline in the next decades [57].

In this work, extrapolation is employed to predict two major dam variables that can affect the soil's mechanical characteristics in the future and influence the opportunity for soil liquefaction occurrence. These variables include:

(A) the ambient temperature around the soil, and

(B) the dam discharge rate.

Figure 3.2 represents the datasets defined for the extrapolation process regarding the temperature amounts of the Azami region closer to the Karakaya dam.

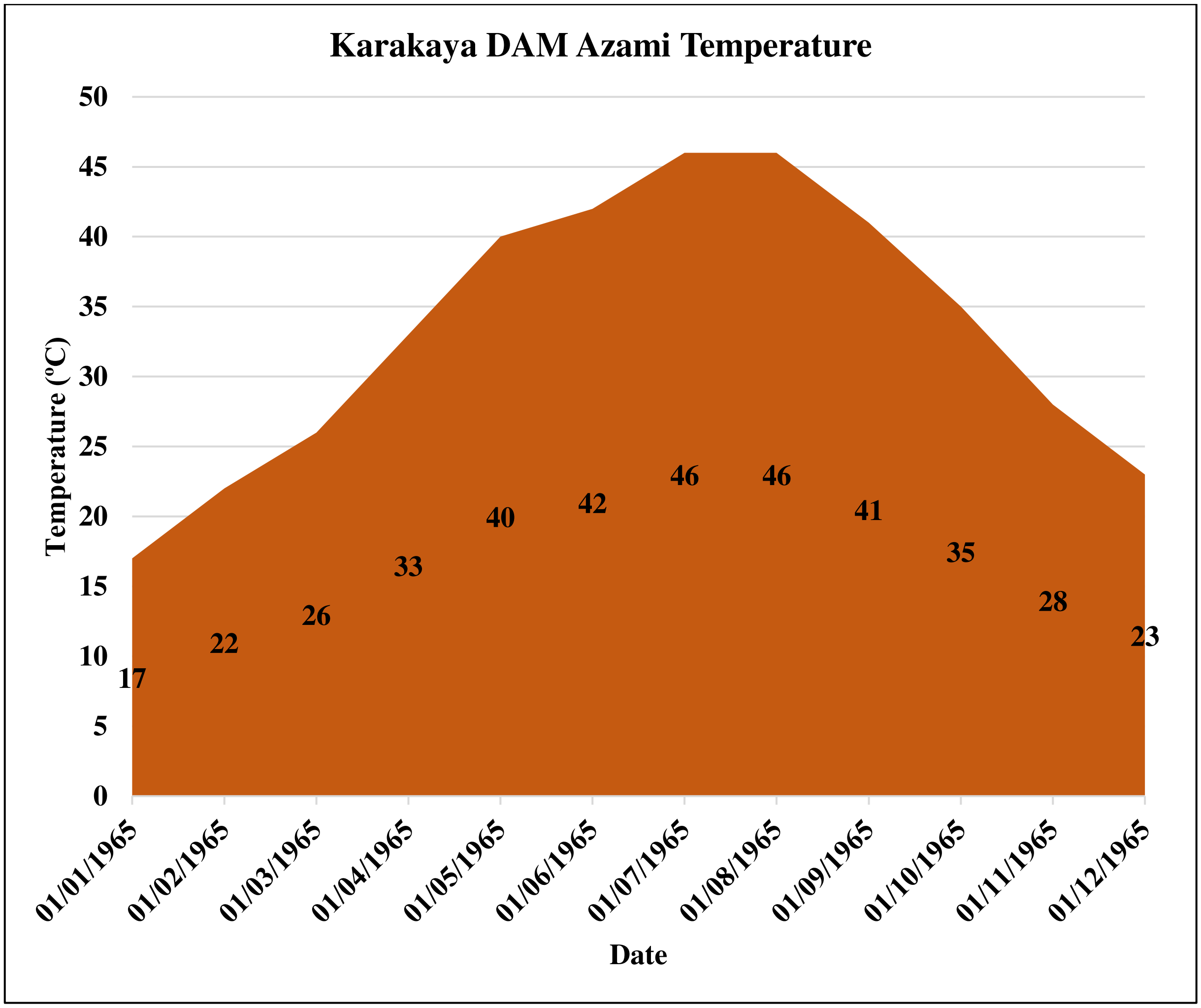

Figure 3.2: The temperature profile of the Azami area near the Karakaya dam in 1965 (datasets defined).

In addition, Figure 3.3 represents the temperature profile of another region located closer to the Karakaya dam, which is Ortalama.

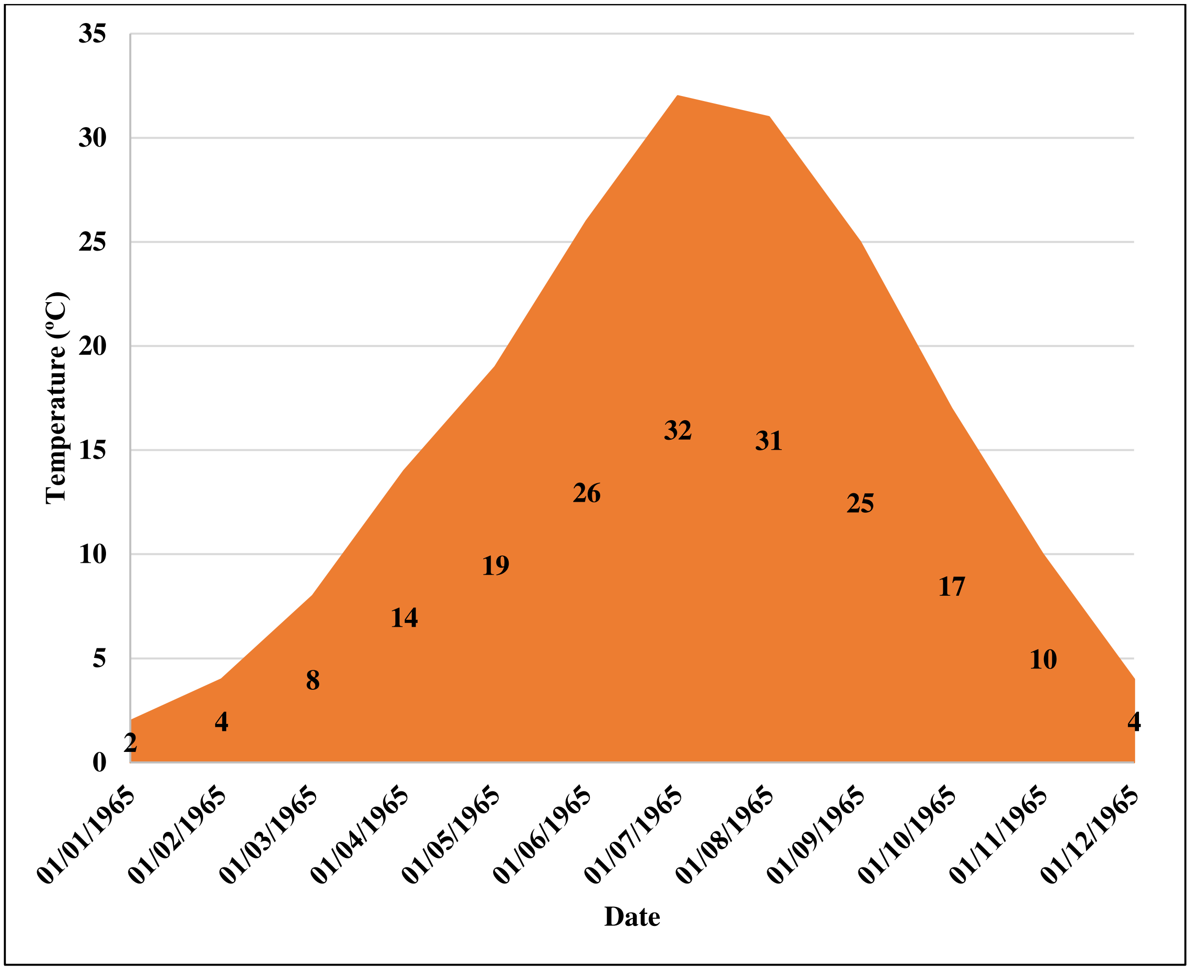

Figure 3.3: The temperature profile of the Ortalama area near the Karakaya dam in 1965 (datasets defined).

Further, a third zone is selected around the Karakaya dam to predict its temperature profile, representing the Asgari zone. Figure 3.4 illustrates the temperature profile of this region.
It is worth mentioning that all these data are obtained from the Turkish Ministry of Environment and Forestry.

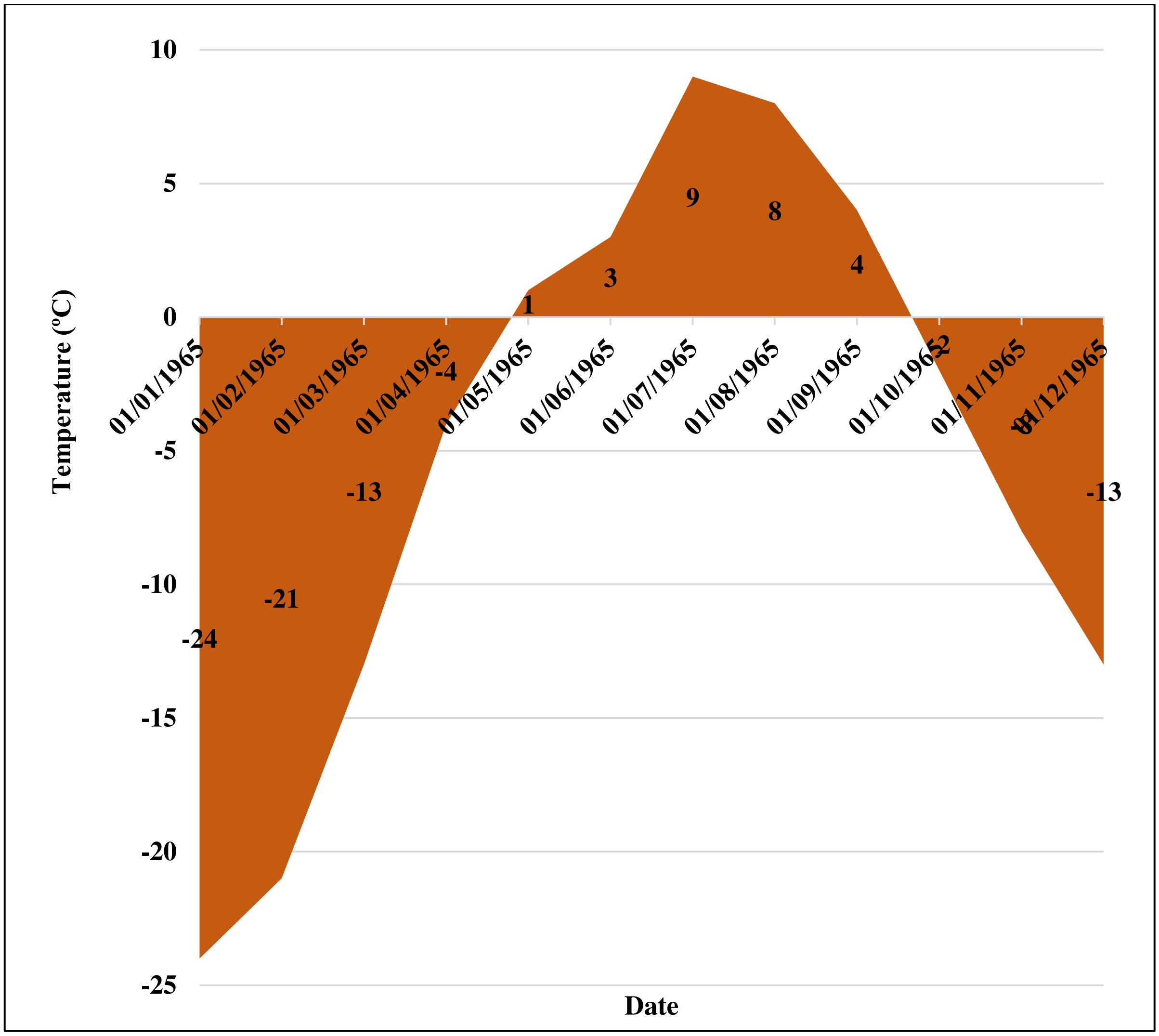

Figure 3.4: The temperature profile of the Asgari area near the Karakaya dam in 1965 (datasets defined).

It can be indicated from Figures 3.2, 3.3, and 3.4 that the Karakaya dam is located in variant temperature zones in which the temperature values in two of them are closer to the tropical regions.

At the same time, one of them, which is Asgari includes very low-temperature values in January, February, March, April, October, November, and December. In addition, the data associated with the dam discharge rate were depicted by the Turkish Ministry of Environment and Forestry, as illustrated in Figure 3.5.

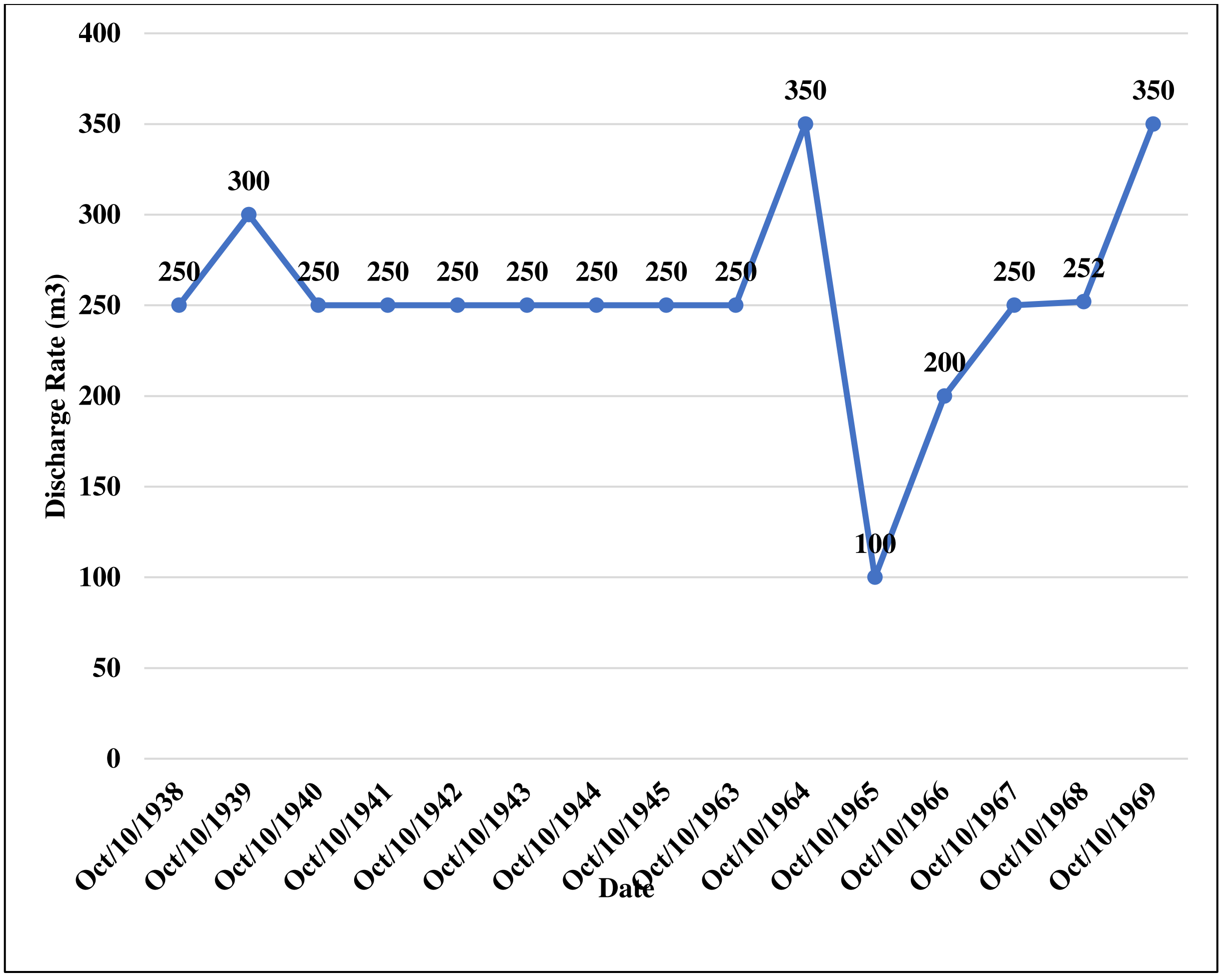

Figure 3.5: The Karakaya dam discharge rate between 1938 and 1969 (datasets defined).

3.3.2 Machine Learning

Machine learning is used in this work to train Linear Regression Optimization Algorithm (LROA) to help forecast the concentrations of (a) NO_2, (b) PO_3, and (c) pH in the soil under the Karakaya dam. Hence, the soil liquefaction occurrence opportunity can be determined by assessing the amounts of these variables. To achieve this research approach, datasets were defined in Python software using the database from the TensorFlow library. This process can help Python, Artificial intelligence (AI), and Artificial Neural Networks (ANNs) make data visualization, analysis, and forecasting more reliably and flexibly. Figure 3.6 represents some of the datasets defined in the Python software to predict the three parameters using the LROA.

	id	location	Date	Season	COD_mgl	pH	Temp_C	Conduc.	Cu	Cd	Pb	Mn	NO2-N
0	1	St-1	1.4.2001	Spring	13	6.12	20.2	391	0.010	0.002	Ur	Ur	0.003
1	2	St-1	1.9.2001	Summer	20	8.32	27.7	295	0.020	0.005	0.003	0	0.007
2	3	St-1	1.12.2001	Autumn	28	9.71	20.4	380	0.010	0.001	0.003	0.1	0.003
3	4	St-1	1.12.2001	Mean	20.3	8.05	22.8	355	0.013	0.0027	0.002	0.03	0.004
4	5	St-2	1.4.2001	Spring	5	8.43	21.3	411	0.060	0.002	Ur	0.05	0.019
5	6	St-2	1.9.2001	Summer	27	4.14	26.8	642	0.030	0.006	0.006	0.1	0.013
6	7	St-2	1.12.2001	Autumn	nd	8.32	20.4	418	0.080	0.002	0.004	0.1	0.016
7	8	St-2	1.12.2001	Mean	10.7	6.96	22.8	490	0.600	0.003	0.003	0.08	0.016
8	9	St-3	1.4.2001	Spring	11	6.38	21.3	401	0.010	0.002	Ur	0.05	0.008
9	10	St-3	1.9.2001	Summer	28	9.04	26.1	389	0.040	0.001	0.003	0.1	0.014
10	11	St-3	1.12.2001	Autumn	6	9.74	19.5	405	0.010	0	0.003	0.1	0.003
11	12	St-3	1.12.2001	Mean	15	8.39	22.3	398	0.020	0.001	0.002	0.08	0.008
12	13	St-4	1.4.2001	Spring	14	6.50	19.9	388	0.010	0.001	Ur	0.09	0.003
13	14	St-4	1.9.2001	Summer	27	8.71	26.7	490	0.010	0.001	0.005	0.1	0.010
14	15	St-4	1.12.2001	Autumn	18	9.21	20.3	518	0.030	ur	0.002	0	0.003
15	16	St-4	1.12.2001	Mean	19.7	8.14	22.3	465	0.020	0.0007	0.002	0.06	0.005

Figure 3.6: Some of the datasets defined in the Python software to predict the three parameters using the LROA.

3.3.3 The Qualitative Cross-Sectional Approach

There is another third research approach adopted in this work to collect the necessary database and beneficial information from high-experienced individuals and large-knowledge engineers who have participated in at least one or two small and large-scale dam construction projects. The qualitative cross-sectional descriptive approach depends on conducting meetings with important persons with the help of interviews. The most common type of interview used in cross-sectional studies by several researchers globally is the well-structured open-question interview, which provides the opportunity and chance for the participants, including four top managers in Turkey, to express their points of view and vital aspects associated with their experience to identify and highlight major active methods and intelligent strategic approaches that can be used and implemented by project managers and chief engineers to help them achieve and execute the dam construction projects. Table 3.1 represents the list of open questions used in the well-structured interviews in this thesis.

Table 3.1: Major questions used in the open-question interviews with top construction managers.

No.	Question
1	What are the major problems and issues did you face during the execution of small or large-scale construction projects?
2	From your point of view, what are the major modern construction activities and intelligent strategic approaches that can be adopted by engineers and project managers to build dams?
3	What critical techniques and procedures did you follow to provide effective construction of dams with higher performance and stability against seismic effects?
4	What are the active construction processes you adopted and implemented to resolve the problem of soil liquefaction that could cause remarkable damage to the dam's structure and building robustness?
5	How did you prepare the dam's structure in your project to help the dam resist harmful impacts of earthquakes and seismic activities that might influence the dam's robustness and effectiveness through its lifespan?

4. RESULTS AND DISCUSSIONS

4.1 CHAPTER GOAL

This section describes the research findings obtained from the two study methodologies implemented in this work, including extrapolation and numerical forecasting using LROA.

4.2 EXTRAPOLATION RESULTS

Figure 4.1 represents the extrapolation results related to the temperature profile in 2025 obtained using excel software after using the data defined for the Azami region, which is close to the Karakaya dam.

The extrapolation process supported the researcher in determining the general trend of the existing data collected from the Turkish Ministry of Environment and Forestry. The trend line helped identify the future values of the research variables, which can be observed in the following graphs.

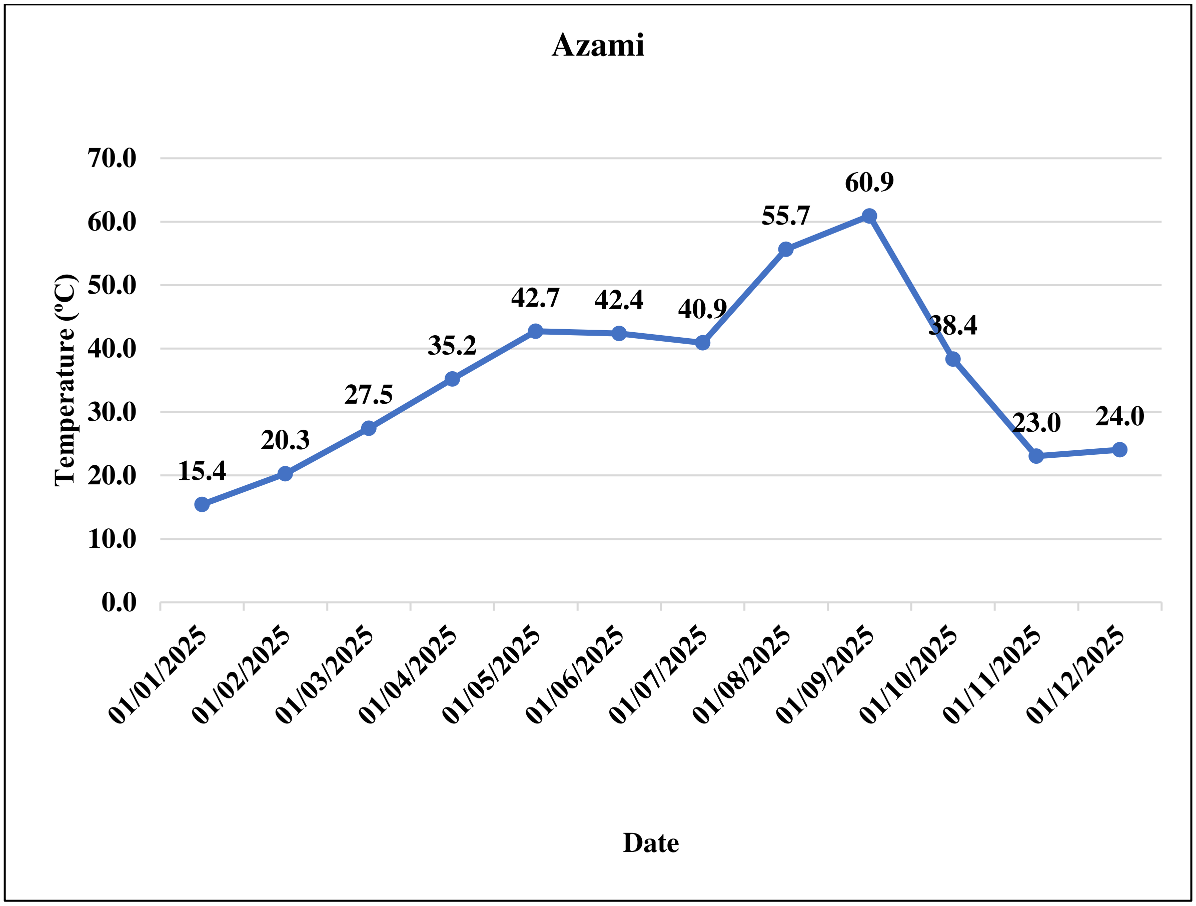

Figure 4.1: The research forecasting findings, according to the extrapolation method of Azami temperature.

It can be noted from Figure 4.1 that the temperature values in Azami for the months of 2025 are larger than the temperature values in 1965. These results can indicate that the soil properties under the Karakaya dam may be influenced due to the high-temperature values.

Furthermore, the extrapolation results indicated the temperature profile linked to the Ortalama zone near the Karakaya dam in 2025, as shown in Figure 4.2.

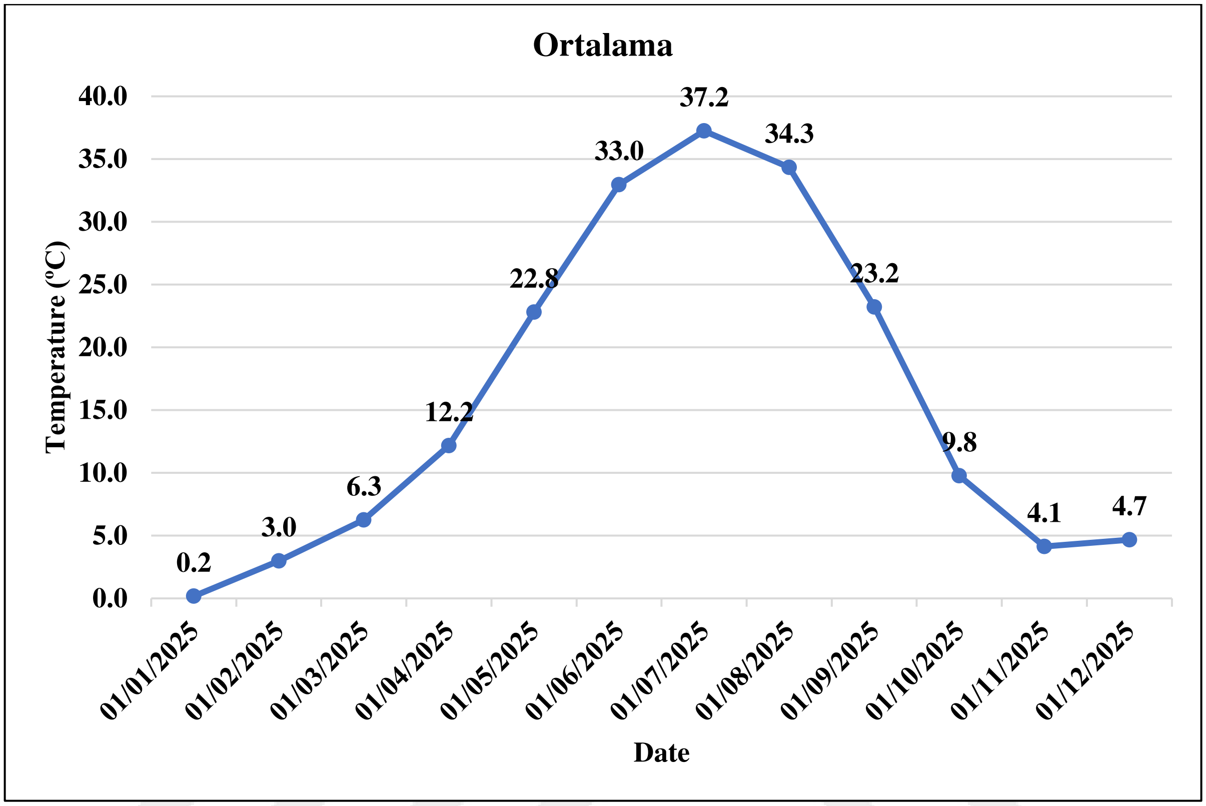

Figure 4.2: The research forecasting findings, according to the extrapolation method of Ortalama temperature.

It can be noted from Figure 4.2 that the temperature values in Ortalama for the months of 2025 are more significant compared with the temperature values in 1965. These results can indicate that the soil properties under the Karakaya dam may be affected because of the high-temperature values. Besides, the extrapolation procedures revealed the temperature profile associated with the Ortalama zone near the Karakaya dam in 2025, as shown in Figure 4.3.

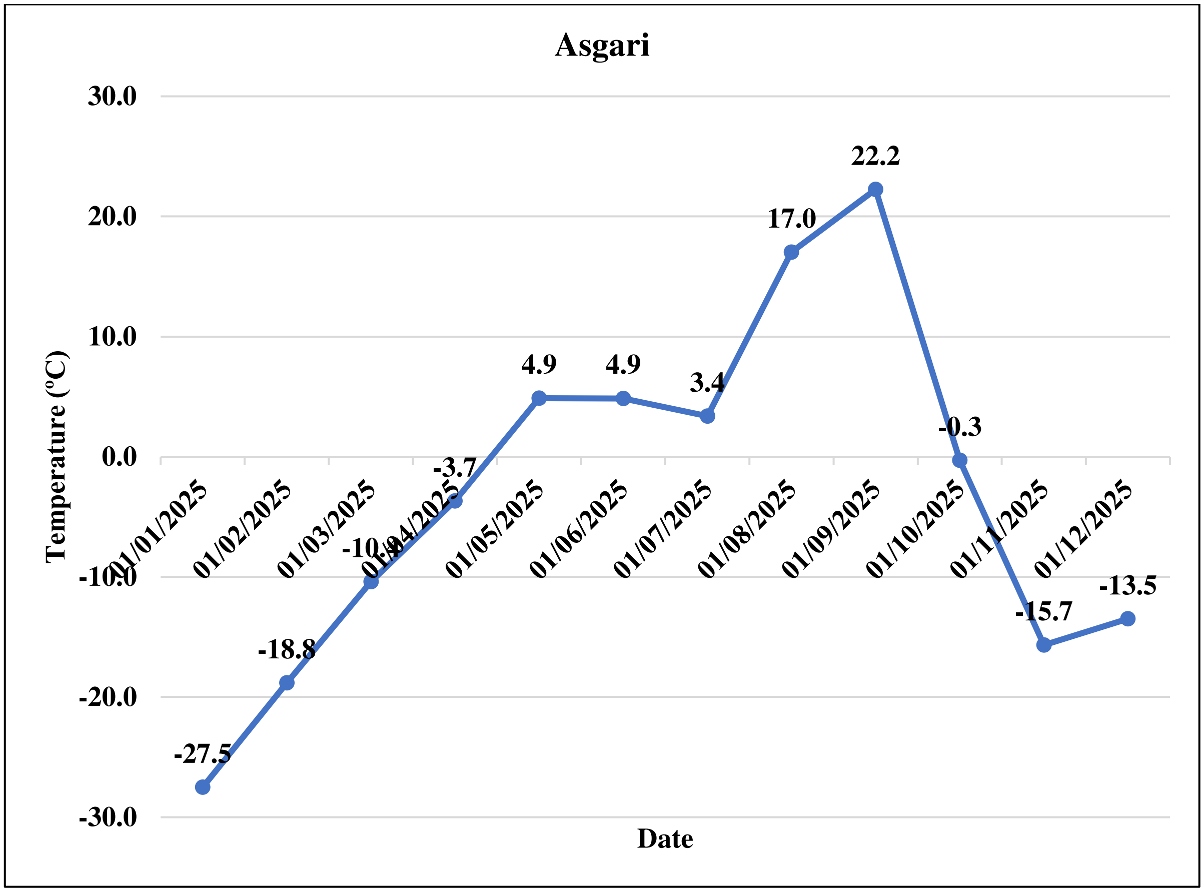

Figure 4.3: The research forecasting findings, according to the extrapolation method of Asgari temperature.

Similar to the two previous regions, it can be noted from Figure 4.3 that the temperature values in Asagari for the months of 2025 are more significant compared with the temperature values in 1965. These results express that the soil characteristics under the Karakaya dam may be impacted because of the high-temperature weights.

Besides, the extrapolation procedures revealed the forecasting results associated with the discharge rate of the Euphrates River closer to the Karakaya Dam for the year 2029. Figure 4.4 represents the prediction findings related to this parameter.

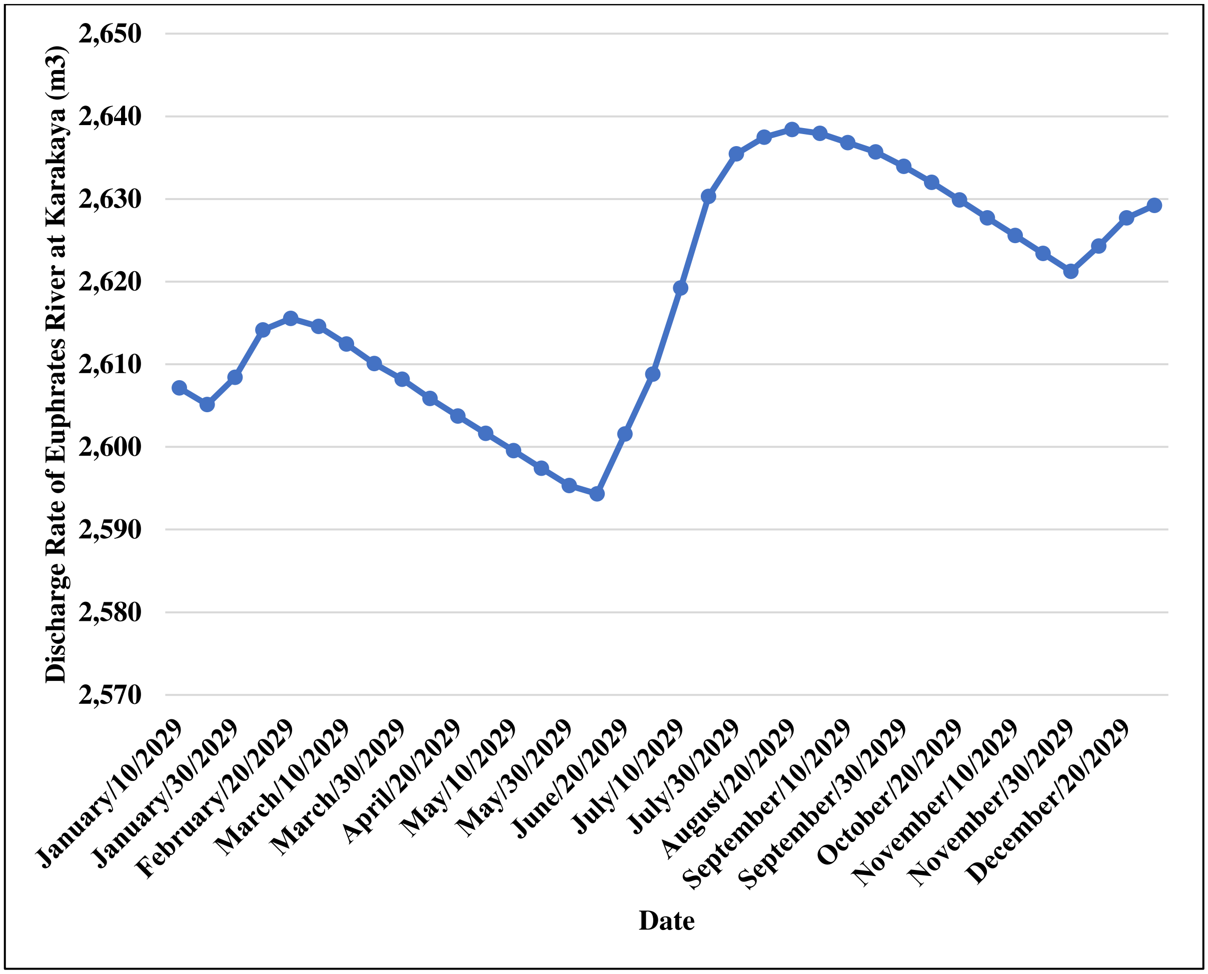

Figure 4.4: The research forecasting findings, according to the extrapolation method of Asgari temperature for 2029.

It can be inferred from Figure 4.4 that the discharge rate of the Euphrates River amounts to approximately 2,605 m^3 at the beginning of January. Then, it starts to increase until it reaches around 2,615 m^3 on March 10. After that, the Euphrates River discharge rate witnessed a continuous decrease until it amounted to a minimum annual discharge value of about 2,595 m^3 on June 20, 2029. Then, it increases until it amounts to a maximum yearly value discharge of 2,645 m^3 on August 20, 2029. Then, it decreases slightly to reach around 2,620 m^3 at the end of November. Then, it increases again to attain a quantity of 2,630 m^3 at the end of December 2029.

4.3 NUMERICAL LROA RESULTS

In addition to the preceded results, the concentrations of some elements in the soil were assessed to examine their impact on the soil liquefaction problem. Table 1 illustrates the forecasting results obtained from the optimization process using the ANN algorithm of linear regression for 2029.

Table 4.1: The LROA numerical forecasting results of some soil parameters and elements for 2029.

Category	Symbol	Unit	Minimum	Maximum	Standard Deviation
Soil Potential Hydrogen Number	pH No.	---	4.140	9.740	1.499
Soil Temperature	T_{Soil}	ºC	19.500	27.70	2.756
Copper	Cu	µg/m^2	0.010	0.600	0.145
Nitrogen Dioxide	NO_2	µg/m^2	0.003	0.020	0.006
Phosphite Anion	PO_3	µg/m^2	0.990	2.030	0.343
Ammonium Ion	NH_4^+	µg/m^2	0.040	0.320	0.082
Ammonia	NH_3	µg/m^2	0.030	0.300	0.079

It can be inferred from Table 4.1 that the predicted soil pH number for 2029 will record a minimum value of 4.140 compared with a maximum amount of 9.740. Further, the soil temperature will record a minimum amount of 19.5 ºC compared with a maximum amount of 27.7 ºC. At the same time, copper concentration will reach a minimal quantity of 0.01 µg/m^2 and a maximum quantity of 0.6 µg/m^2 at some time during 2029. Similarly, the concentrations of other chemical elements in the soil under the Karakaya Dam will not significantly variate in 2029. These results can indicate that soil characteristics may not be remarkably affected or changed next years. Therefore, the opportunity of soil liquefaction phenomenon has a lower opportunity of occurring. Figure 4.5 represents a graphical representation of the chemical elements' concentrations obtained from the LROA analysis (which are described in Table 4.1).

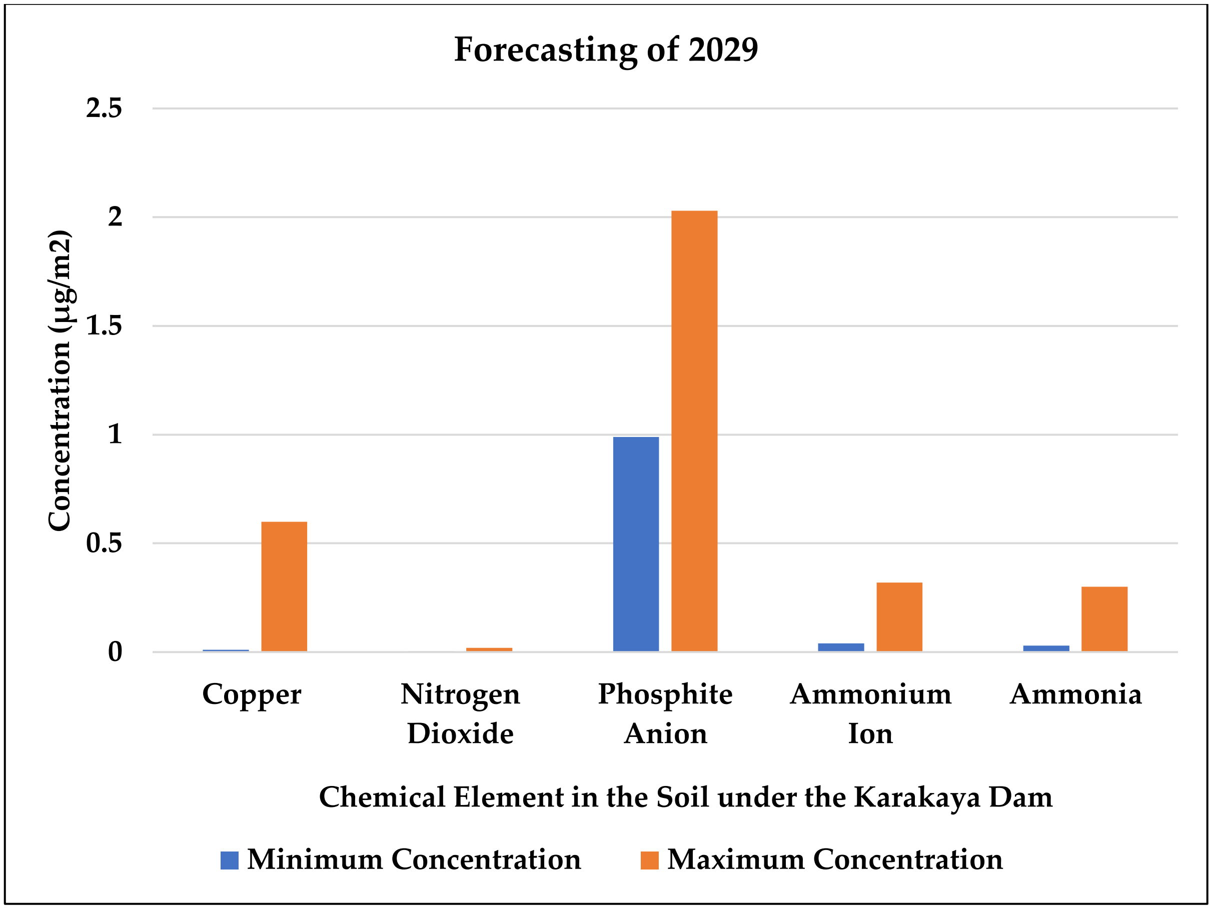

Figure 4.5: The major chemical elements' concentrations in the soil under the Karakaya Dam.

It can be indicated from Figure 10 that the largest chemical molecule existing in the soil under the Karakaya Dam is the phosphite anion, corresponding to a minimum and maximum concentration of 1 and 2 µg/m^2, respectively, followed by copper, ammonia, and ammonium ion, with a concentration between 0 and 0.5 µg/m^2.

4.4 THE QUALITATIVE CROSS-SECTIONAL STUDY RESULTS

Depending on the cross-sectional study conducted with the help of open-question interviews conducted with four top managers working in Turkey and have participated in at least one to two dam construction projects, the following aspects were concluded according to their points of view and high knowledge:

a. Using the principles of BIM technology is remarkably helpful and useful for both junior and senior engineers, as it can cut significant levels of cost, effort, time, and complexity related to the construction activities and building phases of dams.
b. Dams construction is associated with a higher degree of complicated activities and a considerable budget. Thus, errors in these types of projects can be greatly substantial. Therefore, modern construction techniques, including the employment of new machines, high-skilled engineers, and new building codes for dams, are required to avoid any financial losses in the budget and resources of the dam construction project.
c. Increasing the level of awareness and knowledge regarding effective methods and intelligent strategic techniques for building dams is required in the Turkish construction sector to help avoid any wastage of budget, cost overrun, or delay, especially in the execution of large-scale dams.
d. Modern approaches and intelligent methods to build dams include the consideration of large-scale machines and equipment that can cut significant amounts of time, effort, and cost for project managers and workers to excavate the dam's reservoir and other parts and complete the dam project on time without any problems or delay.
e. Vital approaches to soil strengthening are demanded to employ by chief engineers and project managers to help improve the mechanical characteristics of soil and help it resist harmful seismic attacks and dangerous earthquakes that might result in soil liquefaction phenomenon.
f. The utilization of new materials and integration into the soil can enhance its seismic resistance and achieve better stability to support the structure of the dam, such as metal fibers, High-Performance Concrete (HPC), Ultra-High-Performance Concrete (UHPC), smart materials, and nanomaterials.

4.5 DISCUSSIONS

The results of this work revealed that the annual temperature in the future of zones and regions around the Karakaya Dam, including Azami, Ortalama, and Asgari, would witness a moderate increase of about 3 to 6 degrees Celsius next decade. Moreover, the research forecasting analysis confirmed that the Euphrates River discharge rate at the Karakaya Dam would witness a significant increase from (100-350 m^3) to (2,590-2,640 m^3) in 2029, explaining that temperature and discharge rate may influence the occurrence of liquefaction problems due to the increase in the ambient temperature and water flow in the future. On the other hand, the research findings indicated that soil temperature under the Karakaya Dam and chemical elements would not variate significantly next decade.

Nonetheless, the pH number will variate widely from 4.14 to 9.74 in 2029. Also, the numerical linear regression optimization affirmed that the most significant chemical molecule concentration in the soil under the Karakaya Dam is the phosphite anion, corresponding to a minimum and maximum concentration of 1 and 2 $\mu g/m^2$, respectively. Further, data analysis on earthquakes around the Karakaya Dam was not implemented as earthquake opportunities cannot be numerically predicted. These results are consistent with the results of [53]–[58], who conducted an analysis on the soil liquefaction problem that occurs in different infrastructure and significant construction projects, such as earth dams, and found that soil temperature, discharge, soil content, and soil properties play a critical role in affecting the behavior of soil liquefaction problem and this problem can be mitigated by enhancing, promoting, and modifying the soil features and increase its resistance to this severe phenomenon when earthquakes occur.

5. CONCLUSIONS AND RECOMMENDATIONS

5.1 CHAPTER GOAL

This chapter summarizes the major research results and critical study outcomes obtained from the four research approaches adopted in this thesis to collect the necessary data to address beneficial practices and active methods that can support project managers and help chief engineers to build robust and high-performance dams that can resist seismic effects and harmful earthquake events. These four research approaches include the first technique used to collect the secondary data from the literature review. They also contain the three research methods adopted to gather the vital primary data of this work, such as qualitative cross-sectional descriptive study, extrapolation, and numerical simulation using ML principles and intelligent algorithms.

5.2 CONCLUSIONS

This research is carried out to investigate and assess the critical role of soil properties and their content in influencing the soil liquefaction phenomenon that takes place when an earthquake happens. Furthermore, this study is conducted to highlight and address effective practices and active methods that can help project managers and chief engineers construct large-scale dams that have higher stability, mechanical performance, and significant robustness. A case study is taken into account in this work, representing the Karakaya Dam. Four research approaches were implemented to achieve the research goal, including one secondary data collection approach used to identify intelligent and effective construction methods of dams depending on the information existing in the literature review. Also, three research approaches were adopted to collect primary data collection, including extrapolation in Excel, numerical optimization using linear regression, and interviews related to the qualitative cross-sectional study. Datasets were collected of the temperature in three regions (Azami, Ortalama, and Asgari). Besides, the Euphrates River discharge rate database was collected from the Turkish Ministry of Environment and Forestry. Depending on the data analysis using these four research approaches, the extrapolation and numerical optimization findings can be summarized in the following paragraphs:

i. The annual temperature in the future of zones and regions around the Karakaya Dam, including Azami, Ortalama, and Asgari, would witness a moderate increase of about 3 to 6 degrees Celsius next decade.
ii. The Euphrates River discharge rate at the Karakaya Dam would witness a significant increase from (100-350 m^3) to (2,590-2,640 m^3) in 2029, explaining that temperature and discharge rate may influence the occurrence of liquefaction problems.
iii. Soil temperature under the Karakaya Dam and chemical elements would not variate significantly next decade.
iv. The pH number will variate widely from 4.14 to 9.74 in 2029.
v. The most significant chemical molecule concentration in the soil under the Karakaya Dam is the phosphite anion, corresponding to a minimum and maximum concentration of 1 and 2 $\mu g/m^2$, respectively.
vi. Data analysis on earthquakes around the Karakaya Dam was not implemented as earthquake opportunities cannot be numerically predicted.

5.3 RECOMMENDATIONS

According to the results obtained from the four research approaches (containing one of secondary data collection and three of primary data collection processes), this study draws a number of beneficial suggestions and vital recommendations that can help project managers and chief engineers implement modern construction techniques when they build small and large-scale dam projects. These recommendations include the following aspects:

a. To increase the level of awareness and knowledge of engineers and project managers regarding active and practical construction methods related to the dam building.
b. To conduct workshops and educational sessions that can help promote the experience and information regarding active methods and intelligent strategies for building small and large-scale dams.
c. To develop new standards and codes that can help engineers and project managers build dams with higher robustness and mechanical performance to prevent harmful damages and failure of dams.

5.4 FUTURE WORK

This study proposes some critical aspects that are required to follow and implement to enhance the results of this work and improve the effectiveness of the thesis idea regarding active methods and intelligent strategies to build small and large-scale dams with higher robustness. These vital aspects include:

a- To carry out a similar analysis but focus on another case study that represents a Turkish dam with a different scale.

b- To use the principles of Building Information Modeling (BIM) [59]–[62] that have been used recently by different scholars and researchers to monitor and manage the construction of small and large-scale dams reducing the effort, time, cost, and errors related to the project tasks. Also, BIM software tools can be used to assess and examine the earthquake effects on dams with higher rate of accuracy and performance [63], [64].

c- To employ various research approaches, such as a quantitative cross-sectional study with the help of traditional surveys or online survey questionnaires using online and web platforms.

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APPENDIX A

THE INPUT DATABASE USED TO ACHIEVE THE RESEARCH GOALS

Table A.1: The input database used in the research.

Year	Month	Days	Dicharge_M3
1938	Oct	10	250
1938	Oct	20	250
1938	Oct	30	400
1938	Nov	10	600
1938	Nov	20	400
1938	Nov	30	800
1938	Dec	10	1200
1938	Dec	20	400
1938	Dec	30	400
1938	Jan	10	600
1938	Jan	20	400
1938	Jan	30	400
1938	Feb	10	400
1938	Feb	20	400
1938	Feb	30	400

Table A.1: The input database used in the research. “tables continued”

1938	**Mar**	**10**	**400**
1938	**Mar**	**20**	**500**
1938	**Mar**	**30**	**1400**
1938	**Apr**	**10**	**2700**
1938	**Apr**	**20**	**3500**
1938	**Apr**	**30**	**4500**
1938	**May**	**10**	**4400**
1938	**May**	**20**	**2000**
1938	**May**	**30**	**1500**
1938	**Jun**	**10**	**1000**
1938	**Jun**	**20**	**750**
1938	**Jun**	**30**	**600**
1938	**Jul**	**10**	**600**
1938	**Jul**	**20**	**400**
1938	**Jul**	**30**	**300**
1938	**Aug**	**10**	**300**
1938	**Aug**	**20**	**300**
1938	**Aug**	**30**	**300**
1938	**Sep**	**10**	**250**

Table A.1: The input database used in the research. "tables continued"

1938	Sep	20	250
1938	Sep	30	250
1939	Oct	10	300
1939	Oct	20	300
1939	Oct	30	300
1939	Nov	10	700
1939	Nov	20	300
1939	Nov	30	300
1939	Dec	10	400
1939	Dec	20	300
1939	Dec	30	300
1939	Jan	10	500
1939	Jan	20	350
1939	Jan	30	350
1939	Feb	10	600
1939	Feb	20	400
1939	Feb	30	400
1939	Mar	10	400
1939	Mar	20	1200

Table A.1: The input database used in the research. "tables continued"

1939	**Mar**	**30**	**900**
1939	**Apr**	**10**	**1800**
1939	**Apr**	**20**	**1850**
1939	**Apr**	**30**	**3900**
1939	**May**	**10**	**3900**
1939	**May**	**20**	**1750**
1939	**May**	**30**	**1400**
1939	**Jun**	**10**	**900**
1939	**Jun**	**20**	**600**
1939	**Jun**	**30**	**500**
1939	**Jul**	**10**	**500**
1939	**Jul**	**20**	**400**
1939	**Jul**	**30**	**350**
1939	**Aug**	**10**	**300**
1939	**Aug**	**20**	**300**
1939	**Aug**	**30**	**300**
1939	**Sep**	**10**	**250**
1939	**Sep**	**20**	**250**
1939	**Sep**	**30**	**250**

Table A.1: The input database used in the research. “tables continued”

1940	Oct	10	250
1940	Oct	20	250
1940	Oct	30	250
1940	Nov	10	250
1940	Nov	20	300
1940	Nov	30	400
1940	Dec	10	250
1940	Dec	20	400
1940	Dec	30	250
1940	Jan	10	1500
1940	Jan	20	400
1940	Jan	30	400
1940	Feb	10	400
1940	Feb	20	400
1940	Feb	30	1100
1940	Mar	10	500
1940	Mar	20	700
1940	Mar	30	600
1940	Apr	10	4600

Table A.1: The input database used in the research. “tables continued”

1940	**Apr**	**20**	**5100**
1940	**Apr**	**30**	**3400**
1940	**May**	**10**	**2400**
1940	**May**	**20**	**2250**
1940	**May**	**30**	**2100**
1940	**Jun**	**10**	**1400**
1940	**Jun**	**20**	**800**
1940	**Jun**	**30**	**250**
1940	**Jul**	**10**	**600**
1940	**Jul**	**20**	**500**
1940	**Jul**	**30**	**400**
1940	**Aug**	**10**	**250**
1940	**Aug**	**20**	**250**
1940	**Aug**	**30**	**250**
1940	**Sep**	**10**	**250**
1940	**Sep**	**20**	**250**
1940	**Sep**	**30**	**250**
1941	**Oct**	**10**	**250**
1941	**Oct**	**20**	**300**

Table A.1: The input database used in the research. "tables continued"

1941	**Oct**	**30**	**600**
1941	**Nov**	**10**	**400**
1941	**Nov**	**20**	**600**
1941	**Nov**	**30**	**300**
1941	**Dec**	**10**	**600**
1941	**Dec**	**20**	**650**
1941	**Dec**	**30**	**400**
1941	**Jan**	**10**	**400**
1941	**Jan**	**20**	**400**
1941	**Jan**	**30**	**550**
1941	**Feb**	**10**	**400**
1941	**Feb**	**20**	**3250**
1941	**Feb**	**30**	**1500**
1941	**Mar**	**10**	**3900**
1941	**Mar**	**20**	**2500**
1941	**Mar**	**30**	**1000**
1941	**Apr**	**10**	**3000**
1941	**Apr**	**20**	**2300**
1941	**Apr**	**30**	**2550**

Table A.1: The input database used in the research. "tables continued"

1941	**May**	**10**	**2600**
1941	**May**	**20**	**2000**
1941	**May**	**30**	**1500**
1941	**Jun**	**10**	**1000**
1941	**Jun**	**20**	**750**
1941	**Jun**	**30**	**500**
1941	**Jul**	**10**	**500**
1941	**Jul**	**20**	**400**
1941	**Jul**	**30**	**250**
1941	**Aug**	**10**	**250**
1941	**Aug**	**20**	**250**
1941	**Aug**	**30**	**250**
1941	**Sep**	**10**	**250**
1941	**Sep**	**20**	**250**
1941	**Sep**	**30**	**250**
1942	**Oct**	**10**	**250**
1942	**Oct**	**20**	**250**
1942	**Oct**	**30**	**275**
1942	**Nov**	**10**	**250**

Table A.1: The input database used in the research. "tables continued"

1942	**Nov**	**20**	**275**
1942	**Nov**	**30**	**250**
1942	**Dec**	**10**	**250**
1942	**Dec**	**20**	**250**
1942	**Dec**	**30**	**250**
1942	**Jan**	**10**	**300**
1942	**Jan**	**20**	**300**
1942	**Jan**	**30**	**300**
1942	**Feb**	**10**	**250**
1942	**Feb**	**20**	**300**
1942	**Feb**	**30**	**400**
1942	**Mar**	**10**	**650**
1942	**Mar**	**20**	**500**
1942	**Mar**	**30**	**1100**
1942	**Apr**	**10**	**2100**
1942	**Apr**	**20**	**4100**
1942	**Apr**	**30**	**3000**
1942	**May**	**10**	**3200**
1942	**May**	**20**	**3750**

Table A.1: The input database used in the research. "tables continued"

1942	**May**	**30**	**1500**
1942	**Jun**	**10**	**1200**
1942	**Jun**	**20**	**750**
1942	**Jun**	**30**	**500**
1942	**Jul**	**10**	**400**
1942	**Jul**	**20**	**350**
1942	**Jul**	**30**	**300**
1942	**Aug**	**10**	**250**
1942	**Aug**	**20**	**250**
1942	**Aug**	**30**	**250**
1942	**Sep**	**10**	**250**
1942	**Sep**	**20**	**250**
1942	**Sep**	**30**	**250**
1943	**Oct**	**10**	**250**
1943	**Oct**	**20**	**250**
1943	**Oct**	**30**	**350**
1943	**Nov**	**10**	**400**
1943	**Nov**	**20**	**1500**
1943	**Nov**	**30**	**2000**

Table A.1: The input database used in the research. “tables continued”

1943	**Dec**	**10**	**1100**
1943	**Dec**	**20**	**600**
1943	**Dec**	**30**	**350**
1943	**Jan**	**10**	**300**
1943	**Jan**	**20**	**400**
1943	**Jan**	**30**	**300**
1943	**Feb**	**10**	**350**
1943	**Feb**	**20**	**350**
1943	**Feb**	**30**	**350**
1943	**Mar**	**10**	**350**
1943	**Mar**	**20**	**350**
1943	**Mar**	**30**	**600**
1943	**Apr**	**10**	**2500**
1943	**Apr**	**20**	**2500**
1943	**Apr**	**30**	**3250**
1943	**May**	**10**	**3400**
1943	**May**	**20**	**2000**
1943	**May**	**30**	**1250**
1943	**Jun**	**10**	**1000**

Table A.1: The input database used in the research. "tables continued"

1943	**Jun**	**20**	**650**
1943	**Jun**	**30**	**500**
1943	**Jul**	**10**	**500**
1943	**Jul**	**20**	**350**
1943	**Jul**	**30**	**300**
1943	**Aug**	**10**	**250**
1943	**Aug**	**20**	**250**
1943	**Aug**	**30**	**250**
1943	**Sep**	**10**	**250**
1943	**Sep**	**20**	**250**
1943	**Sep**	**30**	**250**
1944	**Oct**	**10**	**250**
1944	**Oct**	**20**	**250**
1944	**Oct**	**30**	**300**
1944	**Nov**	**10**	**500**
1944	**Nov**	**20**	**350**
1944	**Nov**	**30**	**400**
1944	**Dec**	**10**	**350**
1944	**Dec**	**20**	**650**

Table A.1: The input database used in the research. “tables continued”

1944	**Dec**	**30**	**350**
1944	**Jan**	**10**	**250**
1944	**Jan**	**20**	**275**
1944	**Jan**	**30**	**250**
1944	**Feb**	**10**	**375**
1944	**Feb**	**20**	**900**
1944	**Feb**	**30**	**400**
1944	**Mar**	**10**	**900**
1944	**Mar**	**20**	**3000**
1944	**Mar**	**30**	**3200**
1944	**Apr**	**10**	**1400**
1944	**Apr**	**20**	**1000**
1944	**Apr**	**30**	**3000**
1944	**May**	**10**	**6593**
1944	**May**	**20**	**2500**
1944	**May**	**30**	**2000**
1944	**Jun**	**10**	**1250**
1944	**Jun**	**20**	**750**
1944	**Jun**	**30**	**500**

Table A.1: The input database used in the research. “tables continued”

1944	**Jul**	**10**	**500**
1944	**Jul**	**20**	**350**
1944	**Jul**	**30**	**200**
1944	**Aug**	**10**	**250**
1944	**Aug**	**20**	**200**
1944	**Aug**	**30**	**200**
1944	**Sep**	**10**	**200**
1944	**Sep**	**20**	**200**
1944	**Sep**	**30**	**200**
1945	**Oct**	**10**	**250**
1945	**Oct**	**20**	**250**
1945	**Oct**	**30**	**300**
1945	**Nov**	**10**	**500**
1945	**Nov**	**20**	**350**
1945	**Nov**	**30**	**400**
1945	**Dec**	**10**	**350**
1945	**Dec**	**20**	**350**
1945	**Dec**	**30**	**350**
1945	**Jan**	**10**	**375**

Table A.1: The input database used in the research. "tables continued"

1945	**Jan**	**20**	**275**
1945	**Jan**	**30**	**375**
1945	**Feb**	**10**	**375**
1945	**Feb**	**20**	**375**
1945	**Feb**	**30**	**375**
1945	**Mar**	**10**	**400**
1945	**Mar**	**20**	**500**
1945	**Mar**	**30**	**400**
1945	**Apr**	**10**	**1100**
1945	**Apr**	**20**	**2000**
1945	**Apr**	**30**	**2000**
1945	**May**	**10**	**1500**
1945	**May**	**20**	**2000**
1945	**May**	**30**	**1250**
1945	**Jun**	**10**	**1000**
1945	**Jun**	**20**	**650**
1945	**Jun**	**30**	**650**
1945	**Jul**	**10**	**500**
1945	**Jul**	**20**	**350**

Table A.1: The input database used in the research. "tables continued"

1945	**Jul**	**30**	**200**
1945	**Aug**	**10**	**250**
1945	**Aug**	**20**	**200**
1945	**Aug**	**30**	**200**
1945	**Sep**	**10**	**200**
1945	**Sep**	**20**	**200**
1945	**Sep**	**30**	**200**
1963	**Oct**	**10**	**250**
1963	**Oct**	**20**	**250**
1963	**Oct**	**30**	**250**
1963	**Nov**	**10**	**250**
1963	**Nov**	**20**	**250**
1963	**Nov**	**30**	**250**
1963	**Dec**	**10**	**250**
1963	**Dec**	**20**	**1000**
1963	**Dec**	**30**	**900**
1963	**Jan**	**10**	**400**
1963	**Jan**	**20**	**300**
1963	**Jan**	**30**	**600**

Table A.1: The input database used in the research. "tables continued"

1963	**Feb**	**10**	**750**
1963	**Feb**	**20**	**1450**
1963	**Feb**	**30**	**1600**
1963	**Mar**	**10**	**350**
1963	**Mar**	**20**	**1000**
1963	**Mar**	**30**	**800**
1963	**Apr**	**10**	**2500**
1963	**Apr**	**20**	**3450**
1963	**Apr**	**30**	**3700**
1963	**May**	**10**	**2600**
1963	**May**	**20**	**3400**
1963	**May**	**30**	**3600**
1963	**Jun**	**10**	**3200**
1963	**Jun**	**20**	**2000**
1963	**Jun**	**30**	**1000**
1963	**Jul**	**10**	**1000**
1963	**Jul**	**20**	**650**
1963	**Jul**	**30**	**500**
1963	**Aug**	**10**	**500**

Table A.1: The input database used in the research. "tables continued"

1963	**Aug**	**20**	**350**
1963	**Aug**	**30**	**300**
1963	**Sep**	**10**	**300**
1963	**Sep**	**20**	**400**
1963	**Sep**	**30**	**500**
1964	**Oct**	**10**	**350**
1964	**Oct**	**20**	**350**
1964	**Oct**	**30**	**650**
1964	**Nov**	**10**	**600**
1964	**Nov**	**20**	**400**
1964	**Nov**	**30**	**400**
1964	**Dec**	**10**	**450**
1964	**Dec**	**20**	**450**
1964	**Dec**	**30**	**350**
1964	**Jan**	**10**	**350**
1964	**Jan**	**20**	**350**
1964	**Jan**	**30**	**350**
1964	**Feb**	**10**	**350**
1964	**Feb**	**20**	**400**

Table A.1: The input database used in the research. “tables continued”

1964	**Feb**	**30**	**350**
1964	**Mar**	**10**	**400**
1964	**Mar**	**20**	**1500**
1964	**Mar**	**30**	**3500**
1964	**Apr**	**10**	**3400**
1964	**Apr**	**20**	**2000**
1964	**Apr**	**30**	**1500**
1964	**May**	**10**	**2100**
1964	**May**	**20**	**1900**
1964	**May**	**30**	**1600**
1964	**Jun**	**10**	**1250**
1964	**Jun**	**20**	**750**
1964	**Jun**	**30**	**500**
1964	**Jul**	**10**	**500**
1964	**Jul**	**20**	**350**
1964	**Jul**	**30**	**250**
1964	**Aug**	**10**	**250**
1964	**Aug**	**20**	**250**
1964	**Aug**	**30**	**250**

Table A.1: The input database used in the research. "tables continued"

1964	**Sep**	**10**	**250**
1964	**Sep**	**20**	**250**
1964	**Sep**	**30**	**250**
1965	**Oct**	**10**	100
1965	**Oct**	**20**	100
1965	**Oct**	**30**	100
1965	**Nov**	**10**	100
1965	**Nov**	**20**	100
1965	**Nov**	**30**	500
1965	**Dec**	**10**	250
1965	**Dec**	**20**	200
1965	**Dec**	**30**	200
1965	**Jan**	**10**	200
1965	**Jan**	**20**	200
1965	**Jan**	**30**	200
1965	**Feb**	**10**	200
1965	**Feb**	**20**	200
1965	**Feb**	**30**	220
1965	**Mar**	**10**	500

Table A.1: The input database used in the research. "tables continued"

1965	**Mar**	**20**	1100
1965	**Mar**	**30**	500
1965	**Apr**	**10**	1000
1965	**Apr**	**20**	1510
1965	**Apr**	**30**	1000
1965	**May**	**10**	5610
1965	**May**	**20**	6800
1965	**May**	**30**	5800
1965	**Jun**	**10**	2000
1965	**Jun**	**20**	1500
1965	**Jun**	**30**	1000
1965	**Jul**	**10**	700
1965	**Jul**	**20**	500
1965	**Jul**	**30**	450
1965	**Aug**	**10**	300
1965	**Aug**	**20**	200
1965	**Aug**	**30**	200
1965	**Sep**	**10**	150
1965	**Sep**	**20**	100

Table A.1: The input database used in the research. “tables continued”

1965	**Sep**	**30**	100
1966	**Oct**	**10**	200
1966	**Oct**	**20**	250
1966	**Oct**	**30**	300
1966	**Nov**	**10**	400
1966	**Nov**	**20**	500
1966	**Nov**	**30**	250
1966	**Dec**	**10**	500
1966	**Dec**	**20**	400
1966	**Dec**	**30**	1000
1966	**Jan**	**10**	500
1966	**Jan**	**20**	2510
1966	**Jan**	**30**	600
1966	**Feb**	**10**	1000
1966	**Feb**	**20**	900
1966	**Feb**	**30**	1000
1966	**Mar**	**10**	1750
1966	**Mar**	**20**	1300
1966	**Mar**	**30**	1000

Table A.1: The input database used in the research. “tables continued”

1966	**Apr**	**10**	1500
1966	**Apr**	**20**	2000
1966	**Apr**	**30**	2000
1966	**May**	**10**	3800
1966	**May**	**20**	2600
1966	**May**	**30**	2750
1966	**Jun**	**10**	2000
1966	**Jun**	**20**	1650
1966	**Jun**	**30**	1500
1966	**Jul**	**10**	750
1966	**Jul**	**20**	500
1966	**Jul**	**30**	400
1966	**Aug**	**10**	300
1966	**Aug**	**20**	210
1966	**Aug**	**30**	210
1966	**Sep**	**10**	210
1966	**Sep**	**20**	210
1966	**Sep**	**30**	210
1967	**Oct**	**10**	250

Table A.1: The input database used in the research. "tables continued"

1967	**Oct**	**20**	250
1967	**Oct**	**30**	250
1967	**Nov**	**10**	400
1967	**Nov**	**20**	550
1967	**Nov**	**30**	400
1967	**Dec**	**10**	350
1967	**Dec**	**20**	400
1967	**Dec**	**30**	550
1967	**Jan**	**10**	450
1967	**Jan**	**20**	350
1967	**Jan**	**30**	600
1967	**Feb**	**10**	400
1967	**Feb**	**20**	400
1967	**Feb**	**30**	810
1967	**Mar**	**10**	500
1967	**Mar**	**20**	1000
1967	**Mar**	**30**	1200
1967	**Apr**	**10**	5000
1967	**Apr**	**20**	4900

Table A.1: The input database used in the research. "tables continued"

1967	**Apr**	**30**	4000
1967	**May**	**10**	4300
1967	**May**	**20**	1750
1967	**May**	**30**	3000
1967	**Jun**	**10**	2800
1967	**Jun**	**20**	2000
1967	**Jun**	**30**	1600
1967	**Jul**	**10**	4900
1967	**Jul**	**20**	750
1967	**Jul**	**30**	500
1967	**Aug**	**10**	800
1967	**Aug**	**20**	400
1967	**Aug**	**30**	350
1967	**Sep**	**10**	350
1967	**Sep**	**20**	350
1967	**Sep**	**30**	350
1968	**Oct**	**10**	252
1968	**Oct**	**20**	510
1968	**Oct**	**30**	400

Table A.1: The input database used in the research. "tables continued"

1968	**Nov**	**10**	560
1968	**Nov**	**20**	500
1968	**Nov**	**30**	1100
1968	**Dec**	**10**	500
1968	**Dec**	**20**	500
1968	**Dec**	**30**	1000
1968	**Jan**	**10**	1000
1968	**Jan**	**20**	570
1968	**Jan**	**30**	400
1968	**Feb**	**10**	400
1968	**Feb**	**20**	600
1968	**Feb**	**30**	1500
1968	**Mar**	**10**	1200
1968	**Mar**	**20**	2750
1968	**Mar**	**30**	1250
1968	**Apr**	**10**	1500
1968	**Apr**	**20**	2500
1968	**Apr**	**30**	6650
1968	**May**	**10**	2000

Table A.1: The input database used in the research. "tables continued"

1968	**May**	**20**	3800
1968	**May**	**30**	3900
1968	**Jun**	**10**	2400
1968	**Jun**	**20**	2000
1968	**Jun**	**30**	1700
1968	**Jul**	**10**	1250
1968	**Jul**	**20**	1000
1968	**Jul**	**30**	560
1968	**Aug**	**10**	500
1968	**Aug**	**20**	400
1968	**Aug**	**30**	400
1968	**Sep**	**10**	250
1968	**Sep**	**20**	250
1968	**Sep**	**30**	250
1969	**Oct**	**10**	350
1969	**Oct**	**20**	350
1969	**Oct**	**30**	400
1969	**Nov**	**10**	400
1969	**Nov**	**20**	500

Table A.1: The input database used in the research. "tables continued"

1969	**Nov**	**30**	450
1969	**Dec**	**10**	2100
1969	**Dec**	**20**	2500
1969	**Dec**	**30**	4810
1969	**Jan**	**10**	3000
1969	**Jan**	**20**	4750
1969	**Jan**	**30**	4000
1969	**Feb**	**10**	4600
1969	**Feb**	**20**	3500
1969	**Feb**	**30**	2500
1969	**Mar**	**10**	1800
1969	**Mar**	**20**	1000
1969	**Mar**	**30**	2100
1969	**Apr**	**10**	1700
1969	**Apr**	**20**	3000
1969	**Apr**	**30**	4550
1969	**May**	**10**	3000
1969	**May**	**20**	4900
1969	**May**	**30**	4000

Table A.1: The input database used in the research. "tables continued"

1969	**Jun**	**10**	4600
1969	**Jun**	**20**	3000
1969	**Jun**	**30**	2500
1969	**Jul**	**10**	1000
1969	**Jul**	**20**	700
1969	**Jul**	**30**	500
1969	**Aug**	**10**	300
1969	**Aug**	**20**	250
1969	**Aug**	**30**	250
1969	**Sep**	**10**	250
1969	**Sep**	**20**	250
1969	**Sep**	**30**	250