CASE STUDIES OF ENVIRONMENTAL IMPACTS OF SAND MINING AND GRAVEL EXTRACTION FOR URBAN DEVELOPMENT IN GABORONE

by

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DECLARATION

STUDENT NUMBER: 5066-598-7

I hereby declare that the study on ‘CASE STUDIES OF ENVIRONMENTAL IMPACTS OF SAND MINING AND GRAVEL EXTRACTION FOR URBAN DEVELOPMENT IN GABORONE’ is my own research work and that all sources that I have used are indicated and acknowledged by means of complete references.

SIGNATURE: ……………………………………………………………………

TARIRO MADYISE (MRS)

DATE: ………………………………………………………………………

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DEDICATION

This research is dedicated to my father, Mr Joseph Beka Ndanga for paying for my education, in remembrance of my late mother, Mrs Sophia Ndanga, all the Ndanga and Madyise families for their unwavering support throughout the study.

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ABSTRACT

Economic development is one of the main objectives of developed and developing nations worldwide. Development comes with growth of urban areas. Urban growth is achieved through sand and gravel mining for construction of modern, attractive and durable structures. The study examined positive and negative environmental impacts of the continuous removal of river sand, pit sand and gravel from sampled rivers and open areas surrounding Gaborone developing Central Business District, malls and private properties in city.

Quantitative and qualitative research designs that is questionnaire survey, oral interviews, field observation and measurements were used to collect data from selected sampled points. Metsimotlhabe and Ditlhakane rivers were selected because they are nearer to Gaborone and most river sand is mined from these rivers. More points were sampled from open areas in Kumakwane, Kopong and Bela Bela farms where pit sand and gravel are mined. Convenience and purposive sampling methods were used to pick questionnaire survey respondents (175) from Kumakwane and Metsimotlhabe villages where people affected lives.

Findings of the study highlighted that river sand was mined most from rivers near Gaborone compared to pit sand and gravel because of its multi uses. Mining is important for economic development, to construct durable, modern structures, employment creation and revenue collection but removal of river sand leads to deepening and widening of rivers. Artificial rivulets are formed as resource is extracted uncontrollably. Pit sand and gravel are extracted from open areas creating uncovered deep pits, which caused of accidents to children and livestock. Erosion and environmental degradation occur due to continuous mining. Miners dispose waste on open areas and riverbeds causing land pollution. Dust and noise pollution from tipper trucks ferrying sand and gravel are a cause of concern to villagers as the trucks move even at night, disturbing sleep.

Solutions to uncontrolled mining include 24 hour security and regular raids on illegal miners. The author recommends that heavy penalties should be imposed to curb illegal mining. High level decision making forum involving all stakeholders is necessary to discuss problems of illegal mining and how to limit negative impacts. Department of Mines need to develop an Environmental Management Plan and a close monitoring program nationwide.

TABLE OF CONTENTS

CHAPTER FIVE: SOLUTIONS, CONCLUSION AND RECOMMENDATIONS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

LIST OF ACRONYMS AND ABBREVIATIONS

AIDS	Acquired Immune Deficiency Syndrome
Al	Aluminium atom
CAES	College of Agriculture and Environmental Sciences
CBD	Central Business District
CSO	Central Statistical Office
Cu	Copper atom
DO	Dissolved Oxygen
DOE	Department of Environment
EIA	Environmental Impact Assessment
EMA	Environmental Management Authority
EMP	Environmental Management Plan
Fe	Iron atom
GDP	Gross Domestic Product
HIV	Human Immune-deficiency Virus
NCS	National Conservation Strategy
NEMA	National Environment Management Authority
NMFS	National Marine Fisheries Authority
SPSS	Statistical Package for Social Sciences
SO	Sulphur and Oxygen molecule
UNCED	United Nations Conference on Environment and Development
USA	United States of America
VDC	Village Development Committee

CHAPTER ONE: INTRODUCTION AND BACKGROUND

1.1 Introduction

Soil is a cheap natural resource made up of gravel, sand, clay, loam which constitutes the different types. Pit sand, river sand and gravel are components of soil which take years to be formed but extracted in a matter of days. Sand and gravel are underground geological resources formed from eroding mountain rocks carried by streams and rivers. According to Mwangi (2007), soil has many uses, it is needed for agriculture, as a habitat and in construction but the genesis of cash economy brought many profit driven companies to be involved in its mining both legally and illegally with some having no regard for the environment. Soil mining and harvesting has both positive and negative environmental impacts.

Stebbins (2006) gave the background to formation of sand and gravel deposits, a legacy of the continental ice sheets that melted thousands of years ago. As the ice melted, fast moving rivers were formed leaving deposits of coarse sand. The rivers ran into the sea, large deltas were formed with layers of sand and silt. Now there is no more ice and rivers but scattered deposits of sand and gravel which are used as important natural resources. Sand and gravel deposits are porous, water can pass through this geological material, making it a source of high quality water (Stebbins, 2006).

Draggan (2008) discussed sand and gravel as commodities used in industry especially construction. In construction, the components are used either mixed with other materials or as is, while in industry, sand and gravel are used in production of other materials like aggregates. Sand mostly quartz grains (Silicon dioxide) formed from weathering of granite rocks. The quartz grains accumulated in rivers, streams, deltas and beaches. Therefore, quartz is very valuable as sand because of its silica content. The physical properties of sand and gravel particularly in abrasive property make the resources useful for traction on icy roads, roadways and rail road including sand blasting (Draggan, 2008)..

According to Draggan (2008), sand and gravel are crucial resources to economic development activities in developed and developing nations. Recovery from river channels, flood plains and glacial deposits as well as processing of these resources is costly but valuable in construction and industry (Draggan, 2008). Development is a process of gradually becoming bigger, better, more advanced in business, trade and industrial activities. Growth of towns and cities demands much more infrastructure and construction of strong structures such as tarred roads, commercial shopping malls and accommodation for the ever increasing population. As urban areas develop, there is likely to be a disturbance of the environment. United Nations Conference on Environment and Development Report (2002) supported proper use of the environment and urged governments to develop but recognising conservation and rehabilitation of all natural resources. The report revealed that over extraction of soil for urban development is an environmental problem common worldwide. The use of soil as a source of raw materials is depleting the resource and has adverse impacts.

Impacts of sand mining and gravel extraction can be classified into three categories as presented by Stebbins (2006). There are physical impacts which are a result of mining from streambed causing alteration of channel slope and changes in channel morphology. Water quality impacts are caused by sand mining and dredging activities, reducing water quality for downstream users and increase treatment costs. Ecological impacts such as loss of habitats and species disturbance are a result of mining gravel and sand continuously leading to removal of channel substrate, suspension of sediments and clearance of vegetation.

As a worldwide economic activity, pit and river sand mining and gravel extraction has both positive and negative impacts to the environment. Schaetzl (1990) noted that in United States of America, many states like California and Michigan rely on mining of pit sand and gravel for road and cement aggregates. He further wrote that many prime sources (glacial deposits) of sand and gravel have been exhausted, and now covered by housing developments and farmland. The once abundant supply of sand and gravel is rapidly diminishing. In USA, sand and gravel are used for construction of industries in cities, paving, highway building, brick moulding and even making golf courses. Many states are well developed with advanced infrastructure which is a positive effect of soil mining. However, excessive extraction of soil lead to excavation, destruction of ecosystems and exposure of buried pipelines. Bagchi (2010) exposed illegal sand mining going on in India, mostly done on rivers. The environmental impacts noted were changes in fluvial morphology, deep tunnels on river beds and increase in velocity of flowing water resulting in erosion on river banks. In some cases there is depletion of water resources leading to food shortages and hardships for people.

Lawal (2011) discussed sand mining in Nigeria and highlighted that the activity is rapidly becoming an ecological problem as demand for gravel and sand increases. The resources are used in construction of strong structures which improves the socio economic lives of most Nigerians though with notable negative environmental impacts. According to Mwangi (2007) the rate of soil mining in Kenya is so alarming that the government had to draft the National Environment Management Authority (NEMA), a policy to apply to all mining activities. This policy was put in place to ensure proper and sustainable mining of soil. Mwangi (2007) spelled out the creation of employment in Kenya particularly to people living near the mining areas as a positive impact. Hill and Kleyhans (1999) realised that soil mining is done and important in South Africa for construction purposes but processes involved have great potential in disrupting the natural environment. They noted that excessive soil mining cause adverse impacts to biota and their habitats. Extraction near streambed damage vegetation and aquatic ecosystems.

Mbaiwa (2008) noted that the Botswana Ministry of Lands and Housing has acquired approximately six thousand hectares of tribal land on western outskirts of Gaborone for expansion of the city which will benefit nearby areas. There is need for soil mining in form of pit sand, river sand and extraction of gravel for commercial and residential foundations, driveways, walkways, patios and all other infrastructural construction. This leads to development of advanced infrastructure and creation of employment.

Mines and Minerals Act (1999) highlighted that the Botswana depends on mining of minerals but there is also mining of river sand, pit sand and gravel done both legally and illegally. For thousands of years, various soil components had been used for construction of roads and buildings. Demand for soil in the country has increased today which has led to the excessive stream and land extraction of pit sand, river sand and gravel causing land degradation, riverbank deepening and loss of ecosystems (Mbaiwa, 2008). An article in the Daily News (2011) reported a case involving residents of Metsimotlhabe, a village about fifteen kilometres Northwest of Gaborone who were up in arms due to continuous extraction of sand from the nearby river. They complained of deep pits left on bare land, air and noise pollution caused by tipper trucks transporting soil to Gaborone. The article noted that a lot of land is required for mining the abundant resource. As more impacts are felt, there is need for immediate environmental control and restoration. Soil mining is an environmental issue worldwide. There is need to consider sustainable use of natural resources in project development through sound sand and gravel extraction. The activity is of great concern to environmentalists as it has more negative impacts than positive.

1.2 Need for research/ justification

Soil is an important resource covering the land surface. Mining is the process of getting minerals and soil components for various uses. Human community depend on soil for agriculture, construction and even as a habitat for various organisms (Mwangi, 2007). People benefit from soil particularly sand and gravel but interfere and disturb the resource through excessive exploitation to fulfil their needs. There is worldwide concern about the environment which prompted the researcher to carry out this study on the environment. It seems there is excessive mining of soil components for construction in both rural and urban development. Gravel is mixed with river sand in filling and compacting foundations, river sand is a component of concrete in making slab while pit sand is required for plastering buildings. River sand is used in most mixtures because it is a strong resource which strengthens even pit sand in plastering and makes durable bricks.

The research was meant to obtain increased understanding of the potential positive and negative impacts of sand mining and gravel extraction in stream, bare fields and riparian habitats. The study concentrated on exposing the environmental impacts of mining pit sand, river sand and gravel extraction for Gaborone City expansion from surrounding areas which included Kumakwane, Bela Bela farms, Metsimotlhabe, and Kopong. The researcher found it necessary to carry out a study on finding the environmental impacts of soil extraction, both positive and negative, in pursuit of knowledge and for public good. The outcomes of the research are valuable solutions to rehabilitation of land where soil is extracted and mitigation of negative effects. This research was also meant to provide guidelines for evaluation of potential positive and negative environmental impacts. Recommendations had been made on sustainable use of the environment while supporting the positive impacts. Alternatives to sand had been suggested.

1.3 Statement of the problem

Gaborone is expanding at an alarming rate. Expansion means growth in infrastructure, construction of new roads, commercial malls and residential areas (Wokorach, 2002). There is need for use of various soil components such as pit sand, river sand and gravel from various sites surrounding the city. People seem to be extracting these soil components excessively without considering the impact on the environment. Most likely, there is overexploitation of soil leaving deep pits on bare ground while rivers are widening daily. Soil mining has become a daily sight with tipper trucks carrying pit sand, river sand and gravel from rivers and open fields. It seems there are no strict rules to govern soil extraction. Deep and wide pits are left when pit sand and gravel are collected, riverbeds widen and deepen after removing river sand, affecting aquatic while gravel removal destroy ecosystems, forests and agricultural land (Mbaiwa, 2008). Pit sand organisms is collected from Kumakwane, river sand is from Metsimotlhabe and Ditlhakane rivers while gravel is extracted from Kumakwane, Kopong and Bela Bela farms. There seemed to be a problem of environmental alteration, ecosystem and agricultural land destruction as well as riverbed and bank degradation due to excessive removal of pit sand, river sand and gravel which prompted the researcher to investigate the depth of these environmental impacts.

1.4 Research goal

To assess and evaluate environmental impacts of mining pit sand, river sand and gravel extraction for urban development in the expansion of Gaborone City

1.5 Specific objectives

- To assess and compare the soil component mined most for construction.
- To measure and analyse the size of pits where pit sand and gravel are collected.
- To assess, measure and evaluate the width and depth of rivers at sampled extraction points.
- To evaluate the positive and negative environmental impacts of mining river sand, pit sand and gravel for urban development.
- To make recommendations on sustainable mining of soil which reduce negative impacts on the environment.

1.6 Research questions

- Which soil component is mined most?
- Which method of loading trucks is commonly used for each component?
- What are the positive environmental impacts?
- Which are the negative environmental impacts?
- What recommendations can be given to reduce the negative impacts?

1.7 Study area and context

1.7.1 Introduction

Gaborone is the capital city of Botswana situated on the boundary and the boarder with South Africa. It is in the South East region surrounded by Kweneng District to the West, Kgatleng to the North and Southern District to the South West. The surrounding areas are the sources of sand and gravel for construction. Pit sand for plastering is mined from Kumakwane, a village about twenty five kilometres from the city centre with a population of three thousand, one hundred and thirty nine people (CSO, 2012). River sand is from nearby Metsimotlhabe river which is the main source and tributaries like Ditlhakane in Kweneng District. The rivers contain a lot of sand which is being exploited. Gravel is extracted from Kopong, a village with a population of five thousand, five hundred and seventy one people (CSO, 2012) in Kweneng thirty kilometres North West of Gaborone. More gravel is from Bela Bela farms in Kgatleng, ten kilometres East of Gaborone and Kumakwane lands.

1.7.2 Maps of study area

Kumakwane and Metsimotlhabe maps below show the villages in relation to sampled points were pit sand, river sand and gravel are mined for construction industry in Gaborone. All the sampled points where pit sand is extracted are shown on Kumakwane map, Figure 1.1. River sand Site A and B were in Ditlhakane river shown on the same map while gravel Site D is also included. Metsimotlhabe map on Figure 1.2 shows location of village in relation to Metsimotlhabe river where river sand Site A and B collection points were sampled from. The map also shows the direction to Kopong village where there is gravel sampled point Site B and direction to Bela Bela farms where sampled Site C is located.

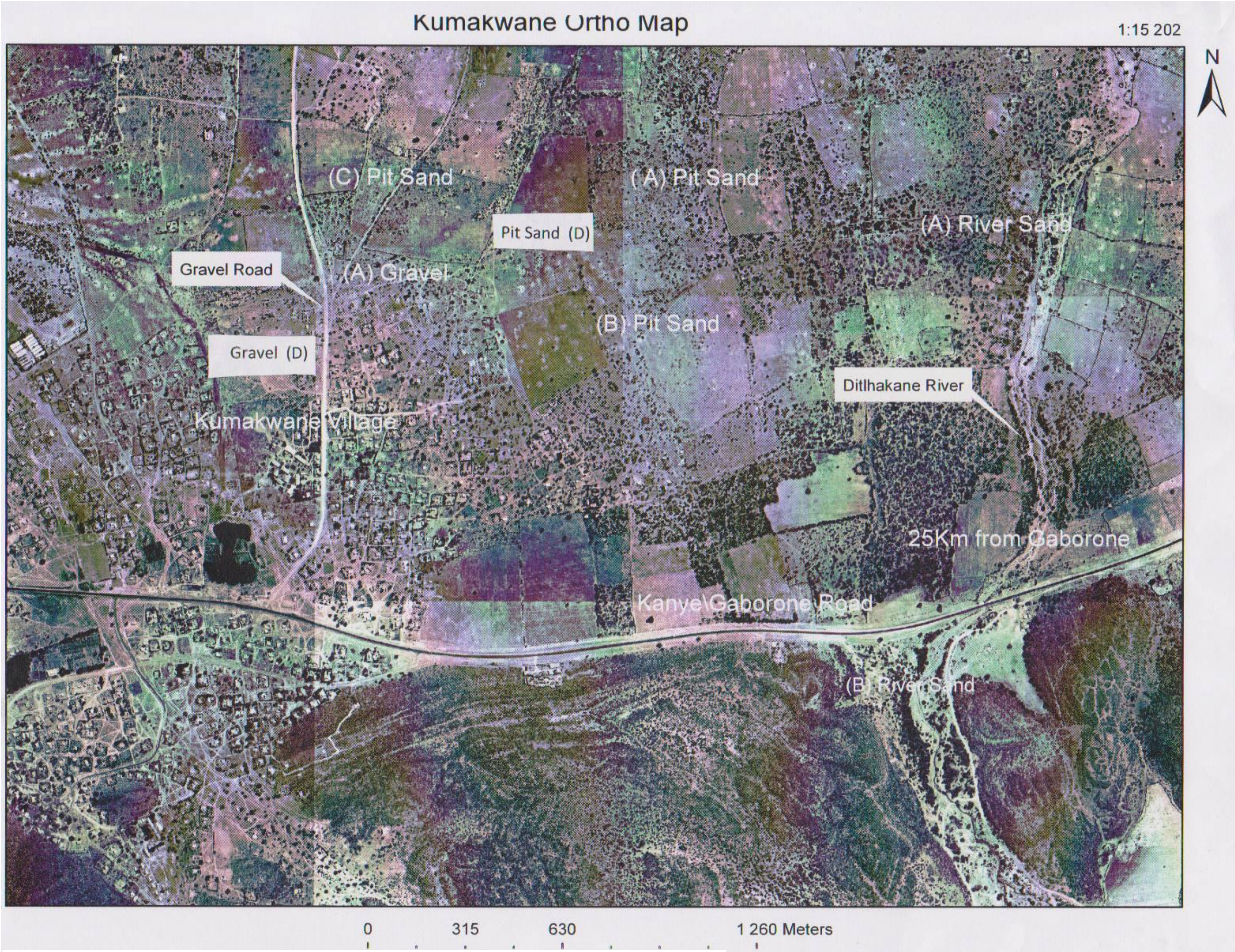


Figure 1.1: Map of Kumakwane showing sampled areas

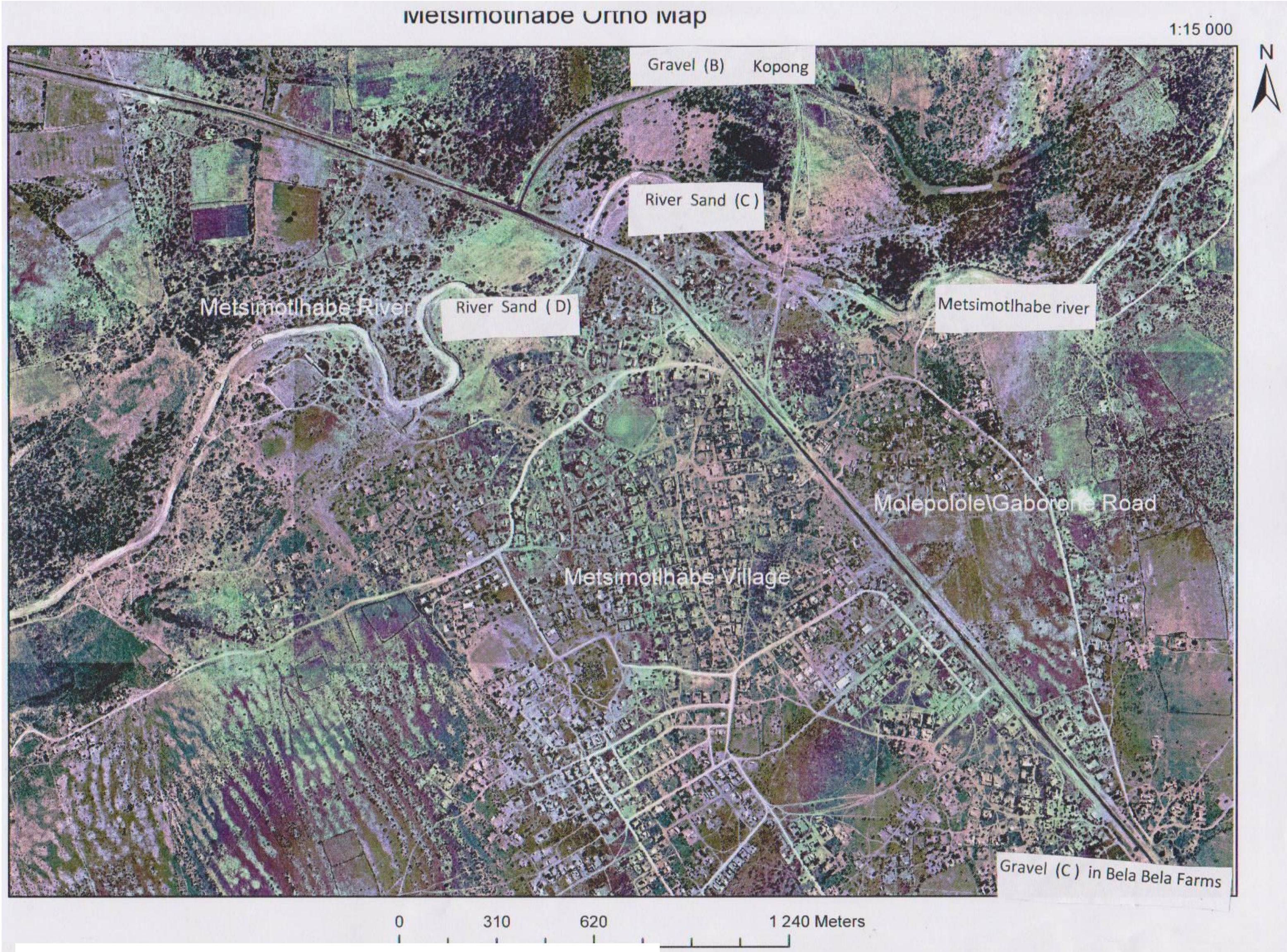


Figure 1.2: Metsimotlhabe Map showing sampled points

1.7.3 Topography, climate and soils

Botswana is a developing nation in a semi-arid region. The land surface for Gaborone and surrounding areas is generally flat with no significant topographic gradients. The area generally experiences high temperatures in summer exceeding forty degrees Celsius while winters are extremely cold with temperatures up to -2 degrees Celsius (The Meteorological Department, 2011). Rainfall is scarce and seasonal. The rainy season usually starts in November ending March. Unreliable and inter-annual variability of rainfall is large which cause significant risks to water supply and agriculture in the region. Sand mining and gravel extraction is done throughout the year. There is increased soil mining even during the rainy season because the ground will be dry and rivers almost empty. The southern region consisting of Kweneng, and Kgatleng Districts are most affected by this activity because they are generally dominated by abundant fine and coarse sand with good drainage.

1.7.4 Economy

Majority of population in Kweneng and Kgatleng districts surrounding Gaborone are involved in subsistence farming growing drought resistant crops like sorghum, water melons and sweet reeds and rearing of livestock, significantly for beef production. Wokorach (2002) noted that Gaborone population is in formal employment in the public service, retailing and wholesaling. There is a lot of expansion in Gaborone as the government, private sector and individuals undertake various developmental activities in construction of malls and residential areas (Wokorach, 2002). The construction industry is working day and night to keep up with the pace. Both licensed and unlicensed companies are involved in extraction of sand and gravel from surrounding areas supplying the private and government contractors.

1.8 Limitations

The author faced challenges during the study which limited accuracy of results. Few villagers formed the sample to represent the populations due to shortages of human resources. Only 175 respondents formed a sample which participated in the survey. One hundred and five respondents were picked from Kumakwane while seventy were Metsimotlhabe villagers. Some participants were not cooperative and unwilling to answer questions truthfully or left some questions unanswered leading to misrepresentation and inaccurate results. Seven questionnaires were incompleted at collection time so were discarded and not considered for data analysis. Four respondents misplaced their questionnaires so did not return and be considered for data analysis. Therefore, only 164 respondents were considered for data analysis.

Another limiting factor was that the researcher is employed so time to collect data from affected areas was not enough therefore data collection was mostly done during the weekends. Mining sites are in dangerous bushy areas, researcher, could not go alone, so had to be accompanied by local police officers on each visit. This reduced the number of visits as the officers were sometimes too busy to accompany the researcher. Native language for Botswana is Setswana but the researcher is Shona speaking. Language barrier was a limiting factor in collection of accurate results since most villagers are not fluent in English Language used on questionnaires and interview guides. Ther had to translate some questionnaires into Setswana because during most visits to subjects, interpreters were busy with other duties.

1.9 Summary

The chapter introduced the research on finding environmental impacts of sand and gravel mining for urban development in Gaborone. Main and specific objectives for the research were listed. The researcher justified the need for the carrying out the study and stated the problem. Map of study area was included and description of collection sites. The researcher consulted other researchers' reviews and read documents and researches related to the topic and compiled a comprehensive literature review in chapter two.

CHAPTER TWO: REVIEW OF RELATED LITERATURE

2.1 Introduction

Soil is an important source of raw materials such as clay, sand, gravel and minerals. It is a non-renewable natural resource with potentially rapid degradation rates and extremely slow formation and regeneration processes (Mwangi, 2007). Sand is a cheap and heavy resource consisting of very small pieces of rocks and minerals, a result of weathering that forms beaches and deserts. Gravel is a heavy and cheap commodity made of small weathered stones used to make surface for paths and roads. The resource's compressibility, plasticity and textural properties have been valued in construction for hundreds of years. The ability of soil to be moulded and its cohesion properties were the basis for using it to build the earliest houses (Goddard, 2007). Saviour (2012) defined soil as a mineral which protect the environment, buffer to strong tidal waves and storms, habitat for crustacean species and marine organisms. The mining of pit sand and gravel can be done on open areas, beaches, inland dunes, mountain sides while river sand is extracted from riverbeds and banks. Unscientific mining has led to degradation accompanied by subsistence and consequential mine fires, severe ecological imbalance around mining areas (Saviour, 2012). The practice is becoming an environmental issue as the demand for sand as an important mineral resource is increasing in the construction industry.

Goddard (2007) realised that decisions on where to mine, how much and how often requires definition of reference state and sand budget. Reference state is the minimal acceptable physical and biological condition of a channel (Goddard, 2007). Though reference state is difficult to determine, a general knowledge of fluvial processes is necessary to minimise detrimental effects of mining. A sand budget for a particular extraction area for example a stream or open area should be done to first determine the amount of sand that can be removed without causing degradation and erosion. Before doing a sand budget, consider mining methods to be used, particle size, characteristics of the sand, riparian vegetation and magnitude as well as frequency of hydrologic events after disturbance.

Therefore minimisation of the negative effects of sand and gravel mining requires a detailed understanding of the response of site to these disturbances (Goddard, 2007).

Hill and Kleynhans (1999) discussed various methods of mining sand and gravel. Dry pit mining is a method used when sand is extracted above water table from a dry stream bed and exposed bars using conventional bulldozers, scrapers and loaders. Wet pit mining involves extraction of sand and gravel from below water table stream channel or a perennial river using hydraulic excavator or dragline. Dewatering can be done in advance to allow easy excavation though this depends on deposit thickness, permeability of the ground as well as after use and restoration requirements. Bar skimming or scalping is a method used when only the top layer of soil is removed by scraping without excavating below summer water table which is the level of underground water in summer season (Hill and Kleynhans, 1999).

2.2 Sand mining and gravel extraction in the world

Sand mining and gravel extraction are a worldwide activity in both developed and developing countries as was realised by Draggan (2008). Industrial sand and gravel are produced, processed and used in construction and industry all over the world. The leading nations in mining and processing sand and gravel are United States of America, Australia, Austria, Belgium, Brazil, India, Spain, Nigeria, Kenya and South Africa. As a cheap and readily accessible resource many companies are involved in its mining both legally and illegally without considering the damage they are causing to the environment (Draggan, 2008).

Soil mining and gravel extraction is a common activity in United States of America. A publication by Schaetzl (1990) showed that historically, from 1920s many states in USA relied on mining of gravel and sand for road and cement aggregate. The uses had doubled by 2008 to date. Sand and gravel are mined more than all other minerals in most States in America. According to Draggan (2008), USA is the largest producer and consumer of sand and gravel in the world as well as the leading exporter of silica sand to every region of the world. This is because it has extensive high quality deposits of the resource combined with technology to process it into any product. Construction sand and gravel are produced in all fifty states. The highest producers are California, Texas, Michigan, Minnesota, Ohio, Arizona, Utah, Colorado and Washington. They all produce about 52% of total amount of construction sand and gravel. More than a billion tonnes of sand and gravel are produced and used annually. Due to high demand in these States, some sand and gravel are still imported from Canada, Mexico, Bahamas, and Australia (Draggan, 2008).

Schaetzl (1990) realised that in California and Michigan, many prime sources of sand and gravel are glacial deposits, eskers, deltaic deposits and old lake beds. These states have an abundant of sand and gravel which are well distributed. Many minerals are mined but sand and gravel are extracted most. Sand and gravel have been exhausted, and the area is now covered by housing developments and farmland. Schaetzl (1990) further noted that river sand, pit sand and gravel are mined around large expanding urban areas. The most urbanised and largest states have greatest areas of sand and gravel pits. The chart below shows that about 58000 acres of land is used to mine sand and gravel which is more compared to all other minerals mined (Figure 2.1).

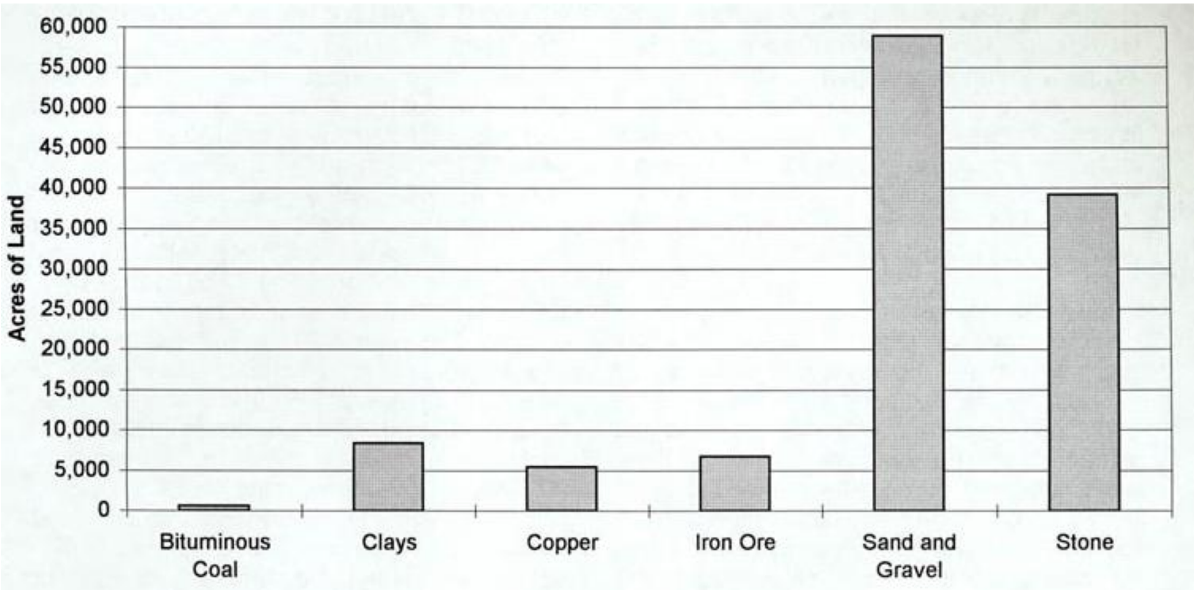


Figure 2.1: Land covered by mining pits in Michigan (Schaetzl, 1990)

Stebbins (2006) highlighted that in State of Maine, sand and gravel deposits cover up to five percent of the land. The resources are mainly used in construction and pumping drinking water which had increased demand so there are many sand and gravel pits. Approximately two hundred and sixty acres of land is used for mining by both companies with and without licences. Construction grade sand and gravel has high volume, hence the resources cannot be transported over long distance. Large trucks are used as transport for up forty eight kilometres, therefore most pits are near the consumer as these bulky commodities normally cannot economically stand costs of long distance transportation. Most mining is done near the consumer in USA. The once abundant supply of gravel and sand is rapidly diminishing in areas surrounding cities (Stebbins, 2006).

Schaetzl (1990) noted that there are four basic operations used to extract sand and gravel from open pit mines in USA. The operations include site clearing to remove vegetation, then mining, processing and finally reclamation of the mined area. Machinery commonly used for mining includes bulldozers, tractor scrapers, front end loaders and stone crushers. The mining is done almost twenty four hours in order to keep up with the high demand internally and externally for sand and gravel (Schaetzl,1990).

According to Goddard (2007) soil mining operations began in 1930s in Australia to supply the expanding Sydney building market and continued into 1990s with an estimate of seventy million tonnes of sand removed. Most important commercial sources of sand and gravel are river floods, river channels and glacial deposits. Goddard (2007) further noted that soil extraction and processing have significant impacts on scenic landscapes. Excessive extraction intensifies coastal and exposed hillside erosion, causing accumulation of seawater upstream of rivers, leaving the coasts more vulnerable to extreme weather conditions. Soil mining contributes to construction of buildings and development but can cause permanent loss of soil as well as major habitat destruction (Goddard, 2007).

Kuttipuran (2006) reviewed soil mining in Indian communities and explained that as urban areas grow, less wood is used with more concrete structures being required leading to demand for low cost sand. Sand and gravel are most accessible cheap and basic raw materials for construction industry in India. There is a business of indiscriminate sand mining in public spaces in India. Soil mining is an environmental issue in India and public awareness of illegal extraction in states of Maharashtra and Goa is going on (Pereira, 2012). Bagchi (2010) supported Kuttipuran (2006) on that construction boom fuelled the demand for sand and gravel facilitating uncontrolled extraction which threatens existence of river systems. Illegal mining of minerals resources is rampant in India such that the country's natural resources are destroyed as forests are clean felled.

Pereira (2012) researched on sand mining in India by studying three villages in Maharashtra and realised that as global demand for sand is exploding and rising rapidly, the sources of sand and gravel such as riverbeds, beaches, creeks are being mined faster than nature can replenish. This creates a highly skewed supply-demand situation. Pereira noted that India has the third largest construction business in the world after USA and China, so sand and gravel are required in large quantities. Mining is done both legally and illegally. The country did not have a regulatory and monitoring framework for excavation of sand sustainably which increased the illegal mining rampantly. There had never been much control because people thought that the resources are low value minor minerals and inexhaustible. This has led the Mumbai High Court to issue a ban on sand mining in 2010 to all licensed and unlicensed miners who were damaging the riverbeds increasing threat of floods. Demand and prices of sand had increased from US$ 110 to 300 US$ per truck load (Pereira, 2012).

Saviour (2012) discussed direct and indirect impacts of mining to the environment in Kerala region of India. The activity has increased since 1990s due to the boom of construction industry. River Bharathapuzha has become a victim of indiscriminate sand mining which has lowered the water table and reduced rice harvest. Illegal mining is high in Papagani catchment area in Karnataka.

According to Kuttipuran (2006), illegal mining is rampant in the Central Province of Madhya Pradesh with contractors emptying river beds of Narmada, Chambal and Wainganga. In the Southern Province of Kerala, miners loot soil from the second longest Bharathapuzha river and third river Pamba, which have become victims of indiscriminate sand mining. In India, soil mining is regulated by law but is still done illegally. Illegal sand mining is rampant on banks of Painganga river creating hundred by fifty feet tunnels across agricultural land. Bagchi (2010) further noted that the state government exempted mining of sand through Minor Minerals Rules of 1996 but this increased illegal extraction of sand. Many leases were issued by the Indian Mining Cooperation of Madhya Pradesh to excavate sand from state land, disregarding environmental regulations.

Bagchi (2010) reported on how the communities view sand mining and gravel extraction. Generally communities in Palakkad and Goa expressed dissatisfaction with the uncontrolled illegal mining. The miners created one hundred feet long by fifty feet deep tunnels across their farmland as well as creating deep pits through crop fields. According to villagers' reports, approximately eighty trucks were seen passing through villages on daily basis. Their reports to authorities seemed not to be heard.

2.3 Sand and gravel mining in Africa

There is a great concern on the way the environment is disturbed by excessive removal of soil for construction industry especially in urban development in Africa. Mwangi (2008) noted that for thousands of years, sand and gravel had been used to construct strong houses, roads and dams in Africa since they are cheap and readily accessible resources. Today demand has increased as socio-economic life of Africans has improved generally. Sand mining and gravel extraction are common in most African states but done both legally and illegally.

Lawal (2011) examined sand and gravel mining activities both on land and in rivers as a business venture in Minna Emirate Council of Niger State. Stakeholders from the mining activities were listed as landowners of quarry sites who sold the sand and gravel to private and government contractors. Local government authorities and Niger State where quarries are located, were also listed as beneficiaries. The activities also involve farmers whose cultivating and grazing lands are destroyed, wildlife community whose habitats are mined areas, aquatic community members as well as miners themselves. Aromolaran (2012) carried out a study to examine effects of sand mining activities on rural people living on agricultural land in Ogun State, Nigeria. Many people supported the good uses of sand but the negative impacts on their land were more than the benefits. Lawal (2011) highlighted that sand mining is rapidly becoming an ecological problem as demand increases in many states of Nigeria's industry and construction sectors. The mining is done both legally and illegally leading to environmental devaluation.

Mwangi (2007) discussed soil mining as a threat to the environment in Kenya though with both positive and negative impacts. The sand mining and gravel extraction are done legally and illegally on rivers, beaches and plain fields. Wachira (2009) supported Mwangi by reporting on a case study survey on sand mining in Machakos District of Kenya which is increasing due to the need for soil in construction industry. The survey showed that approximately two hundred thousand tonnes of soil are harvested and mined for construction every year. Streams around Machakos and Mwala Districts are seriously damaged as trucks transporting soil pass along Mombasa and Thika highways. The trucks pass at intervals of five every half an hour. The government had to establish Natural Environmental Watchdog of Kenya, with a list of guidelines to soil harvesters and traders in Eastern Province.

Hill and Kleynhans (1999) carried out a research on authorisation and licensing of sand mining and realised that it is important in South African economy but the processes of prospecting, extracting, concentrating, refining and transporting the resources have great potential in disrupting the natural environment. The research concentrated on river sand mining which has adverse impacts on the biota and the habitats. Steps in mining sand and gravel in South Africa were given as firstly, finding a mining location and removal of vegetation and topsoil using excavating equipment. Second step involves extraction using dredge machine to suck the resources. Thirdly, a separator is used to separate sand and gravel from large rock particles, while fine sand is removed from coarse sand. At the end, usually excess sand is returned to the pit using a discharge pipe. (Hill and Kleynhans, 1999). Methods of mining were noted as dry pit mining done when sand is extracted from dry streambed. Wet pit mining involves removing sand and gravel below water table using hydraulic machines while bar skimming is when top layer of soil is removed (Hill and Kleynhans, 1999).

According to Lupande (2012), sand mining had not been a common business in Zimbabwe. There had been massive construction of new buildings, extensions and renovations in Harare and surrounding areas since 2009 when the US$ began to be used in the country. This had led to the formation of cooperatives by youth groups to mine sand from nearby farms like Stoneridge. Bedford trucks are used to transport sand into the city and residential areas. An Environmental Management Authority (EMA) sand abstraction licence is obtained first before mining. Steps followed in the mining process according to EMA are removal of topsoil, extraction of sand and gravel to a depth of one metre then land reclamation takes place.

Chimbodza (2012) noted that river sand is abundant in Zimbabwe's Zambezi Valley, particularly along the Ruckomechi and Chewore rivers such that a large mining company was awarded a licence to mine the resource to be used in infrastructural development. Mining methods used by the company include dredging or suction which works like a vacuum cleaner, sucking up sand from the river. Earthmoving is done to dig and remove sand then trucking it away for processing in nearby Chirundu.

Botswana is not an exception in mining of resources. Mbaiwa(2008) noted that the country depends on mining of resources, including sand and gravel which contribute 34,2% of Gross Domestic Product (GDP). The Mines and Minerals Act of 1999 was introduced to control all mining activities in the country including sand mining and gravel extraction. National

Policy on Natural Resources Conservation and Development (1990) commonly referred to as the National Conservation Strategy (NCS) was instated for all members of society to develop but conserving the natural resources. According to Mbaiwa (2008), the country depend on extraction of mineral deposits such as diamond, gold, nickel but there is mining of soil done both legally and illegally. For thousands of years, pit sand, river sand and gravel had been mined from various areas for construction of roads and buildings as part of urban development with Gaborone inclusive and demand has increased today.

Individual companies mine soil both legally and illegally causing land degradation and disturbance of ecosystems. Several communities had expressed their concern on excessive sand and gravel mining. A case was reported in an article in Mmegi Newspaper (2011) on sand mining in Moshupa, a village West of Gaborone. The article highlighted complaints on a lot of sand being mined and sold by individuals and companies. The Village Development Committee (VDC), a board responsible for running affairs of the community complained of lack of consultation by the Department of Mines, Land Board and miners who are the stakeholders in the activity. In a separate incident an article in the Daily News (2012) had a case in Mathangwane, a village near Francistown, a city in Northern part of the country, where a giant company was involved in harvesting sand from the village without licences and consultations with local authorities. Villagers were threatening to place stones across roads for company trucks not to pass.

The Mines and Minerals Act (1999) of Botswana highlights requirements for application of a mining licence and minerals permit for any mining activity including sand and gravel. Anyone is eligible for a licence, citizen or non-citizen but the prospecting miner should obtain surface rights from responsible land board on land authority. The identified area should be surveyed first, then prospected to ensure no one else has exclusive rights over that area. If the area identified is a game reserve, or national park, then clearance has to be given first, by Department of Wildlife and Parks. A feasibility study of the proposed area is done and submitted with details of Environmental Impact Assessment study report and Environmental Management Programme and Mining methods to be used. According to the Act, lease charges are P100 per square kilometre or part thereof. There are royalties payments payable to Botswana government through Director of Mines paid monthly at 3% of gross market value, a fixed percentage for resources classified as other minerals for example sand and gravel mining.

2.4 Positive impacts of sand mining and gravel extraction worldwide

Sand and gravel had been a useful natural resource for thousands of years worldwide and are fundamental to human existence. Today, demand for sand and gravel has increased. Mining operators in conjunction with resource agencies need to work hard and make sure the extraction is done responsibly. Schaetzl (1990) discussed sand and gravel as crucial resources to economic development activities when making aggregate in United States of America. Development is a process of adding improvements to a piece of land such as grading, drainage and access roads. Schaetzl defined aggregate as a substance made from several materials such as river sand and gravel. Pit sand is mixed with cement to form concrete, mortar and plaster for construction of strong structures. Aggregate is used to make road bases and coverings, concrete products and shoreline protection.

Mining of sand and gravel had been done for road and cement aggregate for centuries worldwide. According to Draggan (2008), 50% of sand and gravel mined in USA is used in construction to make concrete for roads, durable bricks, blocks, pipes construction fill and sometimes mixed with asphalt. In industry, 39% sand is used to make glass, 22% as foundry sand, 5% as abrasive sand while 34% is for other uses. The uses of sand and gravel are shown by a pie chart, on Figure 2.2.

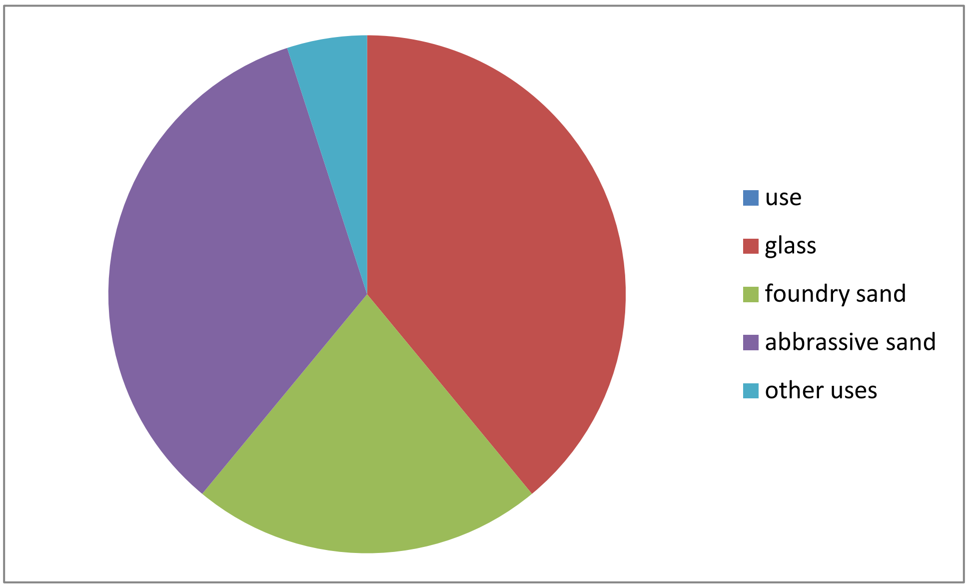


Figure 2.2: Uses of sand and gravel in USA industries (Draggan, 2008)

Kondolf (2008) supported the use of active channel deposits (gravel and sand) as desirable for construction aggregates because they are durable, well sorted and frequently located near market and transportation routes. Besides, sand and gravel being useful resources in construction industry, the resources are useful tools in flood control and river stabilization, in aggrading rivers since most reservoirs are not aggraded in developed countries. Sand mining helps to de-silt rivers which contain a lot of sand (Chimbodza, 2012).

Puller (2009) discussed sand and gravel resources of Europe as large and their geographic distribution, requirements and environmental restrictions for some uses. The resources are mixed with bitumen to make roads, surfaces and gritting. Goddard (2007) viewed sand mining in Australia as important specifically in construction of buildings and economic development. Kuttipuran (2006) supported Goddard (2007) when he discussed the importance of sand and gravel in Indian economy as cheap and most accessible used in construction industry to build strong structures and road bases. Bagchi (2010) realised that sand and gravel are useful in landscaping projects which beautify gardens in India. Sand and gravel are important in construction and manufacturing industries when used in building, making glass, electronic chips and ceramics. Sand mining underpins the development engine, so without sand the construction industry will come to a halt (Pereira, 2012).

Most African states are still developing and benefit from use of natural resources such as sand and gravel for economic development. Lawal (2011) indicated that Nigerians also benefit a lot from sand and gravel mining which results in building of quality permanent structures from aggregates. The demand for the resources increased in most Nigerian States by 1990s when individuals were getting schemes for home ownership such as increase in salaries and house loans which were easily accessible. Every citizen could afford to build a better house. This led to better socio economic life for rural people. In Kenya, soil mining had led to development of better infrastructure (Mwangi, 2007). This was supported by Mbaiwa (2008) as a positive impact of sand mining in Botswana where more land had been used to develop infrastructure in form of shopping malls and residential areas. Zimbabwe is not an exception in benefiting from sand and gravel through infrastructural development (Lupande, 2012).

There is creation of employment for families at mining sites in Indian regions (Saviour, 2012). Lawal (2011) noted that by year 2001 alone, a total of seven thousand, one hundred and thirty one sand and gravel miners had been employed in Nigeria's Niger State alone, according to statistics provided by Mine Safety and Health Administration. Mwangi (2007) supported this positive impact of soil mining in Kenya when he highlighted that there is creation of employment to locals above eighteen years as manual loaders at mining sites. In Botswana, Mbaiwa (2008) realised the same impact of employment creation to youth, both citizens and non citizens seasonally at mining and construction sites to load tipper trucks. While in Zimbabwe, Lupande (2012) noted creation of employment for youth who are licensed to mine sand and some to load the trucks as a positive impact of mining.

Mining activities brought wealth to Indian communities (Saviour, 2012). Sand and gravel activities generate revenue and income to local governments and land owners in Africa's developing nations which reduce poverty. This was noted by Lawal (2011) in Niger State of Nigeria where financial benefits from mining work shows that local government earn about eight percent of total profits from business while the miner gets about ninety two percent of accrued revenue. Kenyan local government also benefits from soil mining as highlighted by Mwangi (2007), when legal miners are to pay for the licences.

2.5 Negative environmental impacts of sand and gravel mining worldwide.

Sand and gravel are important natural resources in economic development worldwide but the continuous removal have adverse effects on the environment. Negative environmental impacts seem to outweigh positive effects in mining worldwide. Different negative impacts had been noted in United States of America due to in stream mining occurring in rivers and streams. Kondolf (2007) defined in stream mining as the mechanical removal of gravel and sand directly from an active channel. Forms of in stream mining such as pit excavation and bar skimming, causes bed degradation of rivers known as channel incision. The process occurs as head cutting or hungry water. When head cutting extraction is done on active channel, it lowers stream bed to create a nick point which steepens channel slope and increases flow energy.

Figure 2.3 shows the development of nick point during more pit excavation, which become a location of bed erosion that gradually moves upstream, shown by A. B shows that continuation in stream mining of sand, lowers the stream bottom leading to bank erosion, bed degradation, high water flow and excavation .

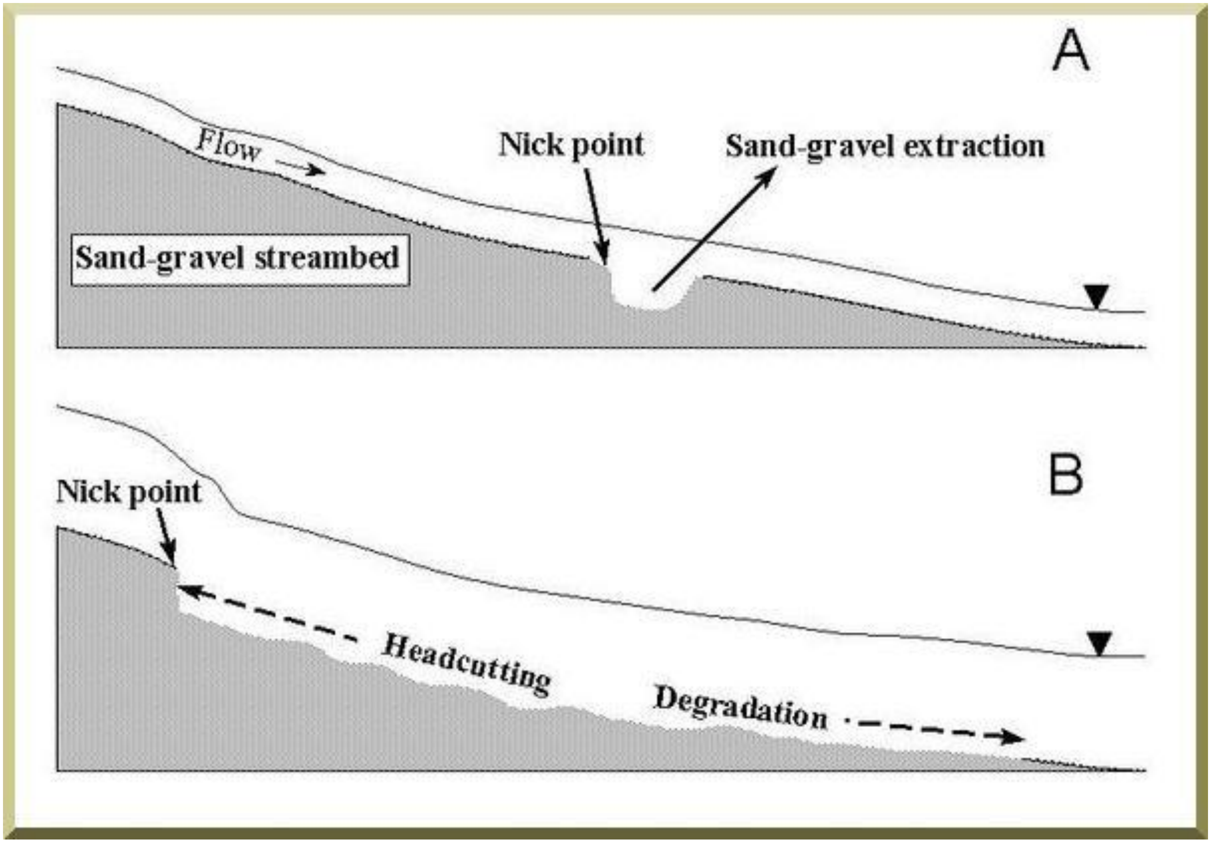


Figure 2.3: Nick point formation (Kondolf, 2007)

Bagchi (2010) discussed environmental land and surface degradation as a serious impact of in stream mining on Indian rivers. There is damage to river banks and general ecosystems due to access ramps to riverbed. Soil erosion occurs as there is disturbance of groundwater and changes in river courses. Continuous removal of sand from river bed increases velocity of flowing water which erodes beds and banks. Kondolf (2007) noted that as the velocity increases, the river bed can propagate both upstream and downstream for many kilometres. This can lower alluvial water tables. Stebbins (2006) added that in stream sand mining causes destruction of aquatic and riparian habitat through large changes in channel morphology, lowered water table, instability and sedimentation at mining sites due to stock piling and dumping of excess mining materials.

Figure 2.4 shows channel cross sections. A is a typical sand and gravel bar in relation to the low flow of channel, riparian zone and water table. B shows the impacts of continuous mining as a wide shallow channel has been formed due to unrestricted mining characterised by bank erosion, braided flow, falling vegetation, sedimentation, lowered water table and increased water temperature.

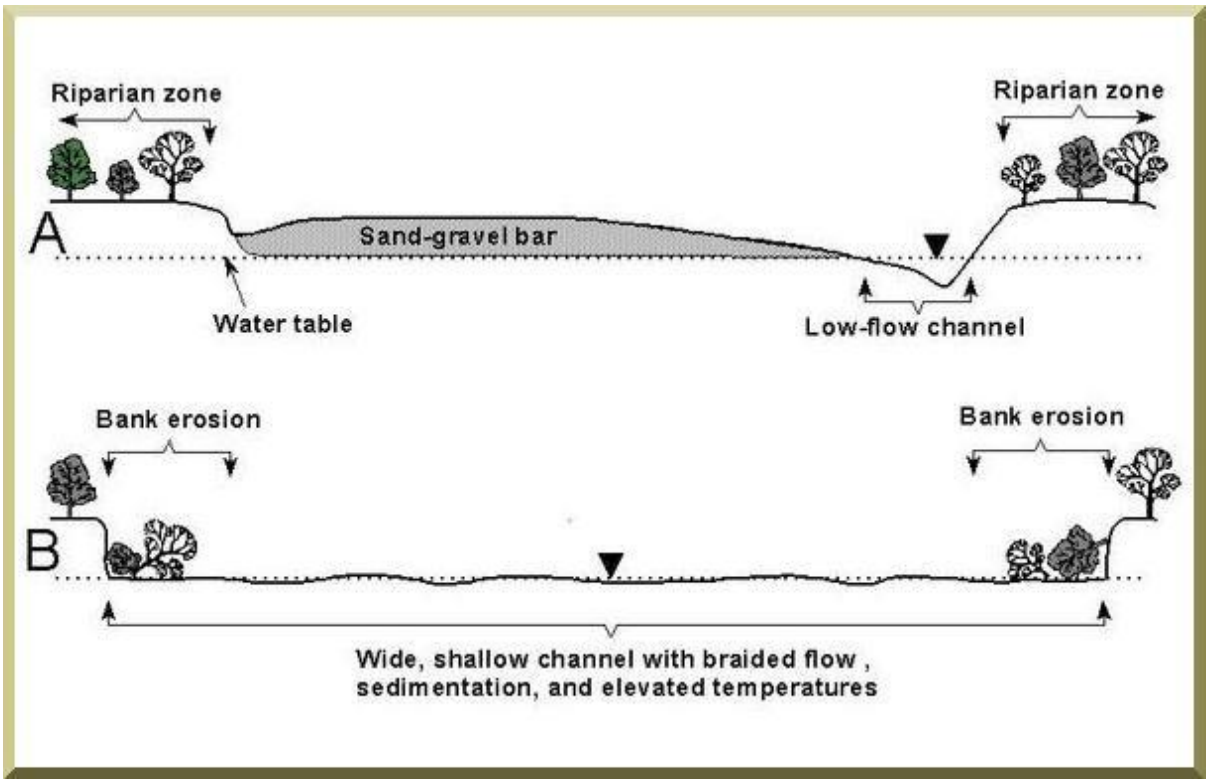


Figure 2.4: Impacts of mining on active channel (Stebbins, 2006)

Pereira (2012) revealed that sand mining is a threat to water security resulting from loss of groundwater storage due to lowering of alluvial water table. For example major rivers in India’s Kerala district such as Pampa and Manimala have been lowered with four to six metres. If sand mining continues in India uncontrollably up to 2050, water table will drop to approximately 2537 square metres. A lowered water table due to mining leave drinking water wells dry, and people starving. Suspended solids affect domestic water users downstream which increase treatment costs. Saviour (2012) also noted the deterioration of water quality due to dissolved suspended materials and solids from mining activities. Water quality can also be compromised by oil spills and leakages from excavation machinery and transportation vehicles which may poison aquatic life (Stebbins, 2006).

Lawal (2011) supported Stebbins on that there are changes in channel morphology because of stream bank mining in Nigeria. Hill and Kleynhans (1999) discussed in stream mining as the main cause of destruction of riparian zone, changes in channel morphology and lowered flood plain. In their study, they revealed alterations of flow patterns, existence of suspended sediments reducing light penetration for photosynthesis by aquatic flora.

Schaetzl (1990) explained some of the negative environmental impacts experienced by various states in America where sand and gravel mining are going on. He noted that depletion of sand in the streambed and along coastal areas causes deepening of rivers and estuaries as well as enlargement of river mouths and coastal inlets in Michigan and California. He further indicated that excessive mining leads to excavation as well as threatening bridges, bridge piers and buried pipelines. Goddard (2007) indicated that gravel extraction and processing have significant negative effects on scenic landscapes. Too much mining intensifies coastal and exposed hillside erosion, accumulation of seawater up rivers, leaving coasts more vulnerable to extreme weather conditions. Pereira (2012) noted that there is decreased protection from sea water and shoreline erosion rates increases especially during ocean disasters when mining continues uncontrollably and unscientifically. Lawal (2011) supported disturbance of landscape and distortion of topography as results of excessive soil mining in Nigeria.

According to Bagchi (2010), there is contamination of sand aquifer water due to formation of ponds as harvesters tend to dig on areas with thick sand bed creating water ponds. Water accumulates in ponds combined with biodegradable materials from flora and fauna wastes causing contamination. Besides, stagnant water on gravel extraction ponds form an environment conducive to mosquito breeding. Lawal (2011) agreed with Bagchi on creation of pools as a result of mining which are breeding sites for pests in Nigeria.

Several negative impacts were noted on habitats. Stebbins (2006) realised that valuable timber resources and wildlife habitats are destroyed as all species require specific conditions to ensure long term survival. Native species in stream and rivers are uniquely adapted to conditions that existed before human began large scale alterations which favour some species over others. This leads to loss of fisheries productivity, biodiversity and recreational potential. As deep pools are filled with gravel and sediments, there is a reduction in habitat complexity and large predatory fish. Channel widening causes streambed to be shallow, producing braided flow or subsurface inter gravel flow in riffle areas hindering movement of fish between pools (Stebbins, 2006). Mining operations involve deforestation, habitat destruction and biodiversity erosion (Saviour, 2012).

Schaetzl (1990) realised that sand and gravel mining generate extra heavy vehicles and traffic, impairing negatively on the environment. Heavy vehicles cause access roads on riparian zone and compact the ground. Kuttipuran (2006) supported Schaetzl (1990) on formation of access roads on river beds as heavy machinery and tipper trucks move to collection points. Some tracks are caused by pedestrians. There is general destruction to roads and bridges. This effect is felt more by villagers near mining sites as the continuous movement of heavy vehicles cause problems to cattle posts, agricultural land, borehole and well users.

Besides compacting land, heavy vehicles are a source of pollution to the villages near mining sites. According to Lawal (2011), noise and air pollution occur as dust accumulates from gravel roads which are a reality to villages near mining areas. There is general degrading of ecosystem in Nigeria. Air pollution caused by dust particles can be a health hazard causing respiratory disorders such as asthma and irritation of lungs (Saviour, 2012). The sand is also extracted from rock blasting which generate noise pollution. The ground vibrations produced can cause ground tremors. Pereira (2012) realised that sand is dredged illegally twenty four hours a day, all year round even during monsoons using mechanical dredgers in India. These produce a lot of noise which hampers sleep and normal school operation hours. Vibration noise generated from overburden excavation and transport is severe at night and is an annoyance to people.

Stebbins (2006) noted that as mining occurs, there is loss of protection provided by soil as it filters out pollutants. Gravel pits are sometimes used as dumping sites with tipper trucks carrying waste to dump as they come to collect sand and gravel. Pollutants from waste filter and contaminate drinking water and affect people's health in Maine State. Goddard (2007) added that there is formation of mine and waste dumps which pollute the environment as a result of soil mining in Australia. Mwangi noted the same impact of converting abandoned gravel pits into dumping sites as a serious effect of uncontrolled gravel mining in Kenya. Wokorach (2002) discussed air and water pollution in Botswana as negative impacts of mining on the environment. Tailing and waste dumps from mining processes pollute ground water resources near mining areas and contaminate soils.

Saviour (2012) discussed pollution of water as a result of some physio-chemical and biological parameters which characterise degradation of water quality by colouration when it turns from brownish to reddish orange, lowering ph and increasing electrical conductivity. This is due to high concentration of ions of sulphate (SO), iron (Fe) and other heavy toxic metals such as Zinc, Nickel, Copper and low dissolved Oxygen (DO). When mined materials for example walls of open pits and waste rocks are exposed to oxygen and water, acid can be formed leading to an acid mine then acid mine drainage which run off into streams and rivers(Saviour, 2012). There is leaching of the acid into the ground causing water pollution. The ph increases to 4 affecting fish, aquatic plants and animals. Acid mine drainage may dissolve toxic metals like Copper (Cu), Aluminium (Al) and Iron (Fe). Iron may coat bottom of rivers and become toxic to humans and wildlife (Saviour, 2012).

Stebbins (2006) highlighted destruction of soil structure and profile in American States due to mining. Continuous mining causes complete removal of vegetation and destruction of topsoil and subsoil resulting in a reduction in faunal population. Saviour (2012) discussed the destruction of existing vegetation and soil profile significantly in topsoil affecting flora and fauna in Indian regions as mining continues. Kuttipuran (2006) supported this impact by noting that loss of vegetation and ecosystems is common around and next to Indian rivers, an eyesore which gives an offensive look to the natural beauty of the environment. Still in India, Pereira (2012) recognised that there is destruction of mangrove forests due to illegal construction of storage docks, roads, infrastructure for easy mining, storage and transportation of sand from the rivers. This has increased vulnerability of land to floods in Mumbai. Aromolaran (2012) noted land degradation in agrarian community by destroying the soil surface and structure as well as declining the nutrient status of agricultural land. Lawal (2011) discussed environmental devaluation as a result of man's activities such as sand and gravel mining in Nigeria. There is loss of valuable fertile land and timber as well as habitat alterations which disrupt ecosystems and destroy native species. Increase in turbidity affect aquatic species, a major impact to fauna. Therefore, there is need for a preliminary investigation into the type of vegetation occurring there and possible impacts before mining.

Gravel extraction and pit sand mining on open areas had left open pits around expanding urban areas in United States of America (Draggan, 2008). Scenes of accidents involving children and grazing animals are common due to the open pits left on bare ground in Nigeria (Lawal, 2011). Water accumulates in the open pits during the rainy season and domestic animals drown in the pits. Livelihoods of fishermen in India are threatened by sand barges which often destroy their nets (Pereira, 2012). Loss of lives had also been recorded in India which impacted tourism, agriculture and fishing potential. Bagchi (2010) reported on accidents as common in Palakkad District of India as children drown in water filled open pits when they try to swim, thus there is loss of recreational potential for the land. Massive construction has led to excess mining which create pits and holes in farms surrounding Harare (Lupande, 2012). Pits created by miners in Botswana pose a danger to wildlife and livestock. Disturbance of land surface areas leave huge open pits difficult physically and economically to rehabilitate after mining takes place (Wokorach, 2002).

Bagchi (2010) gave other general impacts of general impacts of sand mining as a drop in water table in Godavari river in the west of India which is leading to dry wells perennially and drought. Villagers obtain the resource through tankers and pipes over long distances. There is environmental degradation on open land and rivers as well as high evaporation from exposed river beds leading to dry rivers and shortage of water for domestic purposes and animals.

Mining operations involve deforestation and biodiversity erosion. Ekosse (2004) conducted a research to find the environmental impacts of mining in general to soils around mining areas in Botswana. The research concentrated on areas around Kgwakgwe Manganese Mine. Chemical properties of soils and leaves of plants around mining areas were investigated to determine the effects of the mining activity. Demineralisation and pollution of soils and the surroundings was noted which lead to formation of dead zones. The soils become contaminated and stunted growth in plants was noticed. Mining of sand near seas allow intrusion of sea water which is called salinisation (Pereira, 2012). The Mines and Minerals Act (1999) of Botswana listed some of the environmental impacts experienced due to legal and illegal sand mining and gravel extraction. These include accidents due to open pits left uncovered on bare ground. Sand act as a reservoir to charge ground water wells, so when removed, wells have to be dug deeper which increases water costs (Pereira, 2012). Generally, there is loss of employment to farm workers as agricultural land is destroyed to pave way for mining while there is human rights violation to farmers.

2:6 Solutions and mitigation measures to sand mining and gravel extraction worldwide

The United Nations Conference on Environment and Development Report (2002), Agenda 21 advocates sustainable use of natural resources. Sustainable means ability to continue and be used for a long time. Goddard (2007) highlighted that man benefit from sand and gravel, as cheap and readily accessible resources for development, so there should be conservation and rehabilitation of these resources for future use. All governments worldwide should advocate for environmentally sustainable development.

Kondolf (2007) discussed the importance of an environmental assessment management and monitoring program as part of extraction licence in America. This is necessary to minimise negative impacts as mitigation and restoration strategy will be included. Monitoring regularly is important to ensure proper mining. Mitigation processes include minimising extent of mining, repairing and rehabilitation of mines as well as replacement of resources. There is need for restoration and compensation of biotic integrity of ecosystems. Most soil mining affect environment and India is inclusive as Saviour (2012) noted that the country is working hard to tackle negative impacts. The miners are supposed to draft an Environmental Management Plan (EMP) which ensures that potential impacts of projects are assessed and incorporated into early stages of development planning. The preparation of EMP had become a statutory requirement for granting permits in India. Clearance should be obtained from Department of Environment (DOE) and Ministry of Environment and Forests before permits are issued (Saviour, 2012).

Kuttipuran (2006) suggested watershed restoration through replanting of riparian vegetation to replace large woody debris while conserving spawning gravel. This will re-establish ecological carrying capacity of the habitats, ecosystems and increase fish production. Aromolaran (2012) recommended the planting of trees and shrubs that could help to regenerate degraded land and prevent erosion. People in rural areas must be educated on alternative resources to sand such as crushed stone as well as being involved in activities that are less degrading to agriculture land. Pereira (2012) also suggested use of crushed stone as alternative to conserve sand. The requirement of Environmental Management Authority (EMA) in Zimbabwe is to fill pits after mining, then plant trees and grass to minimise erosion. Land is levelled and growth of trees monitored until established as reclamation of land in Zimbabwe (Lupande, 2012).

Stebbins (2006) noted that there is need to review potentially toxic sediment contaminants in or near streambed where gravel will be extracted while monitoring turbidity levels. There should be removal of in stream rough elements and sediments like debris, dumped far from rivers, streams and residential areas so that there is no filtration back into the water. Ekosse (2004) recommended reclamation of contaminated soils around all mining areas for resources to be used productively in future. Bagchi (2010) suggested management of sand and gravel extraction operations to minimise damage to streams, rivers and riparian zone.

Since Kondolf (2007) had realised that gravel bar skimming significantly impacts aquatic habitats, the method can only be allowed under restricted conditions like during low flows with construction of buffer strips to control the flow. Hill and Kleynhans (1999) highlighted that if bar skimming is used as a method of mining, then there is need for close monitoring and refilling of pits on the riparian zone. Allow bar skimming only under restricted conditions but if the river or stream has a history of eroding bars then avoid this method. Kondolf (2007) supported this by suggesting that monitoring of all activities should be done to ensure that there is no gravel recruitment downstream. If a river has a recent history of rapidly eroding bars, then skimming should be avoided. In bar skimming, there is need for strictly limiting gravel removal quantities so that recruitment and accumulation rates are sufficient to avoid extended impacts on channel morphology and fish habitats (Kondolf, 2007).

According to Schaertzl (1990) there is generation of heavy vehicles on river banks and beds. He recommended that extraction should be done on one side of floodplain to eliminate crossing of active channels by heavy equipment. Generally, sand mining sites should be outside active floodplain. Hill and Kleynhans (1999) had also noted the need to apply dry pit mining method in sand mining project on one side of floodplain to avoid compacting active channels with heavy tipper trucks and front end loaders. Crossing active channels with trucks may lead to contamination of water with oil spills and leakages. Wachira (2009) recommended strict laws to be imposed on licence holders as a prerequisite to miners in Kenya. Mwangi (2007) recommended restriction of heavy front end loader equipment on mining areas and instead encouraged use of shovels which have less impact on the ground.

Kuttipuran (2006) suggested that mining of river sand should strictly be done on larger rivers such as Bharathapuzha and Pamba in India containing a lot of sand avoiding smaller rivers and streams which may easily be destroyed. Braided river systems are recommended instead of straight, meandering and split rivers. Strictly, operators should never be allowed to divert streams and rivers creating inactive channels. Lawal (2011) recommended the use of abandoned stream channels on terraces, inactive floodplains and deltas as the best sources of gravel and sand. He noted that gravel pits on floodplain should not go deeper than water table. He recommended that pit excavations on adjacent floodplain or terraces should be separated from active channel for two to three decades by constructing buffers or levees to reduce long term flooding.

Stebbins (2006) researched on co-existence of gravel sand mines and water supply wells and revealed that continuous removal of the resources harm ground water quality. He suggested regulators to assess changes in ground water and develop a methodology on management of both resources effectively. Hill and Kleynhans (1999)'s research included recommendations to decision makers who are involved in reviewing sand mining and gravel extraction to make informed decisions when issuing licences. Lawal (2011) encouraged Nigerian authorities to discourage indiscriminate opening up of plots for sand and gravel mining. The government should evolve a policy compelling miners to reinvest and repair old disused mine sites so as to reduce occurrences of landslides or earth tremors in the locality. Government should consider changes in market prices of sand and gravel so as to charge according to economic value of environment. Ekosse (2004) recommended remedial measures for reclamation of the contaminated soil to appropriate land use.

After reviewing the National Marine Fisheries Service (NMFS), Kondolf (2007) suggested that the government of USA should use modern technology and field sampling prior to extraction to establish and document baseline data and evaluate ways of minimising negative impacts. This can be done through calculating sediment and hydraulic flow budgets, then find possible changes in water quality and channel morphology. There is need to address cumulative impacts and propose possible mitigation and restoration strategies. Close monitoring permitted operations and verifying environmental safeguards by regulating extraction rates and volume is important. Channel cross sections should be benchmarked and documented using aerial photographs taken at regular intervals (Kondolf, 2007). The NMFS Policy highlights the need to give permits with five-year limits subjected to annual review and revision if fishery management objectives are met. This will ensure establishment and implementation of long term monitoring and restoration program in American States.

In Kenya, Mwangi (2007) discussed the establishment of the National Environmental Watchdog of Kenya with a list of guidelines to soil harvesters and traders in the Eastern Province. He gave mitigation measures to sand mining and gravel extraction as refilling and growing appropriate vegetation on eroded areas by licensed miners as a prerequisite. The National Environmental Management Authority (NEMA) was drafted by the Kenyan government to apply to all mining activities including soil. NEMA officials work with District Sand Harvesting Committees to ensure sustainable mining is done.

Hill and Kleynrans (1999) gave fundamental considerations and recommendations on how to reduce negative impacts in all sand and gravel extraction operations. There is need for strict laws to govern sand mining and gravel extraction activities both in rivers and on land. Standard conditions should be part of mining operations. Mitigation and restoration must occur concurrently with extraction activities thus restoration becomes part of mitigation. This is done to restore biotic integrity of riverine ecosystems. Dry pit mining was recommended instead of bar skimming or wet pit mining in most activities because the depth of extraction can easily be controlled.

The Mines and Minerals Act (1999) of Botswana gave guidelines on mitigation measures against negative impacts on mining. The distance of mining from banks of meandering rivers should be 2.5 to 5.0 metres but this depends on height of river bank and thickness of sand to be extracted. The Act prohibits digging of river banks within 500 metres for pit sand and gravel. At least 0.5 metres of sand bed should be left in situ while harvesting sand. No permits are issued to prospective miners who wish to mine near schools, villages, clinics or any other major human activities. The Department of Mine gave an example of intended reclamation/rehabilitation plan to be followed by the licensed miners soon after mining. Figure 2.5 gives an example of how reclamation process can be done in order to end up with a rehabilitated landscape.

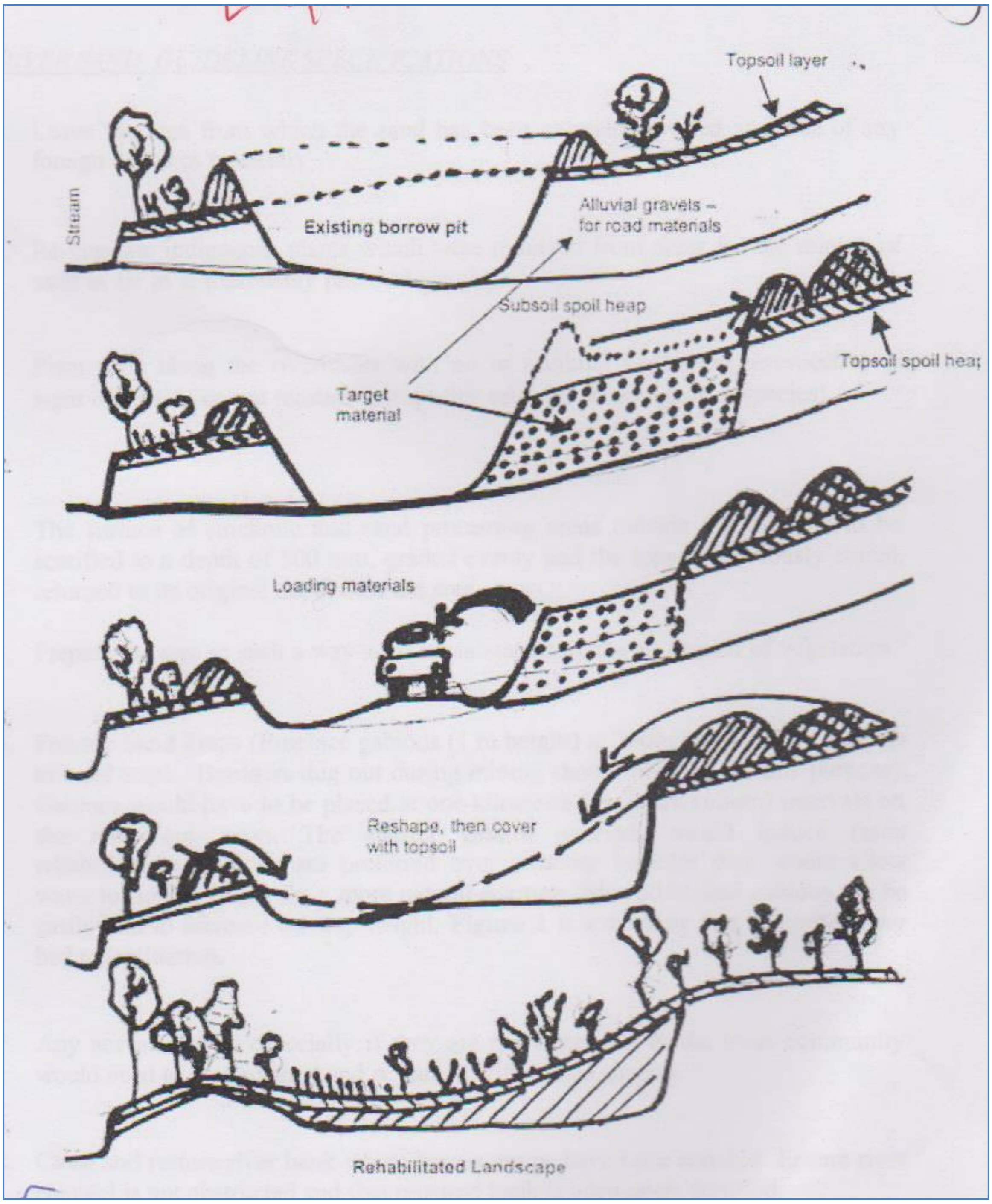


Figure 2.5: A typical example of borrow pit rehabilitation (Department of Mines, 2005)

The rehabilitated landscape shown in Figure 2.5 will enable land restoration to the extent of farming. This had become a prerequisite for miners to obtain a license.

2.7 Summary

Sand and gravel are important natural resources for economic development. These can be mined on open areas, beaches, inland dunes, rivers and streams. Mining is important but processes involved can disrupt natural environment. According to Saviour (2012), weak governance and rampant corruption can facilitate illegal sand mining posing depletion of resources. There is need to protect economic and social benefits of resources from mining operations. Governments must exercise prudence when leasing riverbeds and open land, demarcate clearly and monitor mining through a suitable institutional mechanism. Laws are to be enforced across all countries by a high level committee as a solution to environmental problems (Saviour, 2012).

CHAPTER THREE: RESEARCH METHODOLOGY

3.1 Introduction

This chapter discusses the author's methodology adopted for the study. It gives a detailed account of the data collection processes employed to obtain data. The main objective was to develop a database on positive and negative environmental impacts of sand and gravel mining for Gaborone City expansion. This was done through visiting areas of extraction and key informants. The chapter clarifies the research designs and data collection instruments used in the research. Both primary and secondary data was collected and presented graphically. Statistical Package for Social Science was used for quantitative data analysis. Qualitative research designs such as questionnaires and interviews were used to collect primary data. Background information was collected through field visits by observations, taking measurements, informant interviews and questionnaire surveys. Measurement of depth, width of pits and widening of rivers at sampled collection points were taken. Secondary data was collected through analysis of case studies and related researches in Africa and the whole world.

3.2 Research designs

Gwimbi and Dirwai (2003) defined a research design as a structure or plan of the research which provides glue that holds a project together, groups or samples, observations or measures, programmes or treatments and other aspects of methodology. There are two types of research designs, qualitative and quantitative. Qualitative is a descriptive approach when there is documentation of what is exactly said, observing behaviour or even studying written documents. A qualitative researcher gets ideas from people being studied. Data collected is presented in form of maps, photos, graphs or tables. An example of a qualitative research design is a case study. Gwimbi and Dirwai (2003) defined a case study as a strategy for doing research involving an empirical investigation of a particular contemporary phenomenon within its real life context using multiple sources of evidence. This involves a study on its own right on a specific case with a conceptual framework. A case can be a school, village, river or any phenomenon of interest. Case studies are important in decision making and for policy makers.

According to Polit and Beck (2008), a quantitative research design is an explorative non experimental, descriptive structure which involves quantifying relationships between variables. The design deals with figures and quantities. The design involves precise measurements and statistical analysis of data using computer packages. A good design should ensure that there is maximum control over factors that affect adversely the reliability and validity of research results (Gwimbi and Dirwai, 2003).

3.3. Sammple and sampling procedures

Sampling was necessary to choose respondents before distributing the questionnaire. Polit and Beck (2008) defined sampling as the process of selecting elements which are the basic unit from which data and information will be collected to represent the entire population. Chimedza (2003) defined population as a collection of all individual items or points under investigation. Sample size for this study was one hundred and seventy five (175) respondents which comprised of one hundred and five (105) from Kumakwane and seventy (70) from Metsimotlhabe. Two options of sampling considered were probability and non-probability. In this study, non probability sampling in particular convenience and purposive sampling designs were used. Purposive sampling was used to select the affected area because they meet researcher's study objectives while convenience sampling was used to select the respondents. Convenience sampling allowed the researcher to select respondents who were readily available and willing to take part in the study. According to Chimedza (2003), the disadvantage of such sampling is that some elements are over represented while others are under represented. Available elements may possess different characteristics from those of population with regard to critical variables (Polit and Beck, 2008).

3.4. Research instruments

Various primary data collection tools were used to collect basic raw information. These included a questionnaire survey, interview guides, field observation and recording tools. A digital camera was used to capture photographs from affected areas. Field measurements were done using a measuring wheel and a 100m measuring tape with the help of a field assistant.

3.4.1 Questionnaire Survey

A questionnaire which consisted of both closed and open ended questions following literature review and reference was made to the problem identified and objectives set. Gwimbi and Dirwai (2003) realised that a well designed questionnaire should meet objectives of enquiry, fit between contents and research problem. It was developed to solicit information from key informants on their views concerning sand and gravel mining and the environmental impacts. It was used and administered to the villagers in the affected areas of Kumakwane and Metsimotlhabe. A questionnaire survey was chosen because it allows participants to give their views anonymously reducing bias. Polit and Beck (2008) gave advantages of administering a questionnaire as it is easy to test validity and reliability. It is flexible and may be applied to many different populations within a short time. Same questions are repeated to get valid and reliable answers with minimal resources. Information is quickly obtained and used for many purposes. The disadvantages include some questions may be omitted purposely while some respondents may lose the questionnaires.

The questionnaire was administered to determine a variety of aspects from respondents which included beliefs, thoughts and knowledge about sand mining and gravel extraction in their areas. During this study, the researcher visited sampled households to explain the benefits of research and importance of their participation and involvement. A questionnaire was introduced prior to answering in the presence of an interpreter who translated questions from English to Setswana for illiterate respondents. The researcher had to translate some questionnaires and write in Setswana language since in some cases the interpreter was engaged in other duties and this allowed respondents to be helped by family members.

The questionnaire was administered through a drop and pick survey. On distributing questionnaires, the researcher repeated benefits and importance of answering questions truthfully while assuring participants anonymity and confidentiality. It was administered only to adults above twenty-one (21) years. Each respondent was given up to one week to answer all questions. The researcher had to move around again collecting the questionnaires from respondents' homes.

The questionnaire had open and close ended questions comprising of four parts. Information paragraph at the top was to introduce researcher, purpose and title of research. Contents of questionnaire are discussed in the following table.

Table 3.1: Layout of questions on questionnaire

PART	QUESTIONS
A: Demographic data	Questions 1-3 were on gender, age and position of respondents in the village, data obtained described sample characteristics and the type of respondents the researcher is dealing with.
B: General questions on sand mining and gravel extraction	Respondents were to indicate where they lived in relation to mining areas, their involvement and to establish any knowledge on mining activities.
C: Views on impacts of sand mining and gravel extraction	Questions were meant for subjects to give opinions on positive and negative impacts of mining sand.
D: Solutions to sand mining and gravel extraction.	Respondents were asked to suggest and recommend on how to benefit from soil mining while mitigating the negative effects.

3.4.2 Individual interviews

Individual interviews were administered to various subjects to collect primary data. The key informants were identified and interviewed on the principal parameters of investigating environmental impacts of sand mining and gravel extraction. Inclusion criteria for the interviewee were based on position and involvement in the mining activity. The researcher designed structured questions specifically for each individual to collect primary data. Complexity of questions depended on position and level of education of each participant. Prior consent and appointments were done with the participants in designated offices and homes. Department of Mines Environmental and Licensing Officers were interviewed in their offices. Those directly involved in mining like drivers were interviewed when found on sites of extraction.

There were visits to offices, homes and mining sites in Gaborone, Kweneng and Kgatleng districts to interview key informants. The Licensing Officer was interviewed on the criteria used when issuing mining licence, monitoring strategies and legislation in place to govern sand mining, and the type of punishments given to illegal miners. Department of Mines Environmental Officer was interviewed on the importance of carrying out an Environmental Impact Assessment before mining, requirements of Mines and Minerals Act (1999) pertaining to sand mining, possible alterations to the environment and any methods put in place to rehabilitate the land. Village Development Committee Chairperson and Kumakwane chief's questions were based on complaints from villagers and if prior consultations are done by miners. Front loader and tipper truck drivers were interviewed on areas of collection, frequency of collection per day for each component, how they benefited and any awareness of possible impacts of sand mining activities.

3.4.3 Field observation and measurements

Primary data was collected from sampled points picked at random from areas surrounding Gaborone where river sand, pit sand and gravel are mined. These were areas sampled: for river sand, Metsimotlhabe river (Sampled points C and D) and Ditlhakane river (Sampled points A and B). All sampled points A, B, C and D for pit sand were picked in Kumakwane because most pit sand is mined from this village. Points A and D for gravel where in Kumakwane, point B was in Kopong while point C was in Bela Bela farms. Length, width and depth of pits and trenches was measured every fortnight and recorded on data sheet for comparison later. All the above measurements were collected by picking three disturbed sites, labelled A, B, C and one undisturbed as the control marked D. A one hundred metre measuring tape and a measuring wheel were used to take measurements. A field assistant helped the researcher to take and record measurements on a record sheet on each visit. A digital camera was used to take photographs of affected areas as evidence.

3.4.4 Literature Review and Document analysis

Secondary data was collected from related researches and books. These were used to review previously published literature dealing with the problem of sand mining and gravel extraction worldwide. More information was obtained from analysis of documents such as Mines and Minerals Act (1999) and National Policy on Natural Conservation and Development (1990) to review what the government expects in terms of environment use and conservation. Journals were considered to find recent information on sand mining and gravel extraction. Data from existing records helped the researcher to come up with a historical background of work done.

3.5. Reliability and validity

3.5.1 Reliability

A good research design should be valid and be able to produce reliable results. Gwimbi and Dirwai (2003) defined reliability as the repeatability and consistency of the findings. A reliable measure does not fluctuate randomly and is used to discover relationships between variables. In this research, quantitative and qualitative designs were chosen to deduce impacts of sand and gravel extraction on the environment.

3.5.2 Validity

3.5.2.1 Internal validity

Polit and Beck (2008) defined validity as the ability of an instrument to measure a concept under study and to be able to measure it accurately so that any observed differences are true and not the result of random or constant errors. Instrument validity determines whether an instrument accurately measures that which it is supposed to measure. Gwimbi and Dirwai (2003) highlighted types of validity as content that is how well an instrument represents all the components of variables being measured. In this study, content validity was done by doing a thorough related literature search on which the contents of questionnaire and interview guides were based.

Face validity refers to justification of the study. It is weak when having little practical or theoretical relevance to the real world situation (Gwimbi and Dirwai, 2003). According to Polit and Beck (2008), face validity is a judgement done to determine whether an instrument appears to measure what it is supposed to measure. It considers if the tool is readable and checks clarity of the content. This was done in this study through pilot testing when the questionnaire was administered to a small group of respondents before actual data collection to get a general impression about the kind of answers that could be expected. Validity and reliability of questionnaire and interview guide questions was also done by sending copies to the UNISA's Department of Environmental Science for checking and corrections. Gwimbi and Dirwai (2003) defined analytical validity as ability to realise if correct data analysis methods were chosen to avoid wrong conclusions. In the research, data analysis was done using both quantitative and qualitative analysis tools like descriptive statistics and Statistical Package for Social Science. A statistician was engaged to help with analysis of data.

In this research, to ensure validity of data generated, various methods of collecting data were used. These were questionnaire survey, interview guides, field measurements and taking photographs from mining sites. Many methods were used because each contains its own set of assumptions, strategies, strengths and weaknesses regarding the study of social world and the kind of data that can be produced to increase knowledge. Use of various methods helped to improve quality of research findings since conclusions from one method were used to check validity of results from another method.

3.5.2.2 External Validity

According to Gwimbi and Dirwai (2003), external validity is when results obtained in a study can be generalised to other people and settings. Generalisation is made considering degree of confidence in sample findings in relation to population and whether similar findings can be obtained at other times and places. The researcher met most of the respondents for the first time to explain the purpose of study, the relationship was formal and therefore the effect was minimal. This was important because if respondents are familiar with researcher, they may not provide true information and results will be biased. In this research external validity was influenced by the sampling methods used that is convenience and purposive sampling, therefore findings cannot be generalised to other settings.

3.6 Ethical considerations

3.6.1 Ethics

All research designs should consider ethics of participants and consider sensitivity of the issue. Gwimbi and Dirwai (2003) defined ethics as the acceptable moral principles developed by individuals or groups which govern the conduct of research with regard to sampled subjects, respondents and all stakeholders of the research process. In carrying out a research it is the responsibility of the researcher to protect the respondents from harm and provide them with adequate information on importance of research and enable them to withdraw when they want to.

3.6.2 Permission for study

The aim of this research was to find environmental impacts of sand mining and gravel extraction in Gaborone and surrounding areas. Written permission to conduct the study was sought and obtained from Ministry of Energy and Water Resources through the Department of Mines as well as from the College of Agriculture and Environmental Sciences (CAES), University of South Africa. The researcher applied for an ethical clearance from UNISA Ethics Committee before carrying out the study and permission was granted. The CAES ethics reference number is 2012/CAES/035. Since the study was mainly conducted in Kumakwane village, permission was also obtained from the chief of the area. Copies of consent forms providing information on nature, purpose and research process, assuring respondents confidentiality of data and information provided were made and issued to sampled respondents prior to commencing the study. Respondents were given an option to complete the questionnaire or decline. More time that is an additional one week was given to avoid rushing the subjects. Interviewees were also given options to write down their answers and allocated more time as a way of encouraging them to express themselves freely.

3.6.3 Respect for human dignity

Respect refers to an individual's right to voluntarily take part in a study. Subjects are to be given full information on nature of study and risks attached so that they can make informed choices to participate or not. Their decisions should not be influenced by other people or factors. Only when these conditions are satisfied, then consent is obtained (Polit and Beck, 2008). In this research, all subjects were informed verbally and through consent forms about the, benefits of the study. On every visit to mining sites, the researcher was accompanied by the village leaders and local police who were anxious to know what was happening at extraction sites and they understood the risks and dangers of going to the bushy areas mostly from illegal manual miners.

3.6.4. Freedom from harm

A research involving humans may cause physical, psychological, social or economic harm. A researcher should ensure any harm to study subjects is minimised and that there is a balance between risks and benefits (Polit and Beck, 2008). In this study, respondents were encouraged to participate freely and voluntarily. Contributions and suggestions given were important to policy makers on what can be done to conserve resources from environmental damage. They were given a chance to give possible solutions to reduce negative impacts on agricultural fields and rivers.

3.6.5. Anonymity, Confidentiality and Justice

Anonymity refers to a situation when the researcher cannot link data to respondents. This is when privacy is respected and respondents' identities are kept anonymous. Justice is fair treatment of all respondents (Polit and Beck, 2008). The researcher indicated clearly and stressed verbally on first meeting that the subjects were not supposed to write their names to maintain anonymity and confidentiality. Visits to mining and extraction sites were done in large groups consisting of village leaders and local police which increased security. They voluntarily and willingly accompanied the researcher to obtain first hand information on what is happening in rivers where river sand is mined and open land where pit sand and gravel are extracted. At the end of the study, the researcher will give feedback and submit copies of the research to the Ministry of Energy and Water Resources' Department of Mines, Ministry of Education and Kumakwane village leaders as per requirements of study permit.

3.7. Data presentation and analysis tools

Quantitative and qualitative data analysis methods were used. Throughout the research, data was collected through observations of affected sites, taking photographs, measurements of depth, width, length of the river, pits and trenches once per fortnight and per month. The services of a statistician were sought to analyse data in this research process. Descriptive statistics was used to compare and contrast data collected on degree of extraction. The measurements and data collected from sampled points where pit sand, river sand and gravel extracted were analysed using Statistical Package for Social Science (SPSS version 17). The demographic data of mean age, distance of home from extraction site and the mean of involvement by villagers in extraction activities was calculated. Further analysis was done to find approximate volume of sand and gravel extracted considering sizes of pits, trenches and widening of the river. Data collected was further presented on tables, pie charts and histograms. These are easy to interpret and simplify the results. The information collected was used to suggest solutions and make recommendations for mitigating negative impacts. Plates were used to show primary data collected on visits to sampled sites. Secondary data was collected from related literature sources.

3.8 Summary

This chapter discussed methodology employed in data collection process on the research to find environmental impacts of sand mining and gravel extraction. This chapter also described fully the overall plan of how the whole research was carried out including research designs used, method of data collection and analysis of the results.

CHAPTER FOUR: DATA ANALYSIS, PRESENTATION AND DISCUSSION

4.1 Introduction

This chapter discusses results and findings of a research on environmental impacts of sand mining and gravel extraction for urban development in Gaborone. Data was collected through individual interviews, questionnaire survey, field measurements and observations. The researcher considered and sampled some areas where pit sand, river sand and gravel are mined around Gaborone to investigate the extent of the effects caused by miners on the environment. One hundred and seventy five (175) respondents were picked as a sample to take part in the questionnaire survey. One hundred and five (105) were from Kumakwane while seventy (70) were from Metsimotlhabe villages. Interviews were conducted on people who are directly and indirectly involved in sand mining and gravel extraction.

4.2 Demographic data of respondents

Respondents in this study were both males and females. The inclusion criteria for the questionnaire survey was on any male or female above 21 years who was available in a sampled household and voluntarily take part in the study.

4.2.1 Distribution of respondents by gender

Table 4.1: Distribution of respondents by gender

Gender	**Frequency**	**Percentage**
Male	106	64.6
Female	58	35.4
Total	**164**	**100**

Table 4.1 shows 106 males and 58 females were considered for data analysis. The sample size for the questionnaire survey was 175 but only 164 respondents were considered for the analysis of results because eleven questionnaires were discarded since seven were incomplete

while four respondents misplaced their copies. Of the 164 who formed the final sample, 64.6% were males and 35.4% were females. More males were willing and interested in taking part in the research because sand mining is a male dominated activity. Very few women are involved in sand and gravel extraction and rarely visit the areas so are not aware of what exactly happens at mining sites.

4.2.2. Distribution of respondents by age

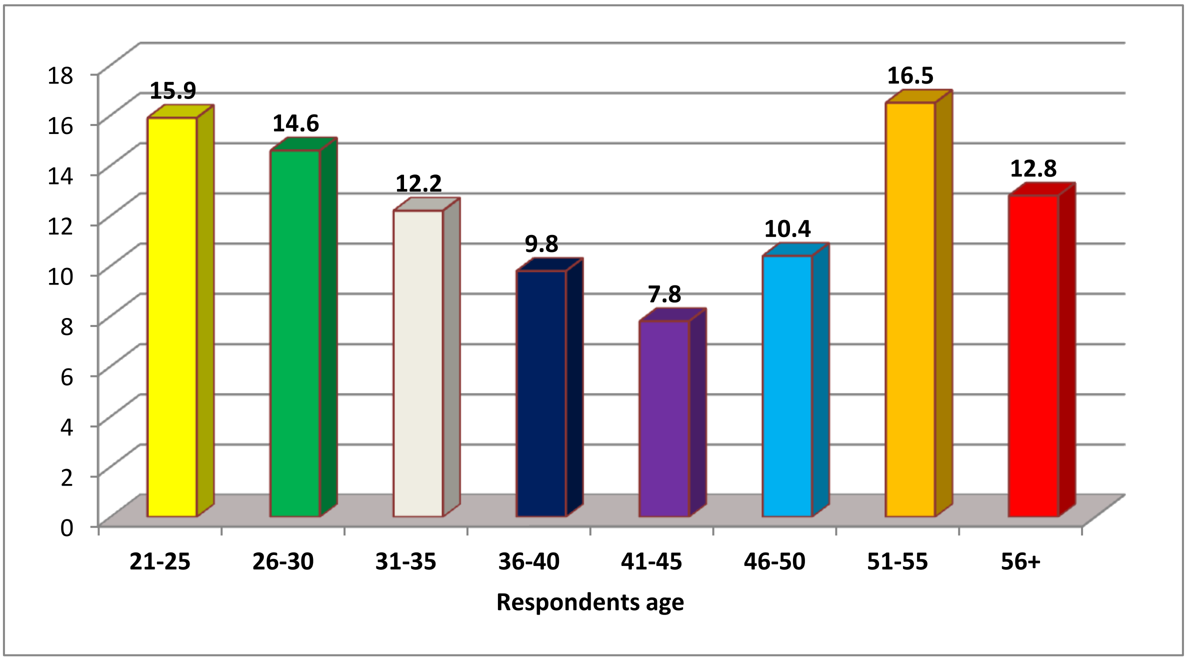


Figure 4.1: Distribution of respondents by age

Figure 4.1 shows the modal age group, 51-55 years. This is because respondents in this age group were readily available and willing to take part in the study since they are affected most when sand and gravel are mined in or near their agricultural land. The median age group is 36-40 years. The data shows that there were fewer respondents for each age group between 31 and 50 years because they were not present in villages at the time of study and most reside in towns where they work. The 21-25 age group had a high frequency and consisted of young literate adults who could understand the questions and are aware of environmental issues.

4.2.3: Distribution of respondents by position in the village

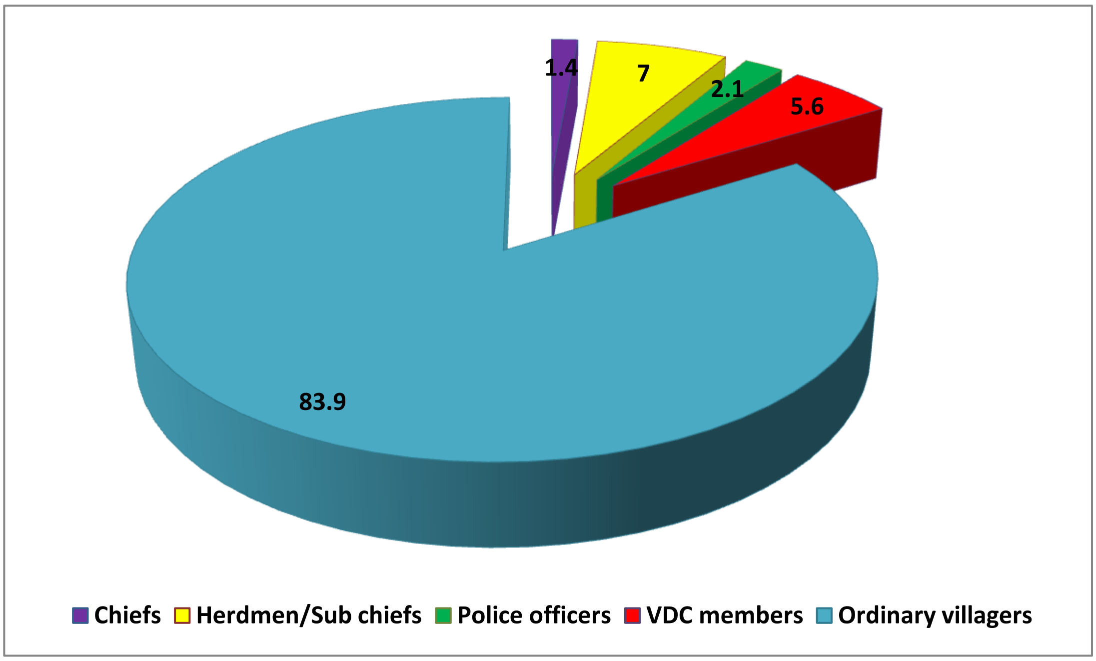


Figure 4.2: Distribution of respondents by position in the village

Figure 4.2 shows positions of respondents in their villages. The sample represented most positions in the villages including those in leadership. The modal class consists of ordinary villagers who form majority of the populations and are mostly the owners of agricultural fields where sand and gravel are mined. The respondents voluntarily took part in the study because they are the most affected members of the society and were willing to suggest solutions and make recommendations to law makers.

4.2.4: Distribution of respondents by distance of homestead from mining area

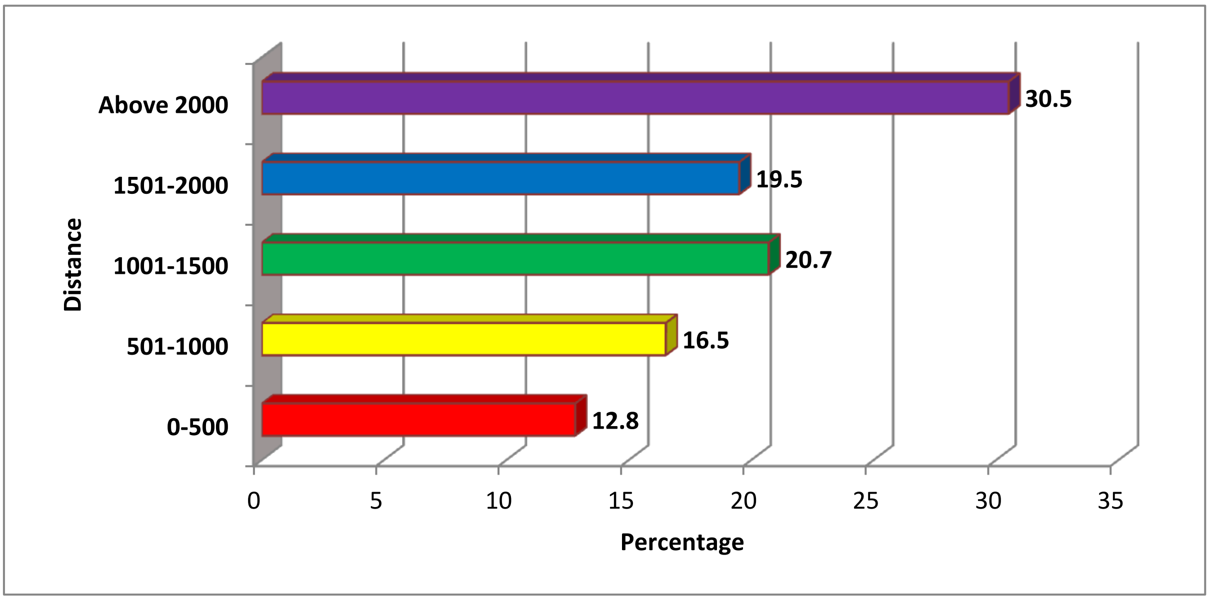


Figure 4.3: Distribution of respondents by homestead distance from mining areas

Data collected and represented in Bar graph on Figure 4.3 shows that fewer people live near mining areas. This is because the Land Tenure System of Botswana has residential areas on one side far from rivers while agricultural fields and grazing lands are on the other side towards the rivers (Wokorach, 2002). Mining of pit sand and gravel is mostly done on open bushy areas which can be grazing land or crop fields while river sand is mined from rivers and streams. Villagers in both Kumakwane and Metsimotlhabe who are involved in small scale mining of sand and gravel for domestic purposes transport the resources using one tonne trucks, donkey carts or wheelbarrows.

4.2.5: Distribution of respondents' homes by distance from gravel roads used by trucks

Table 4.2: Distribution of respondents' homes on distance from the gravel roads used by tipper trucks.

Distance from gravel roads in metres	**Frequency**	**Percentage**
0-500	42	25.6
501-1000	32	19.5
1001-1500	29	17.7
1501-2000	26	15.9
Above 2000	35	21.3
Total	**164**	**100**

Table 4.2 shows that the modal class is 0-500 meaning many people live near gravel roads used by tipper trucks transporting sand and gravel. Kumakwane villagers dominated this range because trucks from both Metsimotlhabe and Ditlhakane rivers carrying river sand pass through gravel roads in the village. Pit sand and gravel are also extracted from Kumakwane lands therefore more respondents are in 501-1000 metre range. This means Kumakwane villagers are affected more by air pollution in form of dust and noise pollution as negative impacts of soil mining from tipper trucks passing day and night than Metsimotlhabe villagers who were sampled. Few gravel roads from the river pass through the village and this is why the respondents from the village dominated the 1501-2000 and above 2 kilometre distance ranges. Trucks pass through the village when using main tarred road to Gaborone so less villagers are affected by air pollution in form of dust and noise.

4.2.6: Visits to sand and gravel extraction sites

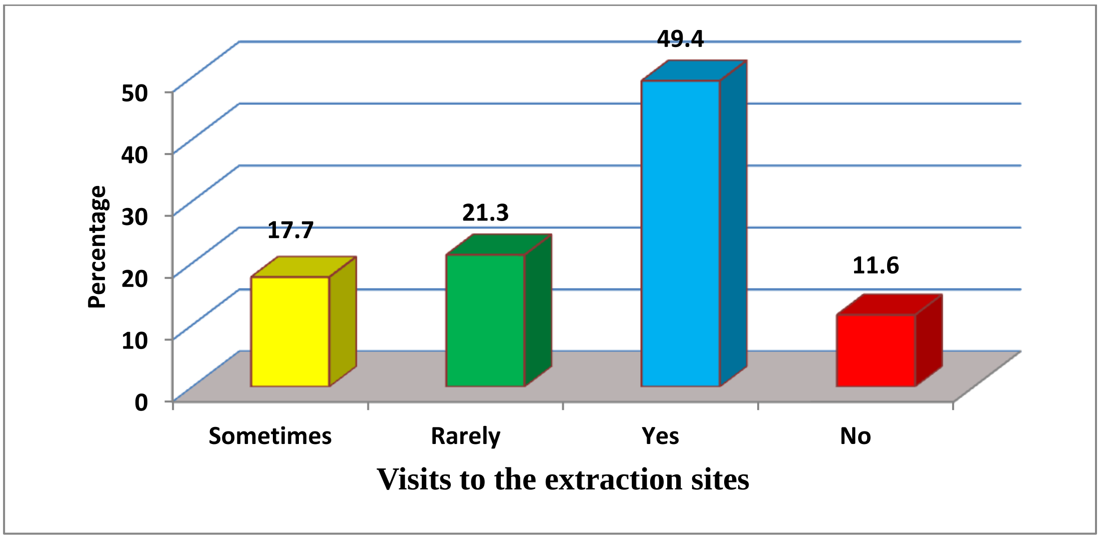


Figure 4.4: Respondents' visits to extraction sites

Figure 4-4 shows that many villagers (49.4%) visit sand and gravel mining areas regularly for various reasons. Most respondents who indicated that they visit extraction sites were men, fifty years and above who go to the farming lands as well as herding livestock. There were many respondents below 30 years who indicated that they never visit extraction sites. This is because it is most likely some are schooling and have little interest in mining as an activity. Few respondents below thirty who indicated that they visit mining sites because they are seeking or on part time jobs to load tipper trucks manually. Women dominated the sometimes and rarely options probably because they are ever occupied by other duties in homes and are not involved much in sand mining activities.

4.2.7: Activities of respondents at and around mining areas

Table 4.3: Activities of respondents

Activity	**Frequency**	**Percentage**
Get domestic water	24	13.9
Soil mining	21	12.1
Fishing	15	8.7
Gardening	21	12.1
Farming	37	21.4
Herding livestock	35	20.2
Others	20	11.6
Total	**173**	**100**

Data collected and displayed in Table 4.3 show that residents of Kumakwane and Metsimotlhabe visit gravel extraction and sand mining areas regularly for various purposes. The main activities are farming and herding livestock by mostly male mature respondents with 21.4% and 20.2% respectively. Soil mining is done by few villagers (12.1%) as private businesses and for domestic purposes. Respondents gave other activities (11.6%) as they visit mining areas for recreational and leisure purposes and on their way to the fields. Local police officers patrol mining areas during the day and at night to arrest and confiscate sand from illegal miners. This is done with help from neighbouring farmers who formed watch groups to guard the extraction sites near their fields. Few women are working for licensed companies as checkers and recorders of trucks loaded per day. Five (5) respondents from the 21-25 age group and seven (7) from 26-30 age group indicated that they visit mining areas when they are on part time jobs to load trucks manually.

Respondents who indicated that they do soil mining, had to explain what they use soil for. Twenty one (21) respondents who indicated that they are involved in sand and gravel mining, 33.3% use it for domestic purposes which include building houses and brick moulding, 57.1% are involved directly in the activity as manual loaders and brick moulding while 9.5% are those who check loading of trucks. When asked about how often they collect soil and what they use for its transportation, some respondents informed the researcher that they buy from the tipper trucks passing through the village at P400-P500 per five tonne truck only when they need it. Ten (10) respondents indicated that they mine sand and gravel on small scale using only for domestic use, transporting with donkey carts. Five (5) respondents use wheelbarrows, loading with spades and mine rarely.

4.2.8: Approximate number of trucks transporting sand and gravel passing through the villages daily

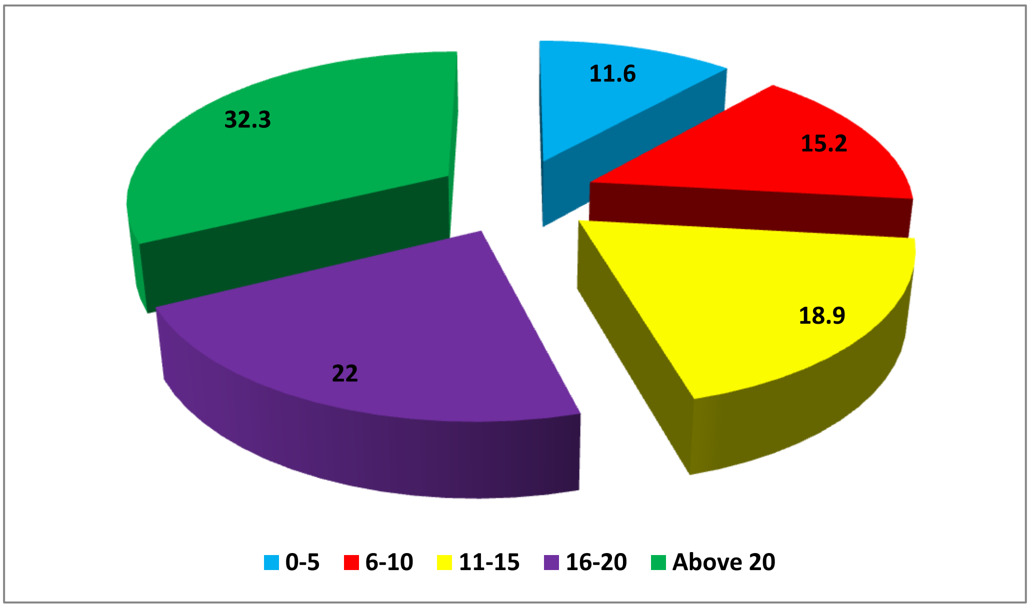


Figure 4.5: Number of trucks passing through the village per day

Figure 4.5 show that all respondents have observed tipper trucks passing through the village though they could not state the exact number. About 32.3% respondents indicated that more than twenty (20) trucks pass through the villages which form the modal class. Data collected from interviews show that less mining is done during the day by licensed companies. Illegal mining is done at night between 18:00 and 06:00 and on weekends which made observing and giving exact number of trucks difficult. Some villagers indicated that more than one hundred trucks pass daily on approximation. The conclusion is that a lot of sand and gravel are mined every day by both legal and illegal miners.

4.3 Questionnaire respondents' general views on sand mining and gravel extraction

The study was carried out to find the environmental impacts of sand and gravel mining. Respondents had realised both positive and negative impacts of the activity and were asked to give general views on mining of soil as well as possible solutions and rehabilitation programmes that can be implemented.

4.3.1 Advantages (positive impacts) of sand mining and gravel extraction

Respondents were asked to outline the advantages of extracting soil from the environment and these were responses obtained:

4.3.1.1. Benefits to residents

Respondents are of the view that extraction of soil:

- Create employment for youth as drivers and loaders (22.3%).
- Villagers buy river sand and gravel at cheap prices since they reside near mining areas (24.6%).
- Many people are affording to build modern, durable and strong houses at cheap cost as sand and gravel are readily available locally (26.9%).
- There is development of the village and country in form of tarred roads, shopping malls and modern infrastructure (14.9%).
- A source of income to individuals who mine and sell sand and gravel or transport for people on small scale using small trucks and donkey carts (7.4%).
- Moulding of bricks for sale is cheap in small scale businesses for individual villagers (4%).

4.3.1.2. Benefits to the community

Respondents believe that the benefits of soil and gravel to the community include:

- Development of villages and better infrastructure (31.4%).

- Source of income to Village Development Committees (VDC) to build houses for rental as well as selling sand and gravel confiscated from illegal miners by local police when raiding mining areas and mounting road blocks (14.7%).
- Cheap raw materials leading to construction of roads and houses at cheap cost (19.2%).
- Growth of cities and towns in form of malls, schools, hospitals and residential areas and creation of employment (21.8%).
- Create rain water catchment points for watering livestock (9.6%).
- Reduces river siltation, for fast water flowing and less stagnant water in pools (2.6%).

Discussion

Generally villagers are aware of sand and gravel extraction and benefits of the activities. Development of infrastructure, use of cheap resources in building, employment creation and source of income for VDCs were noted as positive impacts.

4.3.2 Disadvantages (negative impacts) of sand mining and gravel extraction

4.3.2.1 Respondents' views on the activity

Respondents who participated in the study were asked to share their views about sand mining and gravel extraction, these were the responses:

- Tried to stop the activity in vain, now have given up on the issue and waiting for the police and land board to act (5.7%).
- Do not like the activity since it destroys the environment, vegetation, rivers, ecosystems, crop fields, grazing lands leading to shortage of land (17%).
- Miners should be stopped because this is not a good activity (8.5%).
- Miners create deep gullies and cause deep pits which cause accidents for people and animals, so must cover pits after mining (14.2%).
- River sand mining leads to deepening of rivers, land degradation, destroy soil structure and cause soil erosion (6.6%).
- Mining must be done in one area and avoid extracting from people's fields (9.4%)

- Sand and gravel extraction are good activities which lead to development of the country but it is overdone and leads to destruction of the environment (8.5%).
- Mining should be controlled and done only by licensed companies after getting permission from local authorities (9.4%).
- The activity will finish sand in rivers and cause floods during the rainy season (7.5%)
- The activity disturb recreational activities for example fishing and swimming (10.4%).
- Others indicated that there is no smooth flowing of water in rivers. 2.8%.

Discussion

Respondents sampled from Kumakwane and Metsimotlhabe villages showed disgruntlement over sand and gravel mining activities. They felt that illegal mining practices are destroying the environment. The activities are overdone on rivers and open areas, disturbing recreation such as fishing and swimming.

4.3.2.2. Negative effects of sand and gravel mining on people's lives

Respondents were also asked to share their views on the effects of soil mining in their lives and gave the following:

- Illegal miners are dangerous to farmers and villagers as they bring sharp objects and spades to fight police and watch groups mostly at night (3.7%).
- Trucks from Gaborone bring and dump waste such as used diapers, building rubble, empty bottles in open areas and pits left after mining. Waste spread all over the villages which become untidy and pollute the land (21.2%).
- Many ugly deep pits are left uncovered. During rainy season they will be filled with water and become dangerous to people and livestock. These are breeding grounds for mosquitoes which spread malaria (5%).
- Sand and gravel mining is increasing crime in the villages as many young people both citizens and non-citizens come to wait for trucks going to collect sand and gravel to be hired as manual loaders but when not hired they resort to stealing at night (12.9%)
- Mining cause erosion, destroys grazing land and vegetation (5.4%).
- The activity cause shortage of water in rivers for watering livestock and disturb recreational purposes like fishing, swimming (4.6%).

- Tipper trucks produce a lot of noise pollution mostly at night as illegal mining is between 18:00 and 06:00am when police are less active. Too much noise and impact causing cracks on nearby houses and buildings (10.4%).
- Continuous movement of trucks cause air pollution in form of dust (11.2%).
- Movement of trucks destroy gravel roads (4.1%).
- Cause floods during the rainy season (3.3%).
- Mining deepens rivers and widens river banks (5.8%).
- Many road accidents are caused by slow moving tipper trucks and they also cause traffic congestion (5%).
- Small stones from uncovered sand and gravel when being transported destroy windscreens of cars following behind (2.9%).
- Others are of the view that mined river beds collapse which is dangerous to animals and people (4.6%).

4.3.2.3. Negative impacts of mining observed by respondents

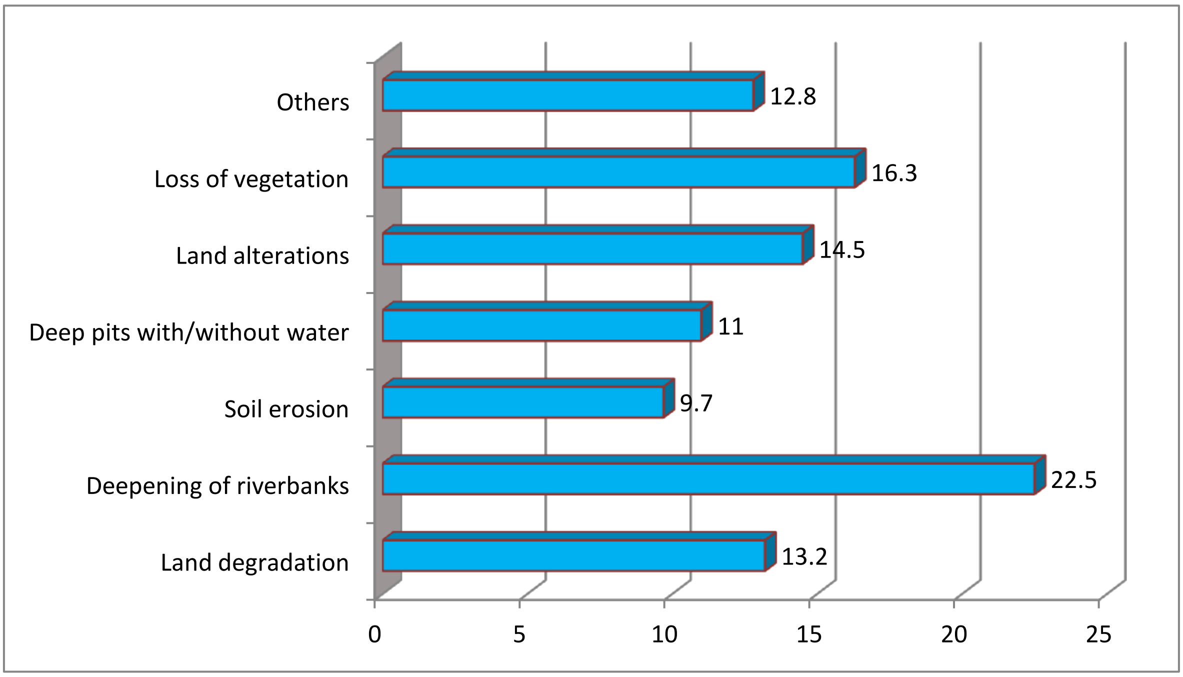


Figure 4.6: Negative impacts observed by respondents

Figure 4.6 shows a list of negative impacts which were given in the questionnaire responses. Most respondents indicated that they are aware of sand mining and gravel extraction going on in their areas so they had observed the following impacts:

- Deepening of riverbanks (22.5%).
- Alteration of the landscape (14.5%).
- Loss of vegetation (16.3%).
- Land degradation (13.2%).
- Other impacts observed by 12.8% of respondents include: livestock stuck in river beds when drinking water, pollution of land as the drivers bring waste from Gaborone and dump in pits and open areas. Waste such as plastics and diapers are eaten by cattle. Building rabble, empty tins and bottles dumped on open areas making the environment dirty. Destruction of grazing lands, agricultural land and noise pollution mostly at night from tipper trucks was also noted. Burnt tyres and engine oil spilled on riverbeds and ground caused land pollution. Air pollution by dust from gravel roads used by trucks. Children and livestock fall into open pits during rainy season. Influx of miners in villages increase spread of Human Immuno Deficiency Virus (HIV) and other sexual transmitted diseases.

Discussion

Respondents are aware of negative effects of sand and gravel mining with majority (21.2%) complaining of waste dumped on the open fields and in rivers. More impacts highlighted were land degradation, pollution, road accidents and increase in crime rate. On the survey when some of the impacts noted were listed, respondents indicated that majority (22.5%) had realised deepening of Metsimotlhabe and Ditlhakane riverbanks due to mining.

4.3.2.4. Accidents reported during soil mining

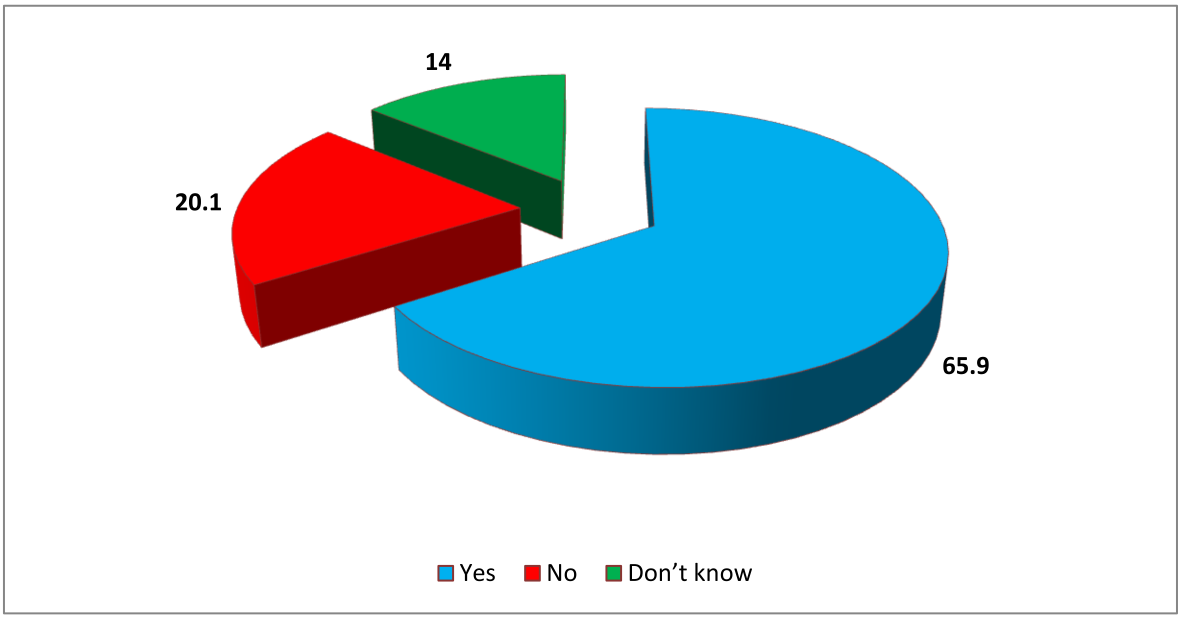


Figure 4.7: Number of accidents reported during sand and gravel mining

Figure 4.7 indicates respondents' responses on accidents reported due to mining. Majority (65.9%) of the respondents who participated in the study are aware of accidents in both deep pits where soil is extracted and on roads caused by trucks transporting it. Some (20.1%) argued that there are no accidents caused by these trucks while (14%) indicated that they don't know if there are accidents caused by trucks or at mining sites.

Respondents discussed types of accidents that had been reported in their villages which included:

- Children attempting to swim and drown in deep pits left by miners (40%).
- Mined river banks fell on miners and they died (17.4%).
- Slow moving or speeding overloaded tipper trucks cause road accidents in the village and on main tarred and gravel roads as well as causing traffic congestion (16.2%).
- A lot of breakdowns from tipper trucks which are not road worthy (9%).

- Small stones falling from loaded trucks damaging other cars' windscreens when transporting uncovered sand and gravel (17.4%).

When asked about their reactions to these accidents caused by the miners, the respondents had different views as follows:

- Residents are furious and want illegal miners to be jailed (18.9%).
- They are not happy and disturbed by the sand and gravel mining activities which destroy their agricultural land, cause many accidents leading to death of people in the community (31.7%).
- Miners should ask for permission from village leaders and be given a limited and controlled area to mine (20.1%).
- Villagers explained that they have reported to the village leaders and police so that such activities can be stopped by the law makers (14%).
- Complaints had been made to regional authorities and now residents threaten to strike by throwing stones at trucks, blocking the gravel roads passing through the villages using tree branches and stones (8.5%).
- Sand and gravel block main roads when trucks have accidents and are forced to off load (6.8%).

Discussion

Many residents indicated that they are aware and not happy with many accidents occurring involving children, livestock and miners due to sand and gravel mining activities. The accidents are on roads and in open pits left by miners. They feel there should be more police patrols, twenty four security and public education specifically children on dangers of swimming in stagnant water.

4.3.3. Solutions and rehabilitation to sand and gravel mined areas

The study allowed the villagers to give suggestions on solutions to sand and gravel activities in their areas. When asked about what they can recommend as the immediate solutions to the negative impacts of sand mining and gravel extraction, respondents gave suggestions at community, district and national levels (Botswana as a whole).

4.3.3.1: Solutions at community level

The following are some of the suggestions given by respondents to be done at community level to reduce negative impacts of sand and gravel extraction:

- Respondents volunteered to form committees, clusters and watch groups to monitor, supervise and guard mining areas with help of VDC (6.9%).
- Twenty four hour security to be employed to apprehend illegal miners on daily basis (11.3%).
- Only miners with licences should be allowed into mining areas and stop illegal miners through tight security (5.9%).
- Reuse and recycling of building material to reduce demand for river sand, pit sand and gravel (2.5%).
- Tipper trucks should not be allowed to use gravel roads passing through villages but roads outside residential areas to reduce dust causing air pollution (17.2%).
- Construction of soil conservation structures to reduce soil erosion (3.4%).
- Sand and gravel miners should pay royalties to the village leaders so that the community benefit directly (9.4%).
- Consultations to be done by land boards with village leaders before permits are issued so that they may be involved in surveying land and recommend on where to mine (15.3%).
- All community members must cooperate and report illegal miners to responsible authorities instead of harbouring them (3.4%).
- All trucks transporting sand and gravel should pass through village leaders for inspection and verifying licences since some miners use fake documents (5.4%).
- Village leaders including chiefs must be involved in imposing punishments to illegal miners and confiscate sand then sell it to benefit the whole community (14.3%).
- There must be regular formal meetings between miners and all stakeholders affected by the activity to discuss the impacts and come up with a way forward to the issue (4.9%).

4.3.3.2: Solutions at District level

Respondents suggested the following:

- Issuance of permits and licences to be strictly done on condition that miners will be monitored by Land Board and ensure that pits are covered as rehabilitation (29.9%).
- Allow sand mining to be done only during certain seasons of the year but not in rainy season (19.7%).
- Number of permits and licences issued must be very minimal (7%).
- The committees formed to guard and monitor mining should control and restrict number of truck loads per day (3.8%).
- Restrict time of harvesting which should only be done during the day (13.4%).
- Sand and gravel mining must not be done on one area but alternating sites to reduce over extraction which destroy the environment beyond rehabilitation (14.6%).
- Regular patrols must be done by Land Board, Department of Mines and police to restrict some areas for example riverbanks, near schools, clinics or residential (8.3%).
- Land Board should compensate affected citizens (3.2%).

4.3.3.3 Solutions at national level

Respondents suggested the following to be done at national level to prevent or reduce the negative impacts of soil extraction:

- Strict laws and legislature to prohibit and control mining, buying and selling of sand and gravel which include severe punishments like arresting illegal miners, heavy fines and penalties of up to P20000, long imprisonment sentences such as up to 10 year jail term (24.3%).
- Controlling number of permits and licences issued (18.1%).
- Close monitoring and evaluation of the activity (4%), restrict mining in summer and during rainy season (7.3%).
- Construction of separate gravel roads for tipper trucks to reduce traffic congestion, accidents as well as noise and air pollution (6.8%).
- Mining should use dry pit method of mining (2.1%).
- Prohibit sand and gravel mining at night (9%).

- Covering sand and gravel on transportation to be a prerequisite (5.1%).
- Twenty four hour security on mining areas with help of Botswana Defence Force to scare off illegal miners (1.7%).
- Regular meetings between Land Board, Department of Mines and village leadership to discuss the soil mining activity and possible impacts (5.6%).
- Educate and inform public about the impacts and accidents caused by sand and gravel mining through media for example television, radio and newspapers (7.3%).
- Heavy police patrols and road blocks on roads to and from mining areas to arrest illegal miners and confiscate the soil (10.7%).

Discussion

Villagers of both Kumakwane and Metsimotlhabe gave many suggestions as solutions to sand and gravel mining. Strict laws, regular meetings and consultations, restriction of mining time, recycling of resources and issuance of licences were some of the solutions noted. All these means as the residents are aware of the environmental impacts and are willing to be involved in reducing the negative effects.

4.3.3.4: Rehabilitation programmes to sand mining and gravel extraction

The study required villagers to suggest rehabilitation programmes which could be implemented in their communities and on sand and gravel mining sites. Respondents suggested several rehabilitation programmes that could be implemented in their areas which included:

- Covering of pits created by all miners as a way of rehabilitation (26.8%).
- Replanting vegetation on mined areas to prevent further damage (20.5).
- Construction of special roads for tipper trucks to reduce accidents and pollution (12.6%).
- Perpetrators must be stopped from mining in residents' fields without permission (11.1%).
- Miners should be educated on short and long term negative impacts of continuous mining from same areas through regular meetings (7.4%).
- Close monitoring and evaluation of mined areas (6.8%).

- Use of alternative resources to river sand and gravel such as crushed stone (2.1%).
- Prohibit dumping of waste by placing signs on all open areas (2.1%).
- Open a dumping site or landfill next to sand and gravel mining areas to reclaim land since there are none near Kumakwane village (2.6%).
- Fence abandoned pits and use them as water source for livestock (5.8%).
- Use of open pits as dumping sites and landfills (2.1%).

Discussion

Several rehabilitation programmes were also given by the villagers which can be implemented in their communities. Covering of pits created by mining was the general consensus of villagers because of the problem of waste dumped in these pits. Respondents were very cooperative and willing to suggest on what can be done to curb environmental damage caused by sand and gravel mining.

4.4 Interview respondents' general comments on sand and gravel mining

Interviewing key people directly or indirectly involved in sand and gravel mining was one of the methods used to compile data in the research. The researcher interviewed Kumakwane chief on background to mining and discovered that the activity started around 1989 when Gaborone started to expand at a faster rate. Miners were extracting mainly river sand from Metsimotlhabe river for construction of suburbs such as Block 5. There were no consultations done with village leaders before mining. The activity now involves many people but mostly illegal miners. Village leaders with help of local police patrol mining areas on several occasions to confiscate sand and gravel from illegal miners. The soil is then sold by Village Development Committee to communities and government departments at P3 per medium size wheelbarrow. The village leaders had received complaints from villagers mostly on the damage to their land and dumping of waste in the village. Negative impacts highlighted were mining is done everywhere so water in rivers take wrong route, destruction of vegetation, creation of dangerous deep pits and destruction of agricultural land. Solutions suggested were need for 24 hour security with help of Botswana Defence Force to be employed at mining areas including regular consultations and meetings between Department of Mines and village leadership.

In a separate interview with Department of Mines' Licensing officer, the researcher discovered that the department is responsible for issuing all mining licences with validity of 6 months up to 5 years to most mining activities including sand and gravel. The conditions for getting a licence include the company or individual obtaining a letter of surface rights with surveyed coordinates, sketch map plan and total area to be mined from land board, and get clearance on the quality and quantity of the resources. The company must apply for a waiver from Geological Surveys Department then a licence from Department of Mines.

Department of Mines is aware of illegal mining in the country. Officers from the Department always inspect and raid mining areas, mount road blocks with help of police, conduct and consult villagers for information, as well as confiscating trucks and sand (see figure 4.8). There are penalties to illegal mining and those who have licences but mine outside boundaries. Penalties depend on how frequent the miner does it, amount of sand extracted, how sensitive the area of extraction is and extend of destruction to the environment.

Figure 4.8: Authorities mount road block to arrest illegal miners

The officer explained that there are laws to govern mining activities such as the need for an Environmental Impact Assessment report from Department of Environmental Affairs before a licence is issued. The miner must include in his plan, an environmental reclamation plan, methods of mining, how to access the mining area from one side to reduce damage to the environment.

Positive environmental impacts noted were creation of employment, utilisation of resources, low cost of construction using cheap and readily available resources and sand mining can be done with less investment. Negative impacts given were permanent environmental damage, destruction of river banks and ecosystems, contamination and scarcity of water, naked riverbed and deep pits causing accidents to livestock and children. Solutions to illegal mining included close monitoring, cancellation of licence, heavy penalties like long jail term for mining on sensitive areas such as a school and confiscation of vehicles. Public awareness and education is necessary. There is need for identifying alternative sources to river sand, a most sensitive resource for example use of sand bearing rocks.

In an interview with Department of Mines Environment officers, the EIA and Mines and Minerals Acts were highlighted as some of the policies protecting the environment from damage due to mining. EIA is done by the Department of Environmental Affairs who give the final clearance, then Mines department review and give advice on the reports. Positive impacts noted were revenue collection and infrastructure development. Negative impacts included destruction of vegetation and environment, widening of river banks increasing chances of flooding, deep pits not rehabilitated and pollution due to dust. Solutions included the need for finding alternative sources to river sand such as crushed stone from quarries.

In an interview with the Village Development Chairperson, he suggested that miners should meet with the village leaders to get permission. VDC then writes a letter of acceptance to land board for a certificate to be issued before the mining area is allocated and paid for. There is need for consultation before mining rights are given then close monitoring during the activity. Positive impacts given were development of roads and villages. Negative impacts included accidents involving miners and children, destruction of agricultural land. Solutions noted were miners must mine up to acceptable depth and the law of mining should be followed which state that 2.5 metres should be left on both sides of the river bank and mining should be done in the middle of the river. Close monitoring and rehabilitation of the land is a prerequisite.

Tipper truck drivers were interviewed when found at mining sites. Most of the drivers were foreign nationals. They indicated that collection points depended on where they are to deliver the soil. River sand is highly demanded and transported most which can be 4-5 loads per day on average depending on distance to the contract site. Clients are mostly individuals building residential homes and even companies. Charges per load depend on individuals, type of soil, size of truck and distance to delivery point. Pit sand and gravel loads are cheaper than river sand. The charges range from P1200 to P1800 per load. Positive impacts noted were source of income and construction of roads and houses. Negative impacts were river beds are deepening and shortage of water for livestock. Generally, they recommended other miners not to overdo it in one area.

More interviews were done with officials from Kweneng Land board and police officers. The land board officials indicated that they are the only board responsible for issuing surface rights before an applicant can acquire a mining licence from the Department of Mines. There are penalties for mining without a licence. Individuals are charged P10000 while companies pay P20000 for mining without surface rights. Issuance of mining rights had been frozen for the past five years and that is why there is an increase in illegal mining. Reports from police showed that they had dealt with the issue for a long time but the same illegal miners commit the same offences time and again. They are charged P1000 when caught but they still continue with mining. The police officers indicated that the size of excavations show that illegal sand miners have means of loading trucks. Negative impacts noted were dumping of waste which is eaten by livestock and farmers lose money from selling their cattle. Police officers highlighted regular raids and road blocks to get rid of illegal miners as shown on Figure 4.9 though illegal miners always drive off to avoid being arrested.

Figure 4.9: Police officers' regular raids.

Residents were also picked at random to share their views on sand and gravel mining. Ramagapu and Garamotlokwa land farmers expressed bitterness at the activities of illegal sand miners in Metsimotlhabe river. The miners are violent, armed with sharp objects always overpower the farmers. In revenge, farmers team up to puncture the miners' trucks. The areas have belts of high quality sand attracting more miners. Impacts noted were depletion of river sand and there is nothing to hold water for livestock. In a separate interview, a resident of Kumakwane complained of illegal gravel mining in her farm mostly at night. The villager indicated that mining in the farm started in 1999 when a small area was given off by land board for mining. The activity became uncontrollable and illegal miners collect gravel from the field day and night. The issue had been reported to responsible authorities at district level for possible solutions and rehabilitation of the land.

4.5 Field measurements and observations

The researcher visited and sampled sand and gravel extraction areas to observe and take measurements within six visits. However, the visits to mining sites were not consistent within the first two months between December 2012 and January 2013 due to lack of people to accompany the researcher because it was festive season and lack of transport. There after visits were done every fortnight. For each component, 4 sites were sampled that is A, B, C where mining is going on and D undisturbed area as the control.

GRAVEL EXTRACTION

SITE A

Table 4.4: Field measurements from gravel extraction Site A

Fortnight	**1**	**2**	**3**	**4**	**5**	**6**
Date	**14/12/12**	**13/01/12**	**10/02/12**	**24/02/12**	**10/03/12**	**24/03/13**
Pit depth(m)	40.8	40.85	40.9	40.9	42.1	42.3
Pit width(m)	38	39	39.3	39.4	39.9	41.2
Pit length(m)	185	187	187	209	211	212
Water present	Yes	No	Yes	No	No	No
Trucks/miners present	No	No	No	No	No	No
Dumped waste present	Yes	Yes	Yes	Yes	Yes	Yes
Mining in progress	No	No	No	No	No	No

Table 4.4 above shows the field measurements collected in six visits from sampled gravel extraction point A. Depth of pit was showing a slight increase on each visit to give a difference of 1.5m when the initial depth was 40.8 m and final depth was 42.3 m. The width showed an increase of 3.2m while the length of pit increased from 185m to 212m in six visits. General increase in size of pit was due to erosion since there was no more mining going on.

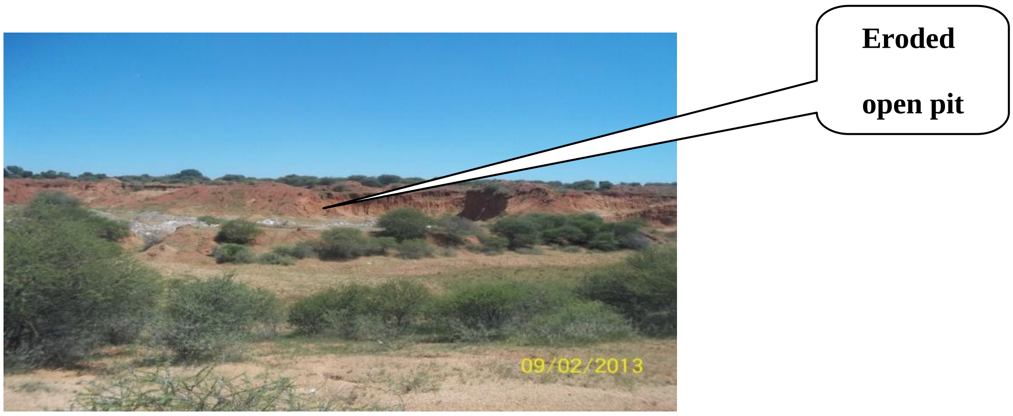


Figure 4.10: Eroded open pit on sampled Site A

Figure 4.10 shows sampled gravel extraction Site A. The researcher observed that no more mining is going on as the depth, width and length were increasing due to erosion. The area is now a huge dumping site for waste by illegal miners from Gaborone which is done at night and violent when approached.

SITE B

Table 4.5: Field measurements from gravel extraction Site B

Fortnight	**1**	**2**	**3**	**4**	**5**	**6**
Date	14/12/12	13/01/12	10/02/12	24/02/12	10/03/12	24/03/13
Depth of pit (m)	20	20.2	29.1	33.9	35.3	37.6
Width of pit (m)	81	105	117	125	127.1	129.6
Length of pit (m)	140	164	181	192	193.2	194.8
Water present	No	No	Yes	Yes	Yes	Yes
Trucks/miners	No	No	No	No	No	No
Dumped waste	No	No	No	No	No	No
Other things observed	Fresh wheels	Branch to prevent sinking	Empty fuel containers	Spilled oil, empty containers	No waste observed	Spilled oil, fresh wheels

Measurements in Table 4.5 show that the depth of sampled pit was increasing on every visit. During first week, 20m was recorded as the depth and this increased to 37.6m in 6 visits, while the width of pit increased from 81m to 129.6m and the length from 140m to 194.8m. The approximate volume of gravel extracted considering the measurements obtained in the first visit was 226800 cubic metres. This increased to 949252 cubic metres by the sixth visit, showing that an approximate 722452 cubic metres of gravel had been removed from the site. Results showed that mining was still going on though no trucks were seen on the site. Data collected from interviews, revealed that illegal miners extract gravel at night.

Figure 4.11: Tree branches on ground to prevent sinking on sampled Site B

Figure 4.11 shows sampled site B where gravel is extracted. Fresh track wheels, empty fuel containers and tree branches cut and placed on ground to prevent sinking were observed and noted as evidence of mining in progress. The pit is deepening and widening as a result of continuous mining. Soil erosion is also taking place on the sides of the pit.

SITE C

Table 4.6: Field measurements from gravel extraction Site C

Fortnight	**1**	**2**	**3**	**4**	**5**	**6**
Date	14/12/12	13/01/12	10/02/12	24/02/12	10/03/12	24/03/13
Depth of pit (m)	5.7	6.1	6.8	7	8.8	9.3
Width of pit (m)	171	175	187	194	197	197.8
Length of pit (m)	198	211.5	225	229	231	231
Water present	Yes	Yes	Yes	Yes	Yes	Yes
Trucks/miners	No	No	No	No	No	No
Dumped waste	No	No	No	No	No	No
Other things observed	Heaps of gravel	Cut Branches	Wheel tracks	Dumped tyres	Stock piling of gravel	Fresh tracks
Mining in progress	Yes	Yes	Yes	Yes	Yes	Yes

Table 4.6 shows field measurements on depth, width and length of pit on sampled Site C. Pit depth increased from 5.7m to 9.3m within 6 visits. Width of pit increased from 171m to 197.8m while length increased from 198m to 231m. Approximate volume mined at the first visit was 192990.6 cubic metres which increased to 424933.7 cubic metres by the sixth visit, giving an approximate volume of 231943.1 cubic metres which had been removed. On every visit there was a change in size of pit, a sign of mining in progress. The sampled point is shown on Figure 4.12 below.

Figure 4.12: Stock piling and tree branches on ground, Site C

Mining in the sampled site was in progress as fresh tree branches on the ground, fresh wheel tracks and heaps of stock piled gravel were seen as evidence. No miners were seen on the sampled site but the pit was increasing in length and depth due to continuous mining.
The researcher concluded that mining is done at night.

SITE D

Figure 4.13: Undisturbed land (Control)

General comment
Land was flat with natural vegetation but now a dumping site for all types of waste. Gravel is mined from open areas and is less expensive than river sand because it has less uses. It is required mostly in making foundations, demand for resource is lower.

RIVER SAND MINING

SITE A

Table 4.7: Measurements from river sand mining Site A

Fortnight	**1**	**2**	**3**	**4**	**5**	**6**
Date	14/12/12	13/01/12	10/02/12	24/02/12	10/03/12	24/03/13
River depth (m)	16	17.5	19	19.9	20.1	21.8
River width (m)	125	129	133	135	135.2	135.9
Pit length (m)	10	11.3	12.1	13	13.9	14.4
Water present	Yes	Yes	Yes	Yes	Yes	Yes
Trucks/miners	No	Yes	Yes	Yes	No	No
Dumped waste	Riverbed, banks	Yes	Yes	Yes	Tyres and oil	Burnt tyre
Other things observed	Access road, fresh wheels	Trucks and manual loaders	Trucks and manual loaders	Trucks and manual loaders	Access road, branches of trees	Truck stuck
Mining going on	Yes	Yes	Yes	Yes	Yes	Yes

Table 4.7 shows that river depth increased from 16m to 21.8m at the sampled site A within six visits. River width increased from 125m to135.9m while the pit length where sand was mined increased from 10m to 14.4m. Deductions from data collected show that the river was widening and deepening at sampled site. Miners extracted river sand on the walls of the river as they preferred high quality river sand from inner layer as seen on Figure 4.14a

Figure 4.14a: Extraction of river sand from inner layer on Site A

Continuous extraction of river sand from banks had resulted in accidents and death of miners as revealed by interview results. Mining was in progress at sampled Site A. On several visits, manual loaders were found loading trucks but would always escape as seen in Figure 4.14b. as researcher visited the area accompanied by local police.

Figure 4.14b: Illegal miners escaping from raids at Site A

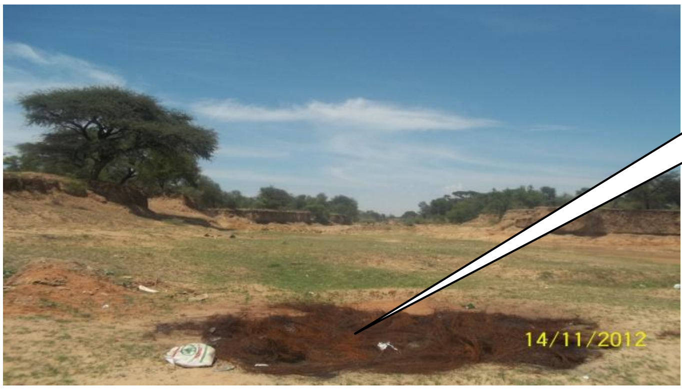
More evidence of mining was trucks loading on five occasions, access roads into the river and branches of trees to prevent sinking into wet ground. Rivers are widening and deepening as miners extract continuously from banks.

SITE B

Table 4.8: Field measurements from river sand mining Site B

Fortnight	1	2	3	4	5	6
Date	14/12/12	13/01/12	10/02/12	24/02/12	10/03/12	24/03/13
River depth (m)	11	13.9	14.3	14.6	14.9	15.2
River width (m)	55	71	83	84.2	85	85.8
Pit length (m)	7	7.3	7.9	8.3	8.4	8.9
Water	Yes	No	Yes	Yes	Yes	Yes
Trucks/miners	No	No	Yes	Yes	No	No
Dumped waste	Yes	No	Yes	Yes	Yes	Yes
Other things observed	Animal stuck	Spilled oil	Truck stuck	Burnt tyres	Spilled oil	Oil, empty containers
Mining in progress	Yes	Yes	Yes	Yes	Yes	Yes

Table 4.8 shows that river depth at sampled point increased from 11m to 15.2m in 6 visits, an increase of 4.2m. Width of river increased from 55m to 85.8m, an increase of 30.8m. Length of pit where sand was collected increased from 7m to 8.9m. Animals were stuck and drowning due to loosed sand particles. More evidence of mining observed included truck stuck on river bed, spilled oil and burnt tyres on river bed as seen on Figure 4.15.



Burnt tyres on a riverbed

Figure 4.15 Burnt tyres on river bed from Site B

Figure 4.15 shows a sample of burnt tyres on riverbed to provide light to the area when mining and warmth during winter season while waiting for the trucks to come and load. Interview results revealed that most of mining is done at night between 18:00-06:00 when villagers and police are not active. Generally, the river is deepening and widening at sampled site due to continuous mining though on most visits there were no trucks seen on site.

SITE C

Table 4.9: Field measurements from river sand mining Site C

Fortnight	**1**	**2**	**3**	**4**	**5**	**6**
Date	14/12/12	13/01/12	10/02/12	24/02/12	10/03/12	24/03/13
River depth (m)	25	37	45	46.3	47.1	47.3
River width (m)	74	74.1	74.6	74.9	75.3	75.5
Pit length (m)	43	60	77	79.9	81.2	81.7
Water present	Yes	No	Yes	Yes	Yes	Yes
Trucks/miners	No	Yes	No	No	Yes	No
Dumped waste	Yes	Yes	Yes	Yes	Yes	Yes
Other things observed	Dumped tyres	Dumped tyres, branches on tracks	Exposed rocks, tracks	River extension tree branches	River extension, signs of erosion	Fresh tracks of wheels, branches
Mining going on	Yes	Yes	Yes	Yes	Yes	Yes

Table 4.9 show measurements of depth and width of the river and length of the pit created by the miners. On the first visit, river depth at sampled point was 25 metres and this gradually increased to 47.3 metres by the sixth visit. River width on sampled point increased from 74 metres to 75 metres. A long river extension was developing and increasing in length on every visit from 43 metres to 81.7 metres by the sixth visit as seen on Figure 4.16 below. Miners continuously extract sand on river banks in search of inner layer with high quality sand. The river extension had been increased by erosion Mining was in progress as fresh wheel tracks c, tree branches and dumped tyres on river bed were recorded as evidence.

Figure 4.16: River extension due to mining

Tree roots on riparian zone are exposed due to continuous mining. Interviewees revealed that miners prefer inner layer and recently river banks collapsed at night killing three miners.

SITE D

Figure 4.17: Undisturbed land (Control)

There are no alterations on river channel. Depth and width of the river are not increasing due to mining but erosion as water flows during the rainy season. There is natural vegetation on river banks and water flows normally.

General comment

Interviews conducted with truck drivers and loaders, revealed that river sand is mined most as compared to pit sand and gravel. River sand highly demanded with many uses in construction and strengthening structures which makes it the most expensive soil component.

PIT SAND MINING

SITE A

Table 4.10: Field measurements from Pit sand sampled Site A

Fortnight	**1**	**2**	**3**	**4**	**5**	**6**
Date	28/11/12	12/01/12	09/02/13	23/02/12	09/03/13	23/03/13
Depth of pit (m)	13	13	13.2	13.5	13.5	13.6
Pit width (m)	77	77	78.1	78.3	79	79.4
Pit length (m)	1000	1000	1000	1000	1000	1000
Water present	No	No	Yes	Yes	Yes	No
Trucks/miners	No	No	No	No	No	No
Dumped waste	Yes	Yes	Yes	Yes	Yes	Yes
Other things observed	Formation of streams	Deepening depression	Deepening depression	Tyres, depression, erosion	Erosion, depression	Erosion

Table 4.10 shows the sampled Site A where pit sand was extracted in Kumakwane. There is no more mining and it seems the area was abandoned a long time ago. A depression had been formed which is increasing in width and depth due to erosion during the rainy season. Depth of depression at sampled point slightly increased from 13m to 13.6m within the 6 visits. Width increased from 77m to 79.4m while the length remained the same throughout the visits. The sampled area is shown in Figure 4.18 below

Figure 4.18: Formation of a stream

The depression left by mining activities is turning into a stream. There is re-growth of vegetation and the area is a dumping site for waste.

SITE B

Table 4.11: Field measurements from pit sand extraction Site B

Fortnight	**1**	**2**	**3**	**4**	**5**	**6**
Date	28/11/12	12/01/12	09/02/13	23/02/12	09/03/13	23/03/13
Depth of pit (m)	5	8.9	9.7	10.8	12.1	12.7
Width of pit (m)	25	27	28.1	29	31	32.5
Length of pit (m)	58	63	65.2	69.1	71	73
Water present	No	No	Yes	No	No	No
Trucks/miners	Yes	Yes	Yes	Yes	Yes	Yes
Dumped waste	No	No	No	No	No	No
Other things observed	JCB loading	Loading trucks	Loading truck	Trucks	Trucks	Trucks
Mining going on	Yes	Yes	Yes	Yes	Yes	Yes

Table 4.11 shows field measurements taken from sampled site B. Mining was in progress during all the visits as the area belongs to a licensed company with land rights to mine and sell pit sand. The area measures 1.0075 hectares. Depth, width and length of mined area were increasing at every visit. Depth increased from 5m to 12.7m, width from 25m to 32.5 while length from 58m to 73m. Approximately, 7250 cubic metres had been mined by the first visit and by the sixth visit about 30130.8 cubic metres pit sand had been removed. This meant approximately 22880.8 cubic metres of pit sand had been removed. It was clear that mining is controlled as trucks came in turns, charged and recorded by company employees before loading as seen in Figure 4.19..

Figure 4.19: Front end loader loading tipper trucks

Miners had a licence for the activities to sell pit sand to individuals and companies. The permit allowed them to load a maximum of 50 trucks of various sizes per day.

SITE C

Table 4.12: Field measurements from pit sand mining Site C

Fortnight	**1**	**2**	**3**	**4**	**5**	**6**
Date	28/11/12	12/01/12	09/02/13	23/02/12	09/03/13	23/03/13
Depth of pit (m)	8	8.2	8.5	8.9	9.2	9.9
Width of pit (m)	15	15.3	15.4	16.2	17.3	18.1
Length of pit (m)	45	45.2	45.7	47.1	48.2	48.7
Water present	No	No	No	No	No	No
Trucks/ miners	No	No	No	No	No	No
Dumped waste	Yes	Yes	Many bottles	Many bottles	Domestic Waste	Domestic Waste
Other things observed	Exposed tree roots	Signs of fire	Bush cut around	Removal of vegetation	Spilt oil	Dumped waste
Mining in progress	No	No	No	Yes	Yes	Yes

Table 4.12 shows depth, width and length of sampled site C where pit sand is extracted. Depth increased from 8m to 9.9m, width from 15m to 18.1m while length from 45m to 48.7m

by the last visit. At the beginning, approximately 5400 cubic metres of pit sand had been mined which increased to 8726.6 cubic metres by the sixth visit. This meant that about 3326.6 cubic metres of pit sand had been removed from the sampled point. Figure 4.20 below shows sampled Site C and the effects of mining on the area. During first 3 visits, it seemed the area had been abandoned but later weeks showed sign of mining as pit was increasing gradually. Interviewees revealed that mining is done at night by illegal miners. Continuous mining of pit sand is leading to destruction of vegetation on riparian zone and exposure of tree roots.

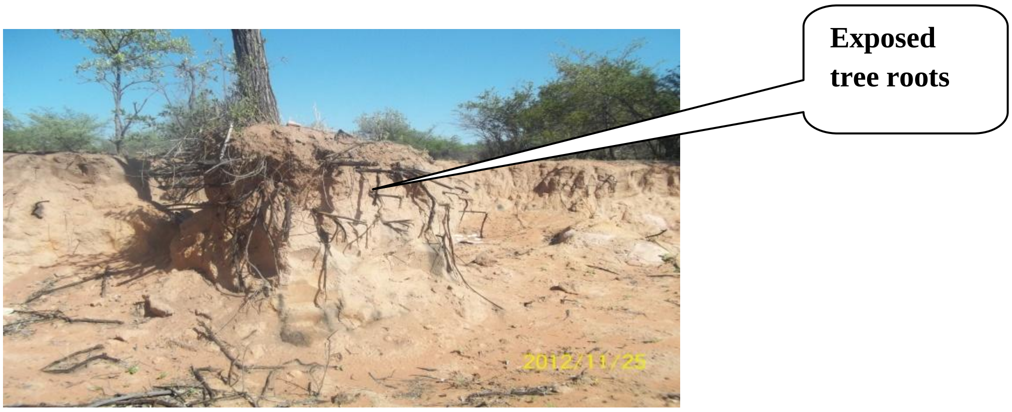


Figure 4.20: Tree roots exposed due to pit sand mining

SITE D

Figure 4.21: Undisturbed land (Control)

Land was flat containing abundant pit sand, access roads and natural vegetation which is exploited by miners.

General comment

Pit sand is mostly used in plastering mixed with river sand so the demand is less and areas where it is mined are fewer than for river sand. Miners are extracting pit sand uncontrollably without regarding vegetation on the surroundings.

4.6: Environmental impacts of sand mining and gravel extraction

Sand is a natural resource which must benefit all citizen of a country. In recent years the sand and gravel mining activity had increased worldwide fuelled by construction boom in both developed and developing world (Schaetzl, 1990). Botswana is not an exception with expansion of the capital city, Gaborone. Impressive development of the new Central Business District and mushrooming residential areas has increased the demand for pit sand, river sand and gravel as miners are eager to cash on these resources (Mbaiwa, 2008). There is rampant mining of the resource by both licensed and unlicensed companies. The activity has both positive and negative impacts to the environment.

4.6.1: Positive impacts of sand mining and gravel extraction

The study revealed positive impacts of sand and gravel mining for Gaborone expansion through interviews, questionnaire survey and observations. Development of infrastructure is one of the important benefits of mining using cheap and readily accessible resources. There is utilisation of abundant high quality river sand, pit sand and gravel in building durable structures. Interviews conducted with builders in Kumakwane and Metsimotlhabe revealed that the resources strengthen buildings when mixed with cement and concrete. They buy sand and gravel from tipper trucks at P700 per 5.5 tonne truck, though the prices are negotiable. River sand is used in plastering, mixed with concrete when making foundations and moulding bricks. The VDC members interviewed highlighted the same positive impact as they use sand and gravel from nearby Metsimotlhabe and Ditlhakane rivers for building rental houses which brings income to the village. Villagers build modern and durable houses at cheap cost. Interviews with officials from Department of Mines also supported sand mining as an important activity for development.

Figure 4.22a: Part of Central Business District under construction

Sand and gravel are used in development and construction of Central Building District, shopping malls and residential homes. Figure 4.22a shows development of a building in construction of Gaborone CBD as a positive impact of sand and gravel mining. Figure 4.22b below is one of the residential homes constructed by residents in the low density suburbs of Gaborone. Many residents benefit from sand and gravel mining as highlighted by interview results that the resources are cheap, accessible and used in construction of durable structures in both urban and rural areas.

Figure 4.22b: Example of residential home under construction

Sand and gravel mining had led to an improvement in road networking systems in Gaborone and surrounding areas. This has improved access roads from gravel to tar in the city. Interview and questionnaire results revealed that gravel when mixed with concrete is used to improve storm water drainage systems on sides of roads which carry water away during rainy season.

Questionnaire survey and interview results revealed that sand and gravel extraction activities create employment. The activities employ both citizen and non citizen youth temporarily to load tipper trucks manually. There are some permanent jobs for tipper truck and front end loader drivers mostly mature adults. Majority of loaders interviewed were Zimbabweans hired on temporary basis to load trucks manually using shovels (seen on Figure 4.23). Loaders indicated that they wait along gravel roads to the mining areas for trucks to hire and pick them. Few Batswana are also involved due to high unemployment rate.

Figure 4.23: Manual loaders loading river sand into a truck using shovels

Loaders indicated that on average, they load 4-5 trucks per day. The charges depend on sizes of trucks. Generally three loaders charge P200 to load a 5.5 tonne truck while 4 loaders charge a minimum P400 for a ten tonne truck. In a separate interview, manual loaders in Ditlhakane river revealed that they charge P50 per load per person. Unemployed youth are earning a living through sand mining and gravel extraction.

Sand and gravel mining activities are a source of revenue for the country and income to some companies and individuals. Interviews with officials from Department of Mines revealed that the Botswana government through the Director of Mines, obtain revenue from small minerals which include sand and gravel as royalties of 3% of the gross market value per month from licensed companies. Miners also pay lease charges of P100 per square kilometre or part thereof. Sand mining is a source of income for licensed companies who buy mining rights from Department of Mines, after surveying land to see if suitability for mining. Specific measurements and the sketch map of the area to be mined are given. The company will then sell sand or gravel to individuals or construction companies at P150 per 5 cubic truck, P300 for 10 cubic, P500 for 15 cubic and P750 for a 20 cubic truck as revealed by a licensed company involved in the activity. Companies charge differently but the money is for buying sand and gravel and loading the resources. Plate 4.14 shows a front end loader ready to load and an employee who records number of tipper trucks loaded per day and charges each truck respectively.

Figure 4.24: Licensed company front end loader ready to load pit sand.

Buyers transport the resources for themselves to sell in Gaborone at various amounts ranging from P800 for smaller trucks to P1800 for 20 cubic truck. Interviews with truck drivers revealed that they are either employed or own trucks which they use to buy, transport and sell sand and gravel to individuals building or construction companies. Front end loader driver indicated that they can load more than fifty trucks of different sizes per day. Twelve percent(12%) villagers involved in mining indicated that the activity is their source of income when they mine, and transport using donkey carts and one tonne trucks for other villagers. Companies in business of moulding bricks also get income from selling bricks.

Other positive impacts noted from the study included sand and gravel are useful in landscaping projects which beautify gardens in Gaborone's CBD, surrounding shopping malls and residential areas. Farmers highlighted that pits left by mining create rain water catchment points for watering livestock. Removal of river sand reduces siltation of rivers which increases the rate of flowing water.

4.6.2: Negative impacts of sand mining and gravel extraction

Sand and gravel, like diamonds are natural resources highly demanded in construction industries of Botswana. All citizens must benefit from this resource but this is not the case with residents and farmers of Kweneng East and Kgatlheng South Districts, that is Kumakwane, Metsimotlhabe, Kopong, Thamaga and Bela Bela farms who live in fear of illegal miners. Interviews conducted with residents revealed that the miners have turned themselves into vicious wolves, depriving them from benefitting from rivers and open areas where they used to dig wells for domestic purposes and watering livestock. Illegal miners attack and overpower residents with spades and sharp objects, forcing them out of the rivers and grazing lands. In some areas river sand is completely depleted, and when it rains there is nothing to hold water for livestock. The activity has many negative impacts to both residents and the environment.

Widening and deepening of rivers had been noted as a negative impact. Continuous mining of river sand alters river courses and increases the general width of the river as seen on Plate 4.15. Respondents (22.5%) realised this widening of rivers. Field measurements from sampled river sand mining Sites A-C showed that at A, river deepened from 16m to 21.8 m and widened from 125m to 135.9m. Site B, river deepened from 11m to 15.2m and widened from 55m to 85.8m. Site C, river deepened from 25m to 47.3m and widened from 74m to 75.5m. The measurements meant that there is a general alteration on river channels due to continuous mining (see Figure 4.25).

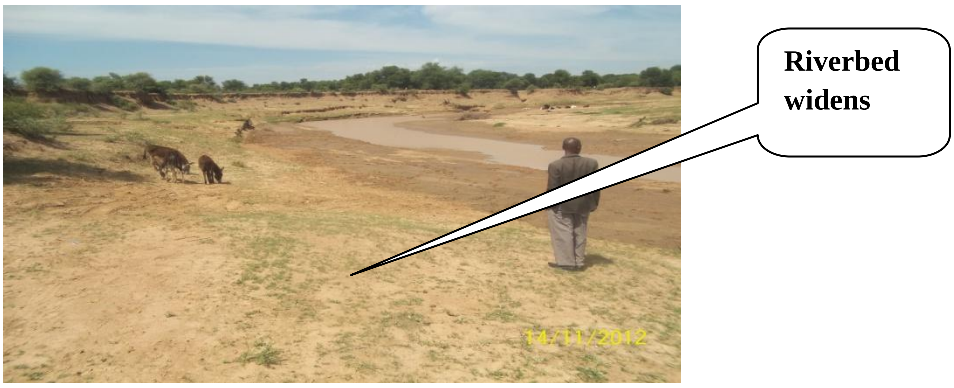


Figure 4.25: Widening of river bed due to mining

There is also general depletion of riverbeds as continuous removal of sand exposes underlying impermeable clay layers, increasing occurrences of floods in rainy season.

Interviews with environmental officers revealed that there is general damage to rivers and environment as mining is done uncontrollably. Widening of river increases possibility of flooding as there is no smooth flow of water. This leads to collapsing of riverbeds. As streams and rivers widen and deepen, there is contamination and shortage of sand aquifer water due to formation of ponds. Sand bed thicknesses vary due to uneven rocky bed of rivers (Stebbins, 2006).

Miners tend to dig more sand from a pocket where there is wide thickness of sand which leads to formation of ponds and water accumulates as seen on Figure 4.26 below.

Figure 4.26: Water accumulation in an open pit

When sand bed water is exposed by mining to dry atmosphere, there is a lot of evaporation. This leads to a micro disturbance of ground water. Cattle watering practices are affected while quality and quantity of water goes down for livestock. Wildlife are affected directly as there is an impediment in their movement. There is shortage of water due to high evaporation rate mostly during the dry winter season.

Deep pits created by mining upstream such as in Figure 4.26 affect river users downstream who do not get enough domestic water as the pits fill first before water flows downstream. Deep pits disturb recreational activities such as fishing and swimming as well as depletion of fish populations. Deep open burrow pits also are a source of pest breeding. As was noted by 5% of the respondents, stagnant water accumulates in open pools left by miners. Biodegradable materials, especially flora waste, settle at the bottom causing contamination of water. Figure 4.27 below shows accumulation of surface water in open burrow pits and growth of grass on surroundings creating an environment suitable for mosquito breeding which spread malaria to villagers nearby.

Figure 4.27: Stagnant water and growth of grass conducive to mosquito breeding

Many accidents had been reported in and around mining areas as a negative impact of sand and gravel extraction. As water accumulates to form pools, children visit these areas to swim and end up drowning. Residents who took part in the study shared the same sentiments when 65.9% of the respondents indicated that the activity had caused many accidents in their communities involving minors and livestock. Dozens of livestock had drowned while some got stuck on deep riverbeds containing a lot of loose sand as seen on Figure 4.28 below.

Figure 4.28: Animal stuck in loosened sand on riverbed

Miners are not excluded from these accidents as they prefer extracting from inner layers of riverbanks as seen on Figure 4.29.

Figure 4.29: Extraction of river sand from inner layers

Subsidence and collapsing of riverbanks is common due to close proximity of sand mining which can lead to accidents and death of manual loaders. Department of Mines officials reported on incident reports received and investigated on death of children and miners at and around extraction sites.

Environmental and land degradation had been noted during the study. Grazing lands and crop fields are turning into gullies as more sand and gravel are mined. There is general shortage of productive land as gully erosion in the rainy season cause man made rivulets dangerous to humans and livestock as shown in figure 4.16.

Destruction of environment and vegetation leading to formation of gullies was realised by 13.2% of respondents who noted that pit sand, gravel and river sand mining activities damage open fields and the ecosystems, creating an eyesore, with an offensive look, making the environment ugly with many scars on the earth's surface. Therefore there is loss of aesthetics value (See Figures 4.20 and 4.32).

Not only accidents at mining sites had been recorded but interviews with police officers revealed that many road accidents are occurring due to slow moving, overloaded tipper trucks which cause traffic congestion on roads (shown in Figure 4.31). Researcher observed that there are regular breakdowns by tipper trucks not road worthy which is dangerous to other road users especially at night. Besides slow moving tipper trucks, well serviced trucks also cause accidents due to over speeding when passing through villages. In an interview with

Kumakwane VDC member, it was revealed that a child was knocked and killed by a truck transporting pit sand as an example of such accidents.

Figure 4.30: Slow truck causing traffic congestion

The study revealed that excessive mining of river sand and gravel leads to excavation as well as threatening bridges, bridge piers and buried pipelines. The Department of Mines officials highlighted that continuous mining reduces infiltration rates. During the rainy season, water rises up to bridge levels, destroying structures. Floods had swept away small bridges and roads before in Metsimotlhabe and Moshupa rivers as water could not infiltrate into the riverbed. There is general surface degradation due to stock piling.

Deforestation and loss of vegetation was noted during the research as a serious negative impact of sand and gravel mining. Vegetation and ecosystems are destroyed along river banks to make access roads into mining areas. Pit sand and gravel extraction requires clearing of large open lands before mining. There is destruction of riverbank hinterland and flora when extraction is done approaching riverbeds as shown on Figure 4.31. Continuous removal of vegetation exposes the land to erosion. Residents who took part in the study (16.3%) identified erosion as a serious effect of mining to rivers, crop fields and grazing lands. Interview results with truck loaders and environmental officers revealed the same impact.

Figure 4.31: Signs of erosion on riparian zone

Movement of heavy vehicles from public roads to pit sand, gravel and river sand collection points need access roads. Most of these roads follow the same alignment of existing tracks used by pedestrians and cart owners. Formation of access roads on riverbed and open lands as seen in Figure 4.32 compact the ground, destroy soil structure so water cannot infiltrate but flows along the surface.

Figure 4.32: Access roads and stock piling on river bed

On the contrary, big wheels of tipper trucks and front end loaders dig into soil, loosening particles due to repeated movements (Shown in Figures 4.19 and 4.32). This increases wind erosion. Interview results from truck drivers and loaders confirmed that many machines move on river bed, pit and gravel areas several times on daily basis which loosen the soil and increase wind erosion.

Continuous movement of heavy machines on rivers weaken riverbeds, causing water table to be nearer the surface as seen on Figure 4.33 where water is forming a pool from underground.

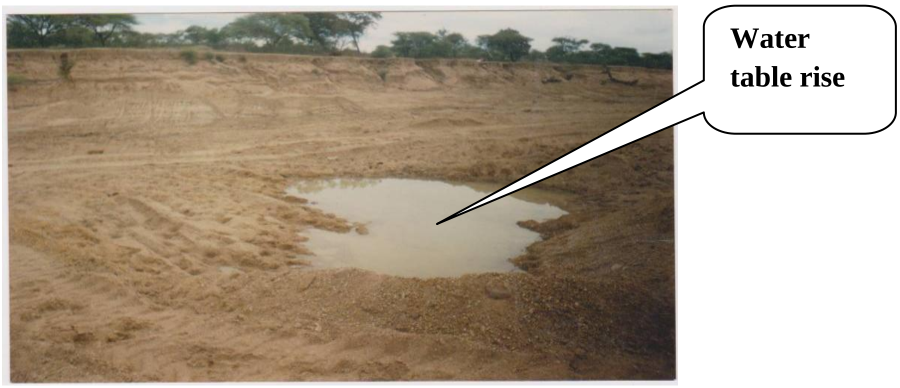


Figure 4.33: Formation of pools due to a raised water table

Raised water table and formation of pools on riverbeds increases evaporation rate in summer such that exposed water is lost to atmosphere, and will not be useful to livestock and crops.

Continuous movement of heavy vehicles disturb agricultural land, human habitations, borehole users and can cause traffic hazards. Trucks' big wheels generally destroy gravel roads leading to mining sites which become uneven for other road users. Residents (4.1%) had identified this impact on gravel roads to and from mining areas.

The research revealed pollution as a major negative impact of sand and gravel mining in areas surrounding Gaborone. There is land, air and noise pollution in Kumakwane, Metsimotlhabe, and Kopong villages including Ditlhakane and Metsimotlhabe rivers where the resources are extracted. Different sizes of tipper trucks mainly from Gaborone transport soil from these areas on daily basis but also bring waste from Gaborone. Interview results with drivers showed that they can make up to five trips each per day depending on demand.

Land pollution in form of waste disposal had become an environmental hazard in the villages. Tipper trucks from Gaborone carry all types of waste in form of used disposable nappies, building rabble (Figure 4.34a), plastics and domestic waste (Figure 4.34b), empty bottles (Figure 4.34c) old tyres, used oil (See Figure 4.36) to dump in uncovered open pits, bare fields and on riverbeds. Residents (21.2%) including village leadership complained of extreme waste spreading in villages.

Figure 4.34a: Building rabble on river bed

Figure 4.34b: Plastics disposed on open area

Figure 4.34c: Empty bottles dumped on open areas

Wind spread disposed waste in and around residential areas, crop fields, making the land untidy. More waste is carried by flowing water during the rainy season, polluting river sources. Pollutants from waste filter and contaminate domestic water in rivers. Farmers complained of waste such as plastics, used sanitary pads and disposable nappies being eaten by livestock (goats, cattle, donkeys) leading to outbreak of diseases such as measles.

Sand and gravel miners dump old tyres on riverbed and open areas as seen on Figure 4.35. They burn tyres on river bed which contaminates water for domestic purposes and livestock (See Figure 4.15). Presence of tyres reduces the aesthetic appearances of the environment..

Figure 4.35: Tyres dumped on riverbed

Figure 4.36: Used oil on open areas

Miners also bring used oil to dump on open areas as seen on Plate 4.26. Used oil pollute ground and destroy vegetation. It seeps into the soil to contaminate ground water table. If oil filters into the river, it can have detrimental effects on aquatic organisms.

Heavy machinery, tipper trucks and front end loaders produce a lot of noise when loading and transporting soil for twenty-four hours from Kweneng and Kgatleng Districts. Licensed companies load and transport resources during the day using front end loaders permanently stationed at mining sites. Illegal miners load and transport soil at night from 18:00pm to 06:00 am including weekends when there are less police roadblocks (See Figure 4.37).

Figure 4.37: Illegal sand mining at night

Illegal trucks are loaded manually while front end loaders may also be hired on special arrangements at night. This means there is continuous noise generated by these machines which hampers sleep for residents living near extraction sites and gravel roads. Too much noise and impact cause cracks on nearby houses and buildings as was revealed by residents (10.4%).

Air pollution in form of dust and smoke is common in and around sand and gravel mining areas. Many gravel roads used by trucks pass through the village mostly in Kumakwane. Residents (11.2%) complained of excessive dust which makes clothing on lines dirty, infiltrate into houses and cause respiratory problems. Interviews with environmental officers showed that besides dust, smoke from old haulage trucks not road worthy but transporting sand and gravel pollute the air.

Negative socio economic impacts

There are socio-economic negative impacts of sand and gravel mining. The activities increase crime in villages near mining sites as was discovered by the researcher from questionnaire survey and interviews with residents. There is an influx of illegal immigrants seeking part time jobs to load trucks manually. Many unemployed citizens and non citizens wait on gravel roads to extraction sites for temporary employment as loaders. Interviews with local police officers revealed that at night when not employed, truck loaders resort to housebreaking and stealing using spades and sharp objects to fight residents. High numbers of miners increase prevalence of sexual transmitted diseases and HIV/AIDS in villages and surrounding areas during mining operations.

4.7 Summary

Sand and gravel mining are important activities to economic development in both developed and developing world. There are many positive and negative environmental impacts to the activity some of which are detrimental to the environment. As mining of resources is done most of the negative impacts cannot be reversed and there is permanent alteration to ecosystems, habitats, species and environment. There is need to limit negative effects and promote positive impacts.

CHAPTER 5: CONCLUSION AND RECOMMENDATIONS

5.1 Introduction

The research was carried out to investigate and expose positive and negative environmental impacts of sand mining and gravel extraction in areas surrounding Gaborone where the resources are extracted for development of the city. The major objectives were to assess and find out the soil component mined most, expose positive and negative impacts of sand and gravel mining as well as recommendations to the responsible authorities at community, district and national levels.

5.2 Conclusion

The study on impacts of sand mining and gravel extraction in Gaborone and surrounding areas revealed both positive and negative effects. It highlighted the views of affected people through questionnaires and interviews. Majority of the respondents were not happy with environmental degradation, accidents caused, waste disposed by miners, threats from illegal miners and general damage to the ecosystems.

The research justified that there are both positive and negative environmental impacts to sand and gravel mining. It revealed that river sand is the soil component mined most in construction industry because of its strength as a resource and has many uses which include building strong structures, plastering, making foundations and bricks. The researcher discovered that pits at extraction sites were increasing on every visit while rivers at sampled areas were widening and deepening. Method of mining commonly used is open pit. There are two main methods of loading being used by miners which are the use of front end loaders by licensed miners while illegal miners mostly prefer the cheaper way of hiring manual loaders who use shovels.

Sand mining and gravel extraction are very important activities for economic development in both developed and developing world. Generally, mining disturb land surface areas, leaving huge open pits which are difficult physically and economically to rehabilitate at the time mining cease. Excessive mining leads to depletion of resources on both riverbeds and open lands. There is need for laws across the globe by high level decision makers to enforce solutions to environmental problems and implement all the stated recommendations.

5.3 Recommendations

The author listed and included recommendations to both the decision makers who are directly involved in the review of sand mining and gravel extraction activities to make informed decisions when issuing licences and to miners considering the rate of illegal mining in the country. More recommendations are on areas which need further research.

5.3.1 Recommendations to decision makers

- The Botswana government through the Department of Mines should call for a high level decision making forum involving all stake holders to discuss the problem of illegal sand and gravel mining and come up with immediate solutions which curb environmental damage.
- Effective legal framework, strict laws and legislature are important as Department of Mines with help of police force and village leadership must impose heavy fines including long jail terms to miners who extract without mining rights and licences. This is possible if trucks transporting sand and gravel pass through community leaders for inspection and verifying genuine permits to reduce use of fake documents. Confiscation of tipper trucks from illegal miners is necessary as a way of banning illegal mining.
- It is important to have an Environmental Assessment Management and Monitoring Program. Close monitoring ensures that there is proper mining and no gravel recruitment downstream.
- Deployment of 24 hour security to guard mining areas and apprehend illegal miners with help of village watch groups and clusters. Only licensed miners will be allowed

into extraction sites and illegal miners will not have access. All residents must be involved in apprehending and reporting illegal miners to authorities instead of befriending them.

- Mining operations must be conducted in a manner that minimises or eliminates adverse impacts on both in stream and riparian components of ecosystems comprising of biota and habitats.
- Authorities are to strengthen laws on not allowing people to enter vulnerable areas through close monitoring of the mining activities in all areas.
- Regular inspection and roadblocks by Botswana Police Service officers through mounting regular roadblocks next to mining areas and along roads used by trucks, setting speed traps on speeding trucks. Inspections of trucks which are not road worthy must be part of the operations.
- The Department of Mines should evolve a policy compelling miners to reinvest and repair old disused mine sites to reduce occurrence of landslides.
- Surface rights rent should be affordable to all miners to allow them to spend part of the money on repairing environmental damage due to mining operations.
- Department of Mines, District Authorities and Land Boards should ensure that farmers whose land is mined, livestock drowning in open pits and cattle dying from measles after eating dumped waste are compensated directly or indirectly by illegal miners.
- Sign boards prohibiting illegal mining such as Figure 5.1 below must be increased by Department of Mines and placed next to all mining and surrounding areas prohibiting illegal mining, dumping of waste, oil spillages and burning tyres and punishment accompanying such offences.

Figure 5.1: Sign board prohibiting illegal mining

- Big river channel cross sections such as Metsimotlhabe, Moshupa and Notwane where there is a lot of mining activities should be benchmarked and documented using aerial photographs taken at regular intervals.
- Mining Licences issued must allow harvesting river sand on braided river systems, abandoned stream channels, terraces and inactive channels. Mining activities should never be done on straight, meandering or split rivers.
- There should be construction of buffers or levees to reduce long term flooding on terraces. Soil erosion can be controlled by gabions on flat land.
- Reuse and recycling of old building material must be encouraged by authorities as a way of reducing over extraction and dumping of waste on the environment.
- Restriction of mining time and days to normal working hours that is 07:30-16:30 on week days is important to reduce illegal mining when there is tight security.
- Department of Roads and Transport with help of Botswana Police Service should restrict tipper trucks transporting sand and gravel from using gravel roads passing through the villages. Constructing temporary roads out of villages to reduce air and noise pollution is necessary.
- Authorities are to restrict heavy front end loader equipment on riverbed which compact the ground and bring water tables near surface.
- Department of Mines should educate the public including miners on the negative impacts of continuous mining through media such as national television, radio and national newspaper, Daily News.
- Regular meetings and consultations with affected communities are important to call for their involvement in mining activities. Part of royalties can be paid to Village Development Committees so that villagers can directly benefit from mining activities in their areas.

5.3.2 Recommendations to miners

- All miners must draft and submit an Environmental Management Plan (EMP) in advance to ensure that potential negative impacts of their mining projects are assessed and incorporated into development plan. This becomes a prerequisite to get a permit.
- Consultations and seeking permission from interested and affected communities before mining is important as sand miners should consult chiefs, sub chiefs and

Village Development Committees so as to control the size of area mined and reduce damage to the environment. Regular meetings between Department of Mines, Land board officials and village leadership can be a good platform for consultations. The village leadership will be involved in surveying and recommending the areas to be mined far from crop fields and grazing lands.

- Miners must change mining areas and not extract from same area continuously but alternate sites to reduce over extraction and environmental damage beyond rehabilitation. Mining should not be done near schools, clinics, residential or any sensitive areas like destroyed rivers.
- Limiting amount of sand and gravel mined per day will help to control depth of mining. Miners should leave 0.5 metres sand bed in situ to reduce sand depletion. The security deployed can monitor the number of trucks loaded per day.
- Controlling time of mining: not to be done throughout the year but during dry season, avoiding rainy season. This is necessary to give the land time to rehabilitate and recover. Mining time must be restricted to day time only.
- Mining should be done approaching the floodplain from one side to minimise crossing riverbed with heavy machinery. Access to river can be determined by steepness and vegetation available to avoid damaging flora. If the channel is too deep, construct access ramps.
- Access roads from public roads must be parallel to the river banks to restrict water flowing along the tracks during rainy season from forming gullies.
- Haulage roads must be a minimum of 100 metres from the banks.
- Covering sand and gravel with nets: when transporting the resources to be a prerequisite to reduce damage of other motorists' windscreens from falling stones.
- Miners must follow the law of mining where no sand is to be extracted within 2.5 metres to 5.0 metres from the banks mostly if the river is meandering, or split.
- All miners must cover and refill pits after mining as reclamation since mitigation and restoration must occur concurrently with extraction activities to conserve biotic integrity of ecosystems.
- Reclamation of contaminated soils around all mining areas must be done by the miners. Stockpiling to be avoided on riverbeds and open areas.
- Miners must plant and establish appropriate vegetation to reduce erosion on reclaimed land.

- Compensation of farmers: whose animals drown in pits and die from measles after eating waste should be done by the miners.
- All miners must use dry pit method of mining in all their extraction activities since depth of mining can be controlled. The method should not be used on one area for too long but alternate areas of mining.

5.3.3 Recommendations for further research

The study was not exhaustive and the researcher observed that more research on the topic is necessary in the following areas:

Interviews are to be done with more people from various departments.

- Questionnaire survey should be revisited, refined and administered to people in other villages countrywide.
- More research must be done during both rainy and dry seasons to compare results.
- More time, for example a year can be allocated to doing the research so as to cover more areas.
- More sampled points in various rivers and open areas countrywide are to be used to determine the extent of environmental damage. More researches: to be done to find alternative resources to river sand such as crushed stone from quarries.

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APPENDICES

APPENDIX A: COPY OF STUDY PERMIT

TELEPHONE: (267) 365 6600
TELEGRAMS: MMEWR
TELEX: (267) 2503 BD
FAX: (267) 390 9368

REPUBLIC OF BOTSWANA

MINISTRY OF MINERALS,
ENERGY AND WATER
RESOURCES, PRIVATE
BAG 0018, GABORONE
BOTSWANA

Ref: GSC 5 XV (20)

16 October 2012

Mrs Tariro N. Madyise
PO Box 917
Gaborone

Tel: 5998639
E-mail: tmadyise@yahoo.com

RE: APPLICATION FOR A RESEARCH PERMIT

Your application for a research permit refers.

By this letter, you are given permission to conduct a research entitled **"CASE STUDIES OF ENVIRONMENTAL IMPACTS OF SAND MINING AND GRAVEL EXTRACTION FOR URBAN DEVELOPMENT IN GABORONE."**

The permit is valid for a period not exceeding twelve (12) months effective from the **1st November 2012 to 31st October 2013**.

The permit is granted subject to the following conditions:

1. Copies of reports produced as a result of the research are directly deposited with the following institutions: Ministry of Minerals, Energy and Water Resources, Private Bag 0018, Gaborone, Botswana; Ministry of Education, Private Bag 005, Gaborone, Botswana; National Archives and Records Services, PO Box 239, Gaborone, Botswana; Department of National Library Services, Private Bag 0036, Gaborone, Botswana; Office of Research and Development, University of Botswana, Private Bag 0022, Gaborone, Botswana.

2. The permit does not give authority to enter premises, private establishments or protected areas. Permission for such entry should be negotiated with those concerned.

3. The study is conducted according to the particulars furnished in the approved application, taking into account the above conditions.

The Ministry that makes a real difference to Botswana

4. Failure to comply with the above stipulated conditions will result in the immediate cancellation of the permit.

Yours faithfully,

L. Ungwang
For/**Permanent Secretary**

cc: Permanent Secretary, Ministry of Education
Director, Botswana Archives and Records Services
Director, Botswana National Library Services
Director, Research and Development Office (University of Botswana)

APPENDIX B

CONSENT FORM

TITLE OF RESEARCH PROJECT

CASE STUDIES OF ENVIRONMENTAL IMPACTS OF SAND MINING AND GRAVEL EXTRACTION FOR URBAN DEVELOPMENT IN GABORONE.

NATURE AND PURPOSE OF STUDY

The purpose of this research is to find both positive and negative environmental impacts of sand mining and gravel extraction for urban development in Gaborone City expansion. The impacts result from removal of pit sand from bare ground, river sand from rivers and gravel taken from various ecosystems for construction purposes. The study involves individual interviews to get views of various people on soil extraction. More information will be gathered from questionnaire surveys to be administered to villagers from communities directly affected by the mining. Photographs will be taken from areas of extraction as evidence of environmental alteration. The research is meant to bring out ways of developing with minimum disturbance to the environment as well as making recommendations to the responsible stakeholders on sustainable use of the environment. The study is essential in pursuit of knowledge and public good.

RESEARCH PROCESS

1. The research requires your individual participation in answering this questionnaire/interview questions on the environmental impacts of soil mining in the community.

2. The questionnaire/interview will offer you an opportunity to express your opinion on the effects of continuous mining of pit sand, river sand and gravel in your area.

3. You do not need to write your name, but remain anonymous.

4. There is no right or wrong answer but just give your opinion which is valuable to the research.

5. The researcher will visit you at home or office, so no advance preparation or transport costs you will incur.

6. For the questionnaire, if you cannot write and not fluent in English, the researcher will bring along an interpreter to translate the questions into Setswana then fill in the answers for you.

7. NOTIFICATION OF TAPE RECORDING

   No tape or video recording of the interview or answering session of the questionnaire will be done but the researcher will take photographs of sand and gravel mining areas as the study is in progress.

   CONFIDENTIALITY

   The views of every participant will be treated as confidential and only the researcher and college will have access to the information provided. No names will be published in dissertations. Your anonymity is therefore assured.

   WITHDRAWAL CLAUSE FOR THE PARTICIPANT

   I understand that I may withdraw from being part of the questionnaire anytime. I therefore participate voluntarily until such time as I request otherwise.

   POTENTIAL BENEFITS OF THE STUDY

   Development is important for all nations including urban expansion but it should take place without damaging the environment. This study will expose both positive and negative impacts of pit sand and river sand mining as well as gravel extraction on the environment. It will help to mitigate negative effects through constructive recommendations. This research will lead to better use and conservation of the environment, preservation of habitats and natural resources.

INFORMATION

If you have any queries concerning the study, you may contact the Supervisor:

Professor S J Moja

Department of Environmental Science

Unisa Florida Campus

Unisa, South Africa

Email:mojasj@unisa.ac.za

Tel:0027114713878

DECLARACTION

I, undersigned……………………………………………………………(full name) have read the above information relating to the research and have also heard the verbal version and declare that I understand it and have been afforded the opportunity to discuss relevant aspects of the study with the researcher and hereby declare that I agree voluntarily to participate in the project.

I further undertake to make no claim against the University in respect of damages to me or reputation that may be incurred as a result of the project.

I have received a signed copy of this consent form.

Signature of participant………………

Signed at…………………………on……………

WITNESSES

1. 2.

CONSENT FORM, COLLEGE OF AGRICULTURE AND ENVIRONMENTAL SCIENCE, UNISA.

APPENDIX C

QUESTIONNAIRE SURVEY

My name is Tariro Madyise. I am carrying out a research on CASE STUDIES OF ENVIRONMENTAL IMPACTS OF SAND MINING AND GRAVEL EXTRACTION FOR URBAN DEVELOPMENT IN GABORONE for Master of Science Degree in Environmental Management with University of South Africa.

The information given will be treated with confidentiality and you do not have to write your name on the questionnaire to remain anonymous. Please read ALL questions and answer them carefully.

PART A

PERSONAL DETAILS

Tick the correct option.

1. GENDER: Male ☐ Female ☐
2. AGE GROUP 21-25 ☐ 26-30 ☐ 31-35 ☐ 36-40 ☐ 41-45 ☐ 46-50 ☐ 51-55 ☐ 56+ ☐
3. POSITION IN VILLAGE: ☐ CHIEF ☐ HERDMAN ☐ VDC MEMBER ☐ ORDINARY VILLAGER

PART B

GENERAL QUESTIONS ON SAND MINING AND GRAVEL EXTRACTION

For questions 4-8, tick the appropriate answer.

4. How far do you live from soil mining areas approximately? 0-500m ☐ 501-1000m ☐ 1001-1500m ☐ 1501-2000m ☐ above 2000m ☐
5. How far do you live from the main gravel road used by tipper trucks transporting sand and gravel? 0-500m ☐ 501-1000 ☐ 1001-1500 ☐ 1501-2000m ☐ above 2000m ☐

6. Do you often visit the soil mining area? YES ☐ NO ☐ SOMETIMI☐ RARELY ☐
7. If yes, choose and tick activities you normally do at the soil mining areas. Get domestic wateı☐ soil mining☐ fishing ☐ gardening☐ farming ☐ herding livestock☐ others, specify☐
8. Approximately, how many trucks pass through your village in a day? ☐0-5 6-10☐ 11-15 ☐ 16-20 ☐ 20 and above☐

9. If one of the activities you chose in question 7 is soil mining,

a) What do you use the soil for?

____

____

b) How often do you collect the soil and what do you use for its transportation?

____

____

This is important for PART C AND D. Fill in your opinions in the spaces provided. All answers are considered correct, important and will be treated with confidentiality

PARTC

RESIDENTS' VIEWS ON ENVIRONMENTAL IMPACTS OF SAND MINING AND GRAVEL EXTRACTION

1. How do you feel about sand mining and gravel extraction?--------------------------------
   ----

   ----
2. The soil mining might be affecting you as a resident in a nearby village. If yes, state the effects the activity has on your life.---
   ----

   ----
3. What can be the advantages of extracting soil from the environment?--------------------
   (a)To residents---

   (b) The community--

   ----

4. Have you observed any negative impacts?
   YE
   NO
   If yes , select the impacts you have observed
   Land degradation Deepening of riverbanks
   Soil erosion Deep pits with/without water Land alterations
   Loss of vegetation
   Others, specify--

   ----
5. (a) Had you ever heard of accidents reported during soil mining?-------------------------
   ----

   (b)How does the community react to such accidents--

PART D

SOLUTIONS TO SAND MINING AND GRAVEL EXTRACTION

6. What can you recommend as the immediate solutions to the negative impacts of sand mining and gravel extraction:
   (a) at Kumakwane community level---

   (b) At District level---

   (c) At national level--

   ----
7. What rehabilitation programmes can be implemented in your area-----------------------
   ----

Thank you for answering this questionnaire truthfully. You are assured that all information will be treated with confidentiality. The feedback will be used to suggest solutions and make recommendations on mitigating negative impacts to sand mining and gravel extraction.

APPENDIX D: UNISA ETHICS CLEARANCE LETTER

UNISA university of south africa

2012-10-10

Ref. Nr.: 2012/CAES/035

To the student:
Mrs T Madyise
Department of Environmental Science
College of Agriculture and Environmental Sciences

Student nr: 50665987

Dear Mrs Madyise

Request for Ethical approval for the following research project:

Environmental impacts of sand mining and gravel extraction for urban development in Gaborone

The application for ethical clearance in respect of the above mentioned research has been reviewed by the Research Ethics Review Committee of the College of Agriculture and Environmental Sciences, Unisa. Ethics clearance (Ref. Nr.: 2012/CAES/035) **is granted for this research project.**

Please be advised that the committee needs to be informed should any part of the research methodology as outlined in the Ethics application (Ref. Nr.: 2012/CAES/035), change in any way. In this instance, a memo should be submitted to the Ethics Committee via Ms Marthie Van Wyk, in which the changes are identified and fully explained.

We trust that sampling, data gathering and processing of the relevant data will be undertaken in a manner that is respectful of the rights and integrity of all participants, as stipulated in the UNISA Research Ethics Policy.

The Ethics Committee wishes you all the best with this research undertaking.

Kind regards,

Prof E Kempen
CAES Ethics Review Committee Chair

University of South Africa
Preller Street, Muckleneuk Ridge, City of Tshwane
PO Box 392 UNISA 0003 South Africa
Telephone: +27 12 429 3111 Facsmile: +27 429 12 429 4150
www.unisa.ac.za

APPENDIX E: PERMISION LETTER FROM KUMAKWANE

Kumakwane Customary Court

P O Box 1

Kumakwane

Botswana

Telephone: 00267 5998500

29 August 2012 REF NO: KM/ADM 1 I (10)

TO: UNIVERSITY OF SOUTH AFRICA (UNISA)

Department of Environmental Sciences

REQUEST TO CONDUCT A RESEARCH STUDY IN OUR AREA (KUMAKWANE AND SURROUNDI

Permission has been granted to your student: **TARIRO MADYISE (MRS)** to conduct a research in our area and the surroundings on **CASE STUDIES OF ENVIRONMENTAL IMPACTS OF SAND MINING AND GRAVEL EXTRACTION FOR URBAN DEVELOPMENT IN GABORONE.**

Thank you

Yours faithfully

CHIEF REPRESENTATIVE
BAKWENA TRIBAL ADMINISTRATION
2012 -08- 29
KUMAKWANE

CHOMIE G. SEBONI

Chief Representative

APPENDIX F: DRAFT MANUSCRIPT

TITLE: CASE STUDIES OF ENVIRONMENTAL IMPACTS OF SAND MINING AND GRAVEL EXTRACTION FOR URBAN DEVELOPMENT IN GABORONE.

AUTHORS: Moja SJ and Madyise T

TARGET JOURNAL: Minerals Engineering

YEAR: 2014