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Map Visualizations Of Contaminated Water - Usability Research In Zimbabwe

GIS Supported Organization And Presentation Of Data On Contaminated Water Caused By Mining Operations

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Submission date: July 2006
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Problem Description

Background:
Mine operations in the Iron Duke Pyrites in Mazowe Walley, Zimbabwe have resulted in considerable contamination of ground water and water systems in general. Measurements of the contamination exists, however these are not included and structured in a geographic framework.

Task:
The student needs to get an overview over existing geographic data of relevance and which reference system these are located in. Necessary data have to be included in a data base within a geographic inforamtion system (GIS). The GIS software must be prepared for the inclusion of additional data and be able to make cartographic presentations that show the widespread of the contamination based on the information that can be extracted from the data. These presentations will be the basis for futher user tests.

Important elements:
- The student has to choose appropiate GIS software for solution of the task. A couple of systems should be compared. The final application must be well adapted to the actual task.
- Possibilities for revealing hidden information based on gegraphical analysis should be considered.
- Methods for easy input of additional data need to be prepared, and it should be considered how the system can help in the selection of supplemental sites for mesurements of contamination.
-The student has to make cartographic presentations focusing on contamination from the mines. The maps have to be easy understandable for people that are assumed to have poor experience using maps. Various methods for presentations and symbolization should be considered. It is supposed that the student will carry out a study on how well the information is communicated to the local users by different map presentations.

Assignment given: 20. January 2006
Supervisor: Terje Midtbø, BAT

Norwegian University of Science and Technology
NTNU

MASTER THESIS

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ACKNOWLEDGEMENTS

I would like to direct my gratitude to the friendly management at Iron Duke Pyrites (Ltd.) Pvt. Without their good attitude, helpfulness, and time this thesis would not be possible. Their supply of information, equipment and labor has been phenomenal during the hard times they were facing at the period of this work. A special thank is given to Mr. Isaac Mafusa, who helped me with the execution of the questionnaire. He came with constructive feedback on the pilot survey, and did an excellent job as a translator.

My gratitude goes to the management at the Metallurgy and Mining Department at the University of Zimbabwe, the personnel at The Royal Norwegian Embassy in Harare, my partner and companion Bård Tobiassen and all the people we met in Harare and Zimbabwe. All of them made my stay in Harare an unforgettable experience. Thank you!!

My supervisor in Norway, Terje Midtbø was helpful and always available on e-mail. My dear friend and psychology student Marianne Andersson did a great effort in feedback on the pilot survey and on the final report.

Thank you everyone!

Merete Sørjoten
Trondheim, 9th of July 2006

ABSTRACT

The aim of this project was to find a method for organization and visualization of water contamination in a mining area north of Harare in Zimbabwe. This was important because it does not exist a synopsis that gives a good picture of the situation of contamination in the area. There is many people living there, and they are dependent on water to survive. Some measurement data from the ground water and from the river flowing through the area has been taken earlier. Those measurement data were not organized, and one could only find them in books and bindings at the mine. Existing measurement data and new measurement data, taken during the fieldwork, were organized into a database. The database was used for subsequent work in a geographic information system.

One wanted to make a map to the local inhabitant that illustrated the water quality along the river. The inhabitants were not used to read and interpret maps, and a survey were carried out about map interpretation and understanding. The locals were asked about symbols and colours they preferred for presentation of symbols and features in the area. They were exposed to four different maps over the mine area. The purpose of this was to find a map that the locals preferred for presentation of water quality. A simple and easy to understand map, with only the most important features were the most appropriate for the respondents of the survey.

It did not exist a map basis of the area. One had to employ creative methods to form a map basis. MicroStation V8 was used to create layers of topographic features from the area. Those layers were imported into ArcMap, and used to make a map to the local inhabitants. The map illustrated dangerous and safe areas along the river for drinking water. The map basis and the database over water quality measurements were implemented into ArcMap as a feasibility study to a geographic information system.

A geographic information system (GIS) was seen as essential for analysis and visualization of contamination in the area. This project illustrated some of the possibilities of a GIS, but there is still much work for development of the system. The target is to make use of a GIS for mapping of contamination of all areas in Zimbabwe. That is feasible if one is able to implement good structure for database management and find a good map basis for the country.

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CHAPTER 1 INTRODUCTION

1.1 BACKGROUND

Mine pollution is an extensive problem in Zimbabwe. Especially pyrite mines produce much waste that contaminates the ground water and other water sources in the area. In this thesis, fieldwork has been done at Iron Duke Pyrites (Pvt.) Ltd.. Iron Duke Pyrites (IDP) is a pyrite mine about 40 km north of Harare. In the early 1914, the mine started of as a gold mine. As the mine grew in depth, pyrite emerged and they started to sell the pyrites to fertiliser production. In 1999 Iron Duke Pyrites initiated export of pyrites to Zambia. (Manda, 2005). As a consequence of the export marked, the mine obtained high demands and the production was maximized. In 2005, it was totally 436 people working at the mine, 262 on permanent contracts while the rest was on temporary contracts (Manda, 2005). The mining facilitates lies within a village. Most of the people living in the village work at the mine or produce different agriculture products.

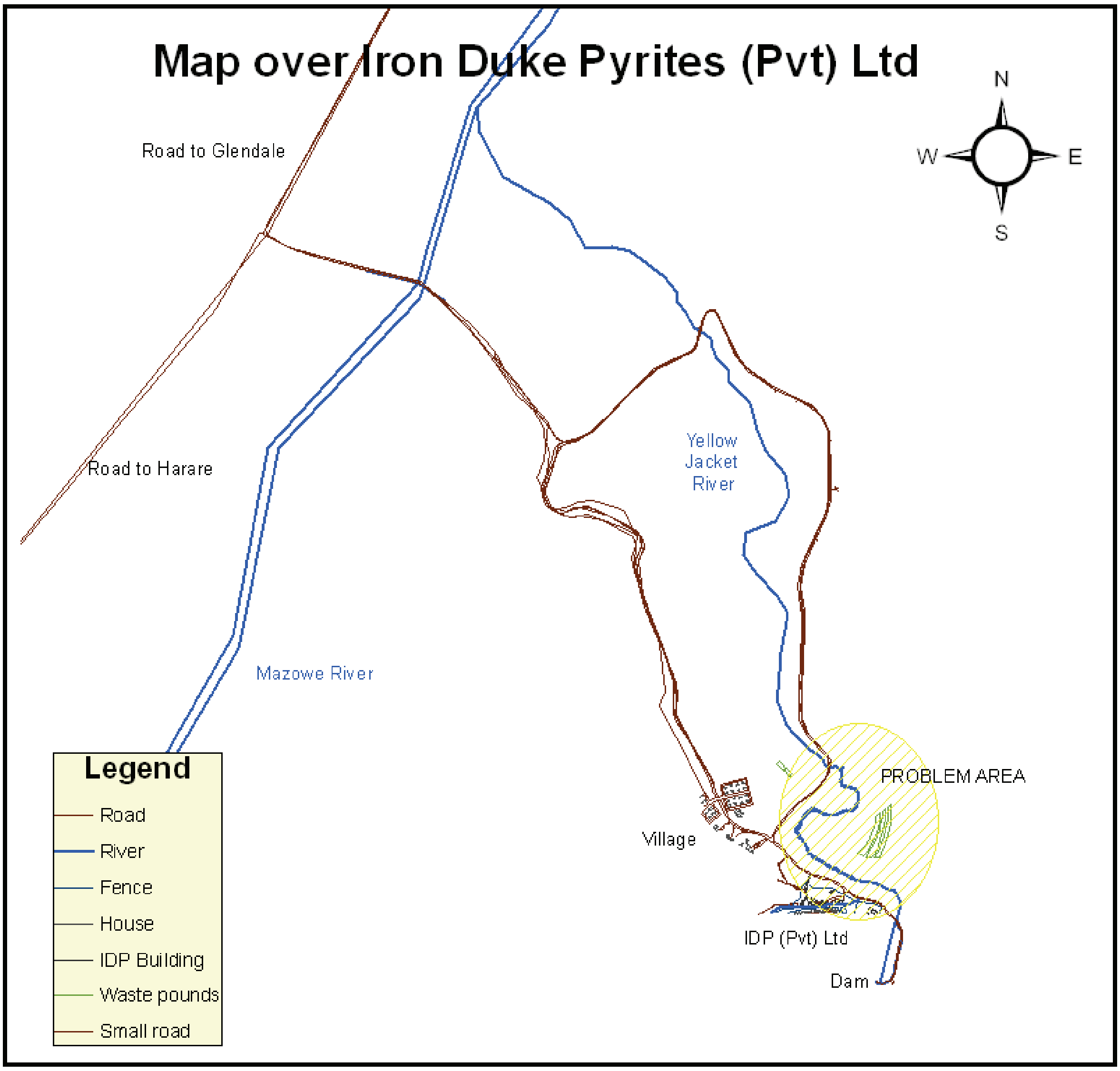

Figure 1 Map over the area of Iron Duke Pyrites (Pvt.) Ltd.

Yellow Jacket River (YJR) flows through the area of IDP. It starts as an outlet from a dam just above the mining area, flows through the area and further down till it runs into the great river, Mazowe. Analysis over the last years shows that the YJR was strongly polluted, with pH-values under 3 because of heavy metals. The contamination originates from waste rocks and evaporation pounds from the mine. There are reasons to believe that the groundwater is just as contaminated and a source to the heavily polluted river. Water is essential for people, animals and agriculture in the area. If this polluted water is used by the local inhabitants, their animals or for agriculture, it can yield serious and chronic illness for people and animals.

1.2 OBJECTIVE AND MOTIVATION

It is essential to inform the local inhabitants about the scope of the serious situation. Most of the inhabitants know that their river is polluted by the mine, and they have the opportunity to get tapped drinking water provided by the mine. Not everyone uses the tapped water. They have to go long distances to get to a tap, and the river is nearby. The symptoms of illness from water contamination can have a long latent period. One will not feel sick immediately after drinking water with high concentration of heavy metals, but that does not mean it is not serious.

It is an inherent presumption that the inhabitants may drink the polluted water when they don't see immediate symptoms, and that their behaviour is a result of risk analysis. Why bother to use two hours to get tapped drinking water so one don't get sick next year, when one has to struggle to get food and to survive the day? It is also known that the mine administration controls the tapped water, they have the authority to close the tap if they want. The inhabitants are absolutely dependent of the mine, their basis of existence vanish if the mine shuts down the water taps. It is important to try to help the inhabitants find an alternative water source, and direct them to where the water is less contaminated if they have no other opportunity than to drink water from the river.

Figure 2 Motivation to writing this thesis; preschool children from IDP with their future ahead of them.

Students and teachers from the University of Zimbabwe (UZ) have co-operated with IDP in different projects, and also the geological department at the Norwegian University of Science and Technology (NTNU) has agreement on co-operation with UZ and IDP. PhD candidate Mr. Chris Magombedze at NTNU and UZ is initiator for this thesis. He needed someone to map the area around IDP and to find a system for organizing all available data about contamination and measurements taken in the area.

The objective and motivation for this thesis is bisected. One part is to help Mr. Chris Magombedze mapping the area and to set up a geographic information system. This can help him to get a better overview of the situation with a spatial dimension, and enable spatial analysis as regards pollution. The other motivation is to help the local inhabitants with information about water quality. A map may act as an illustrative information source for a great number of people if it is adapted to the users.

1.3 SCOPE

The work of this thesis was divided into three distinct parts;

1. to map the area and the contamination
2. to execute a questionnaire that gives a basis for the local inhabitants understanding of maps and map symbolization
3. to set up a GIS that organize data about pollution and render the possibility to make easy comprehensible maps to locals that illustrates the pollution situation.

The intention was to use existing map basis from Zimbabwe for the GIS and map generation. This would form the basis for illustration of contamination in the area, and for extensions to larger areas in Zimbabwe. The questionnaire would give valuable information about if, and how non-experienced users interpret and understands maps. The results from the questionnaire could be implemented into the maps that are intended to the local inhabitants to assure good interpretation and comprehension.

This thesis was based on preparatory work and fieldwork in Zimbabwe and a finishing process back in Norway. Preparatory work has been composed of getting into theory of research, theory about comprehension of maps and map symbols and learning how to take water samples and analysis with a minimum of equipment. Much effort has been employed to make a good and easy-to-understand questionnaire for the local inhabitants around YJR and IDP. A good questionnaire adjusted to the respondents requires much effort to become known with the assumed respondents and to the area of interest.

The fieldwork at IDP consisted in taking water samples and analysis along the river, and in existing and new boreholes drilled for this project. One tried to get an accurate GPS-position of the boreholes, water sample points, and other prominent features in the area around IDP. One had to find map-basis for the GIS and map making, and a synopsis of reference systems used for the map-basis found. At the end of the fieldwork, the survey was executed among people living in the area of interest.

The finishing process back in Norway consisted of processing the results from the survey in a statistical program. Software was evaluated for map making and geographic information system as regards possibilities for editing, manipulation and analysis, user-friendliness and availability. Preparing the map-basis was important, so it can be used for a GIS and for map-making to local inhabitants. Databases have been evaluated and set up for measurement-values of all sample points. One did not have time to run analysis based on hidden geographic information, and the data basis was not complete enough for such analysis. When one manages to get more information into the database, analysis can easily be run in ArcMap.

1.4 SPECIFICATION OF THE REPORT CONSTRUCTION

The report is constructed into 7 main chapters, introduction, literature review, methodology, implementation, results, discussion and conclusion. Each chapter is divided into subchapters and describes work in connection with mapping of water samples, construction and execution of the survey, and work with GIS and making a map.

The literature review gives much information about research and survey. The researcher had no prior knowledge about that topic and it was important that good practice were implemented in each stage of the research process. Some literature about map symbolization was provided. The focus was primarily on map symbolization and not on maps generally. That was because the symbolization process was an especially important factor for success in map generalization. The survey focused on symbolization and intuitive understanding of symbols and colours and therefore should the theory reflect that. The last part of the literature review was concentrated about GIS, about different software available and how GIS could be used in the context of contamination and environmental issues.

The methodology chapter consisted of preliminaries, possibilities and options for construction and realization of the different parts. Different alternatives were discussed and evaluated before a decision about method, tool or software was taken. Implementation described how the different parts had been carried out. How water-samples had been taken, how the questionnaire had been executed and how the GIS and map-construction had been realized. A description on how the different software for construction of a geographic information system was included in the chapter of implementation.

The chapter of results were divided into four sub-chapters. The first subchapter gives the results from water samples and analysis conducted at the mine. The following sub-chapter shows descriptive statistics from the survey, where the main findings were illustrated with graphs. Then result from the construction of a GIS was shortly mentioned, and finally proposals of possible maps for the local inhabitants on the basis of the survey, map, basis and the software used for construction. The Discussion chapter was based on the results and discussed some of the findings, with emphasise on validity of the results.

The last part of the thesis was composed of a chapter with conclusions. The main finding and conclusions of the work done were summarized here.

1.5 CHALLENGES AND CONSTRAINTS

There were some additional challenges with preliminary work and fieldwork in Zimbabwe. The working conditions were not as one is used to in Norway. Electricity supplies were unreliable, there could go days without electricity. The internet connection was useless because of overloaded network and regular power cuts. This reduced the possibility of contact with teaching supervisor, and internet as a tool for sources and references. The preliminary work was a bit affected by those conditions, but one tried to do the best out of each situation.

One hoped to find some literature about interpretation and understanding of map among Zimbabweans prior to the execution of a questionnaire, but books and literature was impossible to find in Harare and at the University of Zimbabwe. The UZ had departments of cartography and geography, but literature was not available. This resulted in a questionnaire with emphasise on exploring basis interpretation and comprehension of maps and symbols.

The differences in culture was considerable, but after a period of time one adjusted to some of the cultural differences, and one learned about the differences and took precautions. The language may have been a element that influenced the results from the questionnaire. Although English was official and understood by most Zimbabweans, one does not know if the same meaning was interpreted into words and expressions.

One surprising occurrence that influenced the work when one was back in Norway was the shape files that one received from the UZ and The Zimbabwe National Water Authority (ZINWA). All shape files were without information about reference system and coordinates had unknown origin. The message from UZ was that “everything you need is there”, but that was far for the truth. Improvisation and new focus was necessary to complete the work.

CHAPTER 2 LITERATURE REVIEW

2.1 MAPPING OF DRINKING WATER QUALITY

The main problem of the drinking water quality around Iron Duke Pyrites (Pvt.) Ltd. is acid mine drainage (AMD). Acid mine drainage is general a big problem in areas that has been, or is doing coal or hard rock mining. It is caused by geochemical oxidization of exposed sulphide minerals from waste rocks or mine tailing. Toxic heavy metals and acidic hydrogen are released into surface- and ground water. It is very difficult to clean up pollution problems that results from acid mine drainage. When the chemical and microbial processes that creates acid mine drainage are set in motion, it will go on for thousands of years. (Horan, 1999) This is good motivation for actions that will clean up the pollution, but it also illustrates how important it is to tell people living around polluted water about the situation.

The problem with hazardous substances from contaminated drinking water is that it is seldom connected to immediate illness; it makes it more difficult to discover and indicate. Heavy metals are among those substances that provoke health damage when one has a long period of exposure. It is often substances that can accumulate in the organism and cause cancer and allergic reactions. The damages may occur after a long period of time when a critical portion of the metal is reached in the body (NIPH, 2003).

The primary factors which determine the rate of acid generation are pH and temperature, together with oxygen concentration, degree of saturation with water, the chemical activity of Fe^{3+} (iron) and the surface area of exposed metal sulphide (Horan, 1999). It tells that measurement of temperature and pH is essential for telling something about the amount of contamination in the area of interest. Temperature and pH can easily be measured with a pH-metre. The amount of iron (Fe) and sulphate (SO_4^{2-}) can be measured with a Dr. Lange Lahsa 20. The Dr. Lange measuring instrument needs power for analysis, and test tubes with reagent. That makes it difficult to do the measurement in the field, but with a sample from the water, it can easily be done shortly after collection in a laboratory.

The pH-metre has the advance that it can measure electrical conductivity as well. Electrical conductivity is a measure of how well a material accommodates transport of electric charge; it is measured in Siemens per metre [S/m]. Electric conductivity for drinking water lies between 0.005 to 0.05 S/m. (TheFreeDictionary, 2006). Electric conductivity is closely coupled to sulphate. If one finds a fixed relation between conductivity and sulphate, one does not have to take samples for both measurements. The amount of sulphate is a better indication than pH, since the amount of sulphate is more constant. pH varies rapidly, and is therefore not as reliable for indication of drinking water quality.

The mapping should cover the whole area, where contamination can be a problem. Open water, but also ground water where it is possible to reach the water for samples. Since the climate is so extreme during the year, it is a goal to get samples from different times of the year. Then one can see if there is variety in concentration of contamination during the dry season and the wet season. It is important for the inhabitants to get information of fixed variations that is dependable of other external factors.

2.2 FRAMEWORK FOR CARRYING OUT A SURVEY

To carry out a survey is one out of many methods for performing research. In the digital dictionary Clue, research is defined as a work that involves studying something and trying to discover facts about it. It sounds easy, but in practice research is often an open-ended process that is likely to generate as many questions as it does answers (O'Leary, 2004). Research is "*a creative and strategic process that involves constantly assessing, reassessing, and making decisions about the best possible means for obtaining trustworthy information, carrying out appropriate analysis, and drawing credible conclusions"* (O'Leary, 2004)

2.2.1 Generally about research

Some parts of research should be taken closer into consideration before one starts a research project. Some of those items will be mentioned in the following sections.

2.2.1.1 Research question

Some authors' emphasis the importance of good research questions because it is what gives focus, set boundaries and provides direction during the research period. It is also said that "*research questions act as a blueprint for the project*" (O'Leary, 2004). The question gives an idea about what theory might be relevant, the data needed to be gathered and the methods to be used. (O'Leary, 2004) In the first phase of a research project it is important to be creative; creativity can develop many interesting research ideas. To find a research question and appropriate literature should be an iterative process, like a cycle. Where questions give an idea about relevant literature, and while reading, other interesting research questions may arise and so on.

A research question can for instance be gaps in the literature. Maybe an important aspect of an issue has been ignored or whether there are assumptions underpinning a body of work that need to be re-examined. Or maybe a question can arise from personal experiences, theory, observations or timely issues. (O'Leary, 2004). No matter where the idea comes form, it is important that the research questions are significant – not only to the researcher, but to a wider academic or professional audience as well. (O'Leary, 2004)

2.2.1.2 Research hypothesis

There are different believes of if a hypothesis is necessary, positivists[1] thinks that the hypothesis is the cornerstone of scientific methods and that a hypothesis is absolutely necessary, while post-positivists[2] view the hypothesis as a reductionism device, that constrain the social research. There are situations where a hypothesis may not be appropriate and the research question may be difficult to convert into a hypothesis. This discussion will not be taken further, but a definition of a hypothesis and some explanation will be necessary so that a considered decision can be made about choosing a hypothesis or not.

A hypothesis is defined as a "*logical conjecture (hunch or educated guess) about the nature of relationships between two or more variables expressed in the form of a testable statement*" (O'Leary, 2004). With the research question as basis, the hypothesis gives a clear and concise

[1] Positivism is a philosophy that states that only authentic knowledge is scientific knowledge. Sometimes referred to as a scientist ideology. (Wikipedia; positivism, 2006)
[2] The term post-positivist are used to refer to scientific philosophies that arose after, and in reaction, to positivism. It addresses criticism to positivism, but preserves the basic assumptions of positivism. Post-positivist are common in social science. (Wikipedia; post-positivist, 2006)

statement of what one will think to find in relation to the variables and what will be tested. The hypothesis is a tentative proposition that is subject to verification through subsequent investigation (O'Leary, 2004). The hypothesis can easy be formulated if the research question is clearly defined. When there are some variables to explore, and a hunch about the relationship between those variables to be tested are gained. (O'Leary, 2004)

2.2.1.3 Evidence for good research

Good research must be seen as credible. Credibility is the "*quality, capability, or power to elicit belief* "(O'Leary, 2004). In the ordinary life, if someone or something has credibility, people believe in them and trust them, but for research it may have a more specialized meaning. Indicators that can be associated with credibility and good research are reliability, validity, objectivity, transferability, consistency and so on.
To get a better understanding of those indicators, a short description will follow together with an insinuation of what paradigm the indicators are significant; positivism or post-positivism.

1. *The first important question to bee asked for insuring that good research is maintained is "Have subjectivities been managed?" (O'Leary, 2004)*

Objectivity is the positivist indicator to ensure that subjectivity has been managed. If objectivity is maintained, conclusions are based on observable phenomena, and not influenced by emotions, personal prejudices or subjectivities. Objectivities imply distance between the researcher and the people or things being researched. The goal is to prevent personal bias from contaminating the results. But is it possible that subjective individuals can conduct objective research? This leads to the indicators used by post-positivists. (O'Leary, 2004)

Neutrality together with "subjectivity with transparency" is the indicators preferred by post-positivists. Neutrality seeks to recognize and negotiate subjectivity in a manner that attempts to avoid biasing results or conclusions. This demands that the researcher reflect on their own subjective positioning and attempt to mediate them in order to be true to the research process, it indicates that the researcher has engaged in reflexive practice and considered personal positioning issues. (O'Leary, 2004)

Subjectivity with transparency does as the name suggest, accept and disclose the subjective position and describes how that position might impact on the research process and conclusions. If the researcher works toward a radical change, has an agenda, the subjectivity may take a key role of the research process. (O'Leary, 2004)

2. *When subjectivity is managed in one way or another, it is important to insure that the methods are approached with consistency. "A quality control in method".*

Reliability is a positivist indicator that insures internal consistency. Reliability is thus the extent to which a measure, procedure or instrument provides the same results on repeated trials. The indicator of reliability gives an assurance that the tools one is using will generate consistent findings – they may be wrong, but they are constant! Reliability assumes standardization in the researched and indicates that methods can consistently capture what is being exposed. (O'Leary, 2004)

Dependability is the post-positivist indicator to insure consistency. Here, it is accepted that the reliability may not be possible, but it attests that methods are systematic, well-documented, and designed to account for research subjectivities. If it is questionable whether reliability is possible for the nature of the researched, dependability can be a useful indicator. (O'Leary, 2004)

3. *Has true essence been captured? Credibility rests on whether the data has the "power to elicit belief"; do others believe what has been said? The indicators to show the truth depends on how one define and understand the nature of truth.*

Validity would be appropriate if one thinks that there is only one truth that can be uncovered and understood. It is the positivists' indicator and is concerned with truth value. It indicates that the conclusions that have been drawn are trustworthy. It also considers whether methods, approaches and techniques actually relate to what is being exposed. (O'Leary, 2004)

Authenticity is more likely to be appropriate if one believe that there may be more than one version of any event, and that truth is dependent on context. It is a post-positivist indicator and is also concerned with truth value, while recognizing that multiple truths may exist. While the links between conceptual frameworks, questions, and findings may not lead to a single valid truth, authenticity indicates that conclusions are justified, credible and trustworthy through rigour and reflexive practice. (O'Leary, 2004)

4. *Good research should be relevant outside the immediate frame of reference.*

Generalizability is a positivist indicator, and tells if findings and/or conclusions from a sample, setting or group are directly applicable to a larger population, a different setting or to another group. Sometimes the possibility of generalize is referred to as external validity. Findings that are considered possible to generalize show statistical probability of being representative and are most appropriate for large-scale studies.

Transferability is common by post-positivist and may be appropriate if the study preformed do not have the sample size necessary to insure generalizability. Transferability highlights that lessons learned are likely to be applicable in alternative settings or across populations, rather then make claims about populations. It suggests that researchers have provided a highly detailed description of the research context and methods, so that determinations regarding applicability can be made by those reading the research account.

5. *The last issue to be considered for good research is whether the research can be verified?*

Reproducibility is concerned with whether results and conclusions would be supported if the same methodology was used in a different study with the same or similar context. This is a more rigorous form of verification used by positivists that requires that all variations in research context can be controlled. (O'Leary, 2004)

Auditability seeks full explication of methods so that others can trace the research process and appreciate how and why researchers came up with their data, findings and conclusions. It is used by post-positivist and expected that research should be open and transparent. (O'Leary, 2004)

Rather than selecting indicators by paradigm, researchers should determine appropriate indicators by critically examining their own worldview and assumptions together with the aims and objectives of their research and their methodological approaches. (O'Leary, 2004)

2.2.2 Different methods for data acquisition

To find out what the knowledge about maps is in the rural areas of Zimbabwe and their meanings about map symbolization, people must be asked and information gathered. There are several ways to get that kind of information, but not all are appropriate for this task

The easiest way would be to find documents and literature about the subject, and use those information sources to make maps to the inhabitants around the polluted area. This kind of analyzes consists of collecting, reviewing, interrogation and analyzing various forms of texts as a primary source of research data. The literature one might find home (Norway) are not well adjusted for less-developed countries. It takes for granted that a map is familiar and that everyone has some prior experiences with some kind of map. That is not an assumption one can take for granted in the areas this map will be used. And in Zimbabwe, book and literature are not easy to find.

As an alternative to document analyzes, one has different kinds of inquires, like interviews, observations and questionnaires. Interviews are a method of data collection that involves researchers asking respondents basically open-ended questions (O'Leary, 2004). In the other end, one finds observations, where the researchers collect data systematically through his or her senses. This form of data collection relies on the researcher's ability to gather data through his or her senses (O'Leary, 2004). Questionnaires are the interviewing method where the researcher is most remote from his or here respondent. Every respondent answers the same questions that are asked in the same way and in the same sequence for all. Survey will be discussed further in chapter 2.2.3.

2.2.3 Preliminaries to a survey

A survey is a study which seeks to generate and analyse data on a specific subject from a particular sample population. In general, surveys use questionnaires to generate quantitative data that can be used to calculate statistical information. (Kitchin and Tate, 2000)

The questionnaire should be designed in a structured way with ordered set of questions which gives the information needed without ambiguity or bias (Cloke *et.al.*, 2004). The purpose to all questions are to elicit meaningful verbal responses from study participants, either written or orally. (Peterson, 2000) Before one designs a questionnaire, some topics should be evaluated. A number of important topics are given below.

2.2.3.1 Administration

A questionnaire can be communicated in different ways. It can be distributed via mail or e-mail, or the questionnaire can be carried out over the telephone or face to face. There are advantage and disadvantages with the different forms. In some situations the researcher has no choice, and in other situations he or she can choose one or more methods for administration. All forms have good response rates, and most depends on the kind of questionnaire one would like to perform. More se (Cloke *et.al.*, 2004).

Some name the different mode of administration possibilities for self-administered questions and other-administered questions. Self-administered questions are those administered through writing like mail surveys and computer-based interviews. Other-administered questions are those communicated orally like through telephone or personal interviews. The mode of administration will impact the construction of questions in the way they are asked and answered. (Peterson, 2000)

2.2.3.2 The importance of carefully encoding and decoding of questions

For a research question to provide meaningful information, some communication-related activities must be successfully carried out. The researcher must encode the questions so that all study participants interpret the questions the same way. The study participants must decode the questions the way the researcher intended and encode answers that contain the requested information. And then, at last, the researcher must decode the answers that were provided in the way the participants intended. Any breakdown in the encoding or decoding processes may result in miscommunication or information that is not as meaningful as it could be. (Peterson, 2000) All this illustrates the importance of construction good questions and survey. Simply stated one can say that "*the quality of the information obtained from a questionnaire is directly proportional to the quality of the questionnaire, which in turn is directly proportional to the quality of the question construction process*" (Peterson, 2000).

2.2.3.3 Choosing dimension for amount of structure

Amount of structure is the extent to which all study participants are asked identical questions in an identical way. Completely structured questions involves asking all study participants exactly the same questions the same way in the same order, and all answers are predetermined so that only closed end questions are used. An example is a standard, uniformed questionnaire mailed to a sample of individuals. In the other end, one finds completely unstructured questioning where no two study participants are asked identical questions and where the questions permit a multitude of answers. Every questions that follow the first one depends on the previous answer, this is typical an in-depth, one-to-one interview with no predefined questionnaire. Unstructured questioning is flexible and can provide insightful information, but is time-consuming and information is difficult to interpret. The most important limitation of unstructured questioning is the inability to broadly generalize the answers provided. With structured questioning, the more structured the questioning process, the more the answers obtained can be generalized because of standardization. But also, the more structured the questioning process, the more the researcher must know about the phenomena, issues or topics being investigated, as well as the individuals being studied before construction research questions. (Peterson, 2000)

Adaptive or tailed questioning is semi-structured and can be very useful as an alternative. In adaptive questioning, a series of questions is constructed to quantify a particular attitude, perception, personality trait or the like. But instead of asking each study participant every question in the series, only a subset of questions can be asked, depending on the answers given in prior questions. (Peterson, 2000)

2.2.3.4 Choosing degree of directness

Degree of directness is the extent to which direct questions are asked about the phenomena, issues or topics of interest in a research project. It is a continuous dimension that refers to how much is disclosed to study participants about the purpose of the project, the sponsor of the project, what the researcher hopes to learn from the project, and the nature of the questions asked. Full disclosure means that participants are told everything about the research project, including purpose and sponsors, and all questions are transparent in that they directly focus on the phenomena, issues or topics of interest. In the other end, one finds projective questioning approaches like indirect or disguised questionings. With an indirect approach, the study participants are told relatively little or nothing about the research project and may not be asked questions that directly relates to the specific subject being investigated. Indirect questioning is not usual, but may be used if it is necessary to protect the identity of the subject matter or the sponsor of the research either for confidentiality reasons or to prevent biasing study participants' answers, or if there is reason to believe that participants cannot accurately answer direct questions, or that the participants will not answer questions about a subject. (Peterson, 2000)

2.2.3.5 Information and instruction

Surveys need to include some background information that identifies the sponsor/university, clarifies the surveys purpose, assures anonymity and thanks for time and assistance. And also for a good survey construction, it may be necessary to provide some instructions. Instructions should introduce each section of the survey instrument. Clear and specific instructions should be given for each question type and examples provided. The instructions should be easy to distinguish for the actual survey questions. (O'Leary, 2004)

2.2.3.6 Open- or closed-end questions

In open questions the respondent can construct answers using their own words. They can offer any information and express any opinion they wish, only limited by the amount of space provided for an answer. These kinds of question can generate rich and candid data, but it can be data that is difficult to analyze, interpret and code. (O'Leary, 2004). An open-ended form can be proper if the interpretative strategy permits written text as data (Cloke *et.al.*, 2004). Open-end questions are often used in the early stages of a research project to generate ideas of obtain a fundamental understanding of the phenomena, issue or topic being investigated when relative little is known about it. They can be used to develop closed-end questions for later research stages. And also if the researcher wants to ensure that answers will not be unduly influenced by the presence of predetermined answer alternatives, open-ended questions is necessary. (Peterson, 2000)

Closed questions force respondents to choose from a range of predetermined responses. The answers are generally easy to code and statically analyze. These questions can come in many forms like agree/disagree or yes/no questions or making the respondent scale or order options in preference. (O'Leary, 2004). Benefits when using closed-end questions is that the cost of administering is lower than with open-ended questions. Close-ended questions are easier to answer because they require less physical and mental effort from the respondents. And finally the use of closed questions by personal or telephone interviews reduces the possible impact of interviewer recording errors that may arise when open-end questions are used. With closed-ended questions, some other effects may arise, the ballot effect and the position effect as possible limitations. (Peterson, 2000)

The ballot effect is the phenomena that if the researcher asks a question, he or she will receive an answer, regardless of how meaningful and relevant the question or answer is. The participants may feel pressured to provide some sort of answer. The concept comes from voting research. The ballot effect may result in overestimating the importance of answers presented and underestimating the importance of answers not presented. *The position effect* occurs when certain answer alternatives are chosen more or less frequently because of their position among other answer alternatives, regardless of their content. This is most typical for questions asked for opinions or "reason why". (Peterson, 2000)

When closed-end questions are used, the answer alternatives must be mutually exclusive and collectively exhaustive. This means that respondents can logically provide one and only one answer that there is an answer for every respondent. To make sure that all respondent can make an answer, it can be a solution to include the alternative "*other__________ (specify)*".

This alternative should only be used for unusual answers, and as a rule of thumb, no more than 15 percent of the respondents should choose this "*other*"-alternative. If answer alternatives are properly constructed, then study participants will seldom select that alternative. (Peterson, 2000)

2.2.3.7 Organization, layout and design

If the survey is to long, the respondent may not complete the questionnaire. The organization is of importance. To start the survey with questions that might be considered as threatening is not a good idea. Where to put the important questions depends on the nature of the questions and the respondents. (O'Leary, 2004). Most surveys starts with questions about age, gender and other classes for classification. It is of great importance that the survey looks professional in means of layout and design. If a survey looks unprofessional, the respondent will be less likely to complete the survey and also the potential of mistakes increases if surveys are cluttered, cramped or messy. (O'Leary, 2004)

2.2.3.8 Pilot survey

There are a lot of reasons why one should do a pilot survey before starting the main data-gathering stage. It is a way to become familiar with the questionnaire in practice, it's an opportunity to find out which questions do not work well, so they can be improved. It's a way to find out if the questions construct data which are useful for the overall research question(s). Questions that don't construct useful data may be removed or transformed into a more useful form. And a pilot survey gives some practical indications, like how long a questionnaire will take to complete. (Cloke *et.al.*, 2004)

2.2.3.9 The role of the researcher

Both the researcher and the respondent will try to interpret each other in different ways. The researcher will interpret aspects of the respondent through the medium of his or her replies. But the respondent will also try to interpret the researcher through the medium of the survey instrument so that a socially constructed relationship will be established. Researchers will usually represent them self as efficient, professional and as careful over important issues of ethics. To get a high response rate it can be profitable to carefully explain the purpose of the survey, the position of the researcher, what will be done with the results, safeguards for confidentiality and the anonymity of the respondent. If the questionnaire will be done face to face, a pre-warning may be necessary to insure that the researcher respects people's privacy and their time management. (Cloke *et.al.*, 2004)

It is nearly impossible to exclude personal characteristics from the social relationship that is formed in the meeting between the two involved. The ability to relate to people will differ between the different people that are questioned. That is regardless of the professionalism in recording answers and asking questions. (Cloke *et.al.*, 2004)
To be scientific neutral may appeal to some respondents, while to others it might appear rude, uncaring and exploitative – that's why it is important to adapt to the situation and the people one are meeting.

2.2.3.10 Knowledge of the respondent

When the questionnaire is administered in a language or culture different from that of the researcher, it is important that one consider the typical vocabulary and education level of the study participants. The mode of questionnaire administration can influence whether a question is understood, how it is understood and whether and how it will be answered. With a selfadministrated questioning, the researcher has no possibility to explain possible obscurity. With an orally questionnaire some obscurity can be explained and because of that comprehended by the respondent. Questions should be evaluated with respect to the language capabilities and cognitive characteristics of the respondents. Whether the participants understands the questions should be evaluated in terms of absolute understanding and relative understanding. Absolute understanding is whether respondents comprehend the literal meaning of a question, if the information requested is likely to be ambiguous or the words and terms used are likely to be too abstract, technical or poorly defined. Relative understanding is whether the respondents comprehend the pragmatic meaning of a question. Meaning that questions should be evaluated on the basis of whether the researcher and the study participants have the same understanding of them. (Peterson, 2000)

Even though the participants understand the questions in absolute and relative terms, they may not have sufficient knowledge to answer questions. And the researcher has no guarantee that the respondents will answer candidly. Important questions for a researcher in the phase of construction of questions are therefore (Peterson, 2000):

"C*an study participants understand the question?*",
"*Can study participants answer the question?*" and
"*Will study participants answer the question?*"

2.2.4 Analysis of answers from a survey

There exists lots of statistical test one can run to analyse and interpret quantitative data. Quantitative data are generally structured and consist of numbers or empirical facts that can easily be "quantified" and analysed using numeric or statistical techniques as a contrast to qualitative data. Qualitative data are characteristic as unstructured and consists of words, pictures and sounds not always as easy to interpret or analyse. (Kitchin and Tate, 2000).

The tests and statistical terms described in the following sections are adapted for quantitative data in this context. Statistical test are mainly used to compare two or more data sets. If one has some presumption of the data sets, hypothesis may be constructed. That is not necessary for all data sets and it depends of the nature of the data. A null hypothesis is usually the hypothesis that indicates that there is no real difference to the data collected, $\mu_1 = \mu_2$ where μ_n is the mean for each group. The alternative hypothesis or research hypothesis says that there is a significant difference, $\mu_1 \neq \mu_2$. When the null hypothesis (H_0) and the alternative hypothesis (H_1) are defined and the sample collected, one can execute tests that fit the data sample to determine which hypothesis to accept. (Kitchin and Tate, 2000)

Dependent on the sample and hypothesis constructed, a selection of test exists. T-test is where one is testing the null hypothesis that two population means are equal. The design of the study indicates which of the tree types of t-test one need to use for analyse. The *one-sample t-test* can be used if one has a single sample of data and want to know whether it might be from a population with a known mean. A *paired sample t-test* or *matched-cases t-test* can be used if one want to test whether two population means are equal, and one have two measurements from pairs of people or objects that are similar in some important way. The last t-test is a *two-independent-samples t-test*. It is used if one have two independent groups of subjects (like men and women or employed and unemployed) and want to test whether they come from populations with the same mean for the variable of interest. There is no relation between the people or objects in the two groups. (Norusis, 2005). Another test is a *one-way analysis of* *variance* which examines the difference between three or more groups by looking at each group mean. That's a parametric[3] test and the data must be at a level of interval or ratio. (Kitchin and Tate, 2000).

Cross tabulation is when a table has counts of the number of cases with particular combinations of values of the two variables. If one wants to draw conclusions about the relationship of the variables in the sample, a *chi-square test* can be used to test the null hypothesis that two categorical variables are independent. Independent means that the probability that a case falls into a particular cell of a table is the product of the probability that a case falls into that row and that column. (Norusis, 2005). It is a non-parametric[4] test that compares portions on nominal or categorical data. (Kitchin and Tate, 2000).

It is possible to measure correlation with Pearson correlation coefficient, Spearman correlation coefficient or partial correlation coefficient. *Pearson's product moment correlation coefficient* is a parametric test that determines if two variables are independent, it says to which degree they vary together. The level of data must be interval or ratio. (Kitchin and Tate, 2000). The *Spearman Rank Order Correlation Coefficient* is a measurement that is designed to handle ordinal data, such as ranks. (Wasson, 2006) It's a non-parametric test that is used on independent data sets and it describes the degree of association between two sets of ranked data. (Kitchin and Tate, 2000). The last correlation test is the *partial correlation coefficients* which must be used if one wants to examine the relationship between two variables, but have to be concerned about the effect of other variables on the relationship of interest. A partial correlation coefficient measures the linear association between two variables while adjusting for the linear effect of one or more additional variables. (Norusis, 2005).

If one wants to predict the values of a dependent variable from the values of a single independent variable or multiple independent variables, one can use *bivariate linear regression* or *multiple linear regressions*. For more see (Norusis, 2005).

Other non-parametric test that may be alternatives in a statistical analyse process is Kolmogorow-Smirnov, Mann-Whitney U test, Wilcoxon signed ranks test and Kruskal-Wallis. *Kolmogorov-Smirnov* uses the ordinal level of data and compares the data sample with some expected population distribution or compares the distribution of two data samples. The other three tests must at least have an ordinal level of data. *Mann-Whitney U test* determines whether two independent samples are from the same population by comparing the scores in each data set. *Wilcoxon signed ranks test* examines the differences between data from the same phenomena collected in two different conditions or times by examining the ranks. And last, the *Kruskal-Wallis* is used on three or more samples and is the non-parametric equivalent to the one way ANOVA[5]. (Kitchin and Tate, 2000).

From statistical software programs like SPSS and MINITAB 14, much descriptive statistics can be generated that outline the results from the survey. Information like mean, median, frequencies and percentage can easily be generated.

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[3] Parametric test is a statistical tes in which assumption are made about the underlying distribution of observed data (Wesstein, 1999)

[4] Non-parametric test are based on rank of samples rather than distribution parameters (mean, standard derivation). (Ward, 1999)

[5] ANOVA is a shortcut for analyse of variance as discussed previous in the section.

2.3 SYMBOLIZATION ON A MAP

Map symbolization is the process where concepts and data are linked to visual symbols for representation on the map. In one way, it can be said that everything on a map is a symbol (Krygier and Wood, 2005). That means that symbols are the graphic language of maps. And because of the nature of those symbols, some has suggested that this form a universal language (Tyner, 1992). That's one statement that will be tested in this thesis; is symbolization a universal language? It is of primary important that lots of preliminaries are done on selection of symbols previous to map design. Both selection and design of symbols are important for a successful map (Tyner, 1992).

Features exist in the real world, and to represent those relevant in a map, consist of different steps. First, some kind of classification must be preformed, and then simplification may be necessary before exaggeration. When those routines are applied, the data can be symbolized as a result. Symbolization is the critical stage. Fore example can good simplification and classification be annulled by poor symbolization. And even as important is the possibility that good symbolization can make an impression of accurate simplification or classification, even when the process of simplification or classification is not sufficient enough. (Robinson *et.al.*, 1995). Emphasis will be to the last stage of the process, symbolization.

It is essential with good background information before the process of symbolization takes place. A factor of success is to know the respondent and have a good understanding of the purpose of the map.

2.3.1 The purpose of the map and the map user

For a cartographer, it is always important to consider the purpose of the map. This is especially important during symbolization process and design. Meaningful questions can be "*What exactly will the map show?*", "*What is the theme?*", "*What will it be used for?*" (Tyner, 1992). Those questions will help the cartographer to choose the best adapted symbols.

Also the map users vary widely in map-reading abilities. For traditional maps, it is necessary to learn how to interpret it. The symbolism should suit the presumed abilities of the intended user, when the map is aimed for a specific group (Tyner, 1992). The knowledge of these abilities must be found before designing the map. The knowledge can be found in publications or from the place of the intended users. Because the eye is the primary sense used in map reading, the cartographer must consider the possibilities and limitations of the eye. For instance; the eye has limitations when it comes to distinguish colour hue, it is easier to recognize colour values, then hue when lost are put together. But for users that are colour-blind, different values are difficult to distinguish, and hue would be a better variable.

2.3.2 Aspects in the process of symbolization

The process of symbolization includes two major aspects; to select the level of measurement and to choose the dimensionality. In the real world, all aspects exist in a combination of level of measurement and dimensionality, and all features can be mapped in a combination of these to aspects. It's worth mentioning that the way features exists in the real world and the way features are mapped, need not be the same! (Robinson *et.al.*, 1995)

The visual variables for static maps are well known among cartographers. Those variables must be considered in the process of symbolization. For more about visual variables see (Krygier and Wood, 2005) or (Tyner, 1992).

2.3.2.1 Selecting the level of measurement/classification (Robinson et.al., 1995)

The four scales of measurements are defined as nominal, ordinal, interval and ration. They are nested in that order, so when symbolizing a map, they can be generalized down the measurement scale. Nominal classification is the lowest level of information, while ordinal, interval and ratio represent successively higher levels of information. (Tyner, 1992) It is for instance possible to generalize from ratio to interval, ordinal or nominal; or from ordinal to nominal. It is not possible to generalize the other way. And information or data in the real world that are nominal must be symbolized as nominal data because nominal data are at the bottom of the scale. (Robinson *et.al.*, 1995)

Nominal classification can only locate and name items. The categories defined from nominal classification are mutually exclusive, qualitative and have no ranking or value attached. One item can be placed in more than one category. (Tyner, 1992) An example is different agricultural fields like maize, wheat and rice, or forest areas. Ordinal measurement classifies data into ranked categories. But the categories do not have exact values. There is often descriptive ranking like small, medium and large or high, medium and low.

Interval is similar to ordinal measurements as it classifies data into ranked categories. Interval classification has actual values and gives function and rank. It has an arbitrary starting point as distinct from ratio classification. Ratio measurement is the same as interval measurement; with the only difference that ratio has an absolute zero point. A good example to illustrate the difference is that Celsius temperature scale begins at an arbitrary assigned zero, it is not correct to say that 5˚C is half the temperature as 10˚C. But with ratio those kind of comparison are possible, it is possible to say that 500 people is half of 1000 people since population measurements begins at an absolute zero. (Tyner, 1992) For symbolization there is practical no difference between those two. The difference can only be seen in a legend with textual or numerical annotation. (Robinson *et.al.*, 1995)

The four levels of measurement illustrated with area symbols:

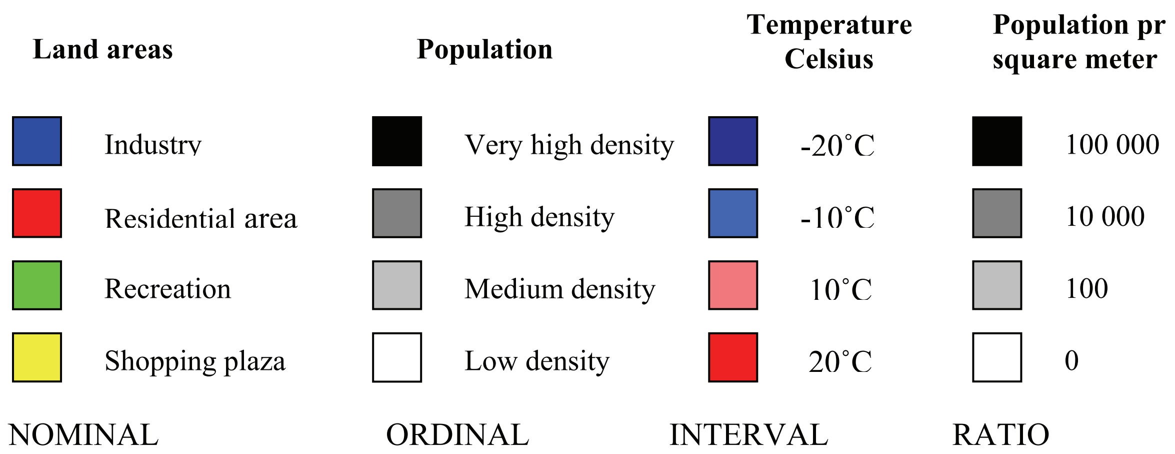


Figure 3 Four levels of measurement classification

It can be seen from the characteristic of the measurement scale in Figure 3 that symbols which connote quality or difference in kind, can only be at the nominal scale. While symbols that connote quantity or difference in number, can be in the ordinal, interval or ratio scale. (Krygier and Wood, 2005; Robinson *et.al.*, 1995)

2.3.2.2 Choosing the dimensionality (Robinson et.al., 1995)

When time is not considered as a dimension, three dimensions are the usual range for features. Zero dimension or dimensionless are points, one dimension can be lines, while area features have two dimensions and volume features have three dimensions. Maps usually depict data at zero, one or two dimensions. That means features with three dimensions are usually generalized to two dimensions on ordinary maps, also known as the projection problem since this reduction of three dimensions has been a cartographic problem for long times. (Robinson *et.al.*, 1995)

In this thesis the choice of dimension will not expand to three dimensions on the map. The dimensionality will be dependent on the geographic location, the scale, the features being mapped and the map basis. Some times it may be appropriate to symbolize a feature as an area, while in other settings it may be more appropriate to generalize the same feature to a point. For instance; a city can be indicated as a point in a map covering a continent, while the same city can be indicated as an area in a map covering one country.

2.3.3 Standards within cartography

International standards that are used for exchange of geographic information are for instance SOSI and ISO. Those standards will not be considered in this work due to time limitations and different focus on this work. But instead, the Norwegian Mapping Authority Land Map Divisions paper about location of geographic information will be mentioned as a proposition to further work. That paper indicates the degree of accuracy for Norwegian mapping and location issues. (NMALMD, 2004) It is a good standard to be based on for further work about environmental pollution and mapping of waste in Zimbabwe. The Norwegian Mapping Authority Land Map Division take aim to give good precision, so that the data can be exchanged when using national and international standards or formats. For more see (NMALMD, 2004)

2.3.4 Symbol fonts for recreation and sport in Norway

A group comprised of representatives from the Norwegian Mapping Authority has worked together to develop a symbol standard. Institutions and organizations that have cooperated with this symbol standard is “The Directorate for Nature Management”, “National Council for Open-air Recreation”, “the Norwegian Mountain Touring Association” (DNT), “the Directorate of Public Roads”, “The Ministry of Cultural Affairs” and “the Norwegian Confederation of Sports”. The motivation to generate such a standard was that up till this project was established, a lot of different symbol «standards» for recreation and sport had been used by different participant for the various hiking and outdoor recreation maps, information posters, signposts in recreational areas, brochures etc. (NMALMD, 1997). This may feel confusing for the users of such maps, where the same activity or area has different symbols dependent on the creator of the map.

Although this symbol font standard aren’t meant for the kind of map generated in this project, it is interesting to see if some of the relevant fonts are seen as intuitive for Africans – and can bee used. The symbol standard from the Norwegian Mapping Authority covers symbols or pictograms for recreation and sport. The symbols are meant to be used on maps and other printed materials, as well as information signs in the field. So in some ways, there are similarities with the usability of the maps, where the resulting map form this project may be as an information sign in the field or as printed materials.

The main symbols from this standard are divided in four categories related to Facilities and Activities, Nature Areas, Culture and Entertainment and Transport respectively. Only those usable for this project will be considered here. Three corresponding symbol fonts for optional use of negative symbols, positive symbols or positive symbols unframed are listed for those that are found interesting for this project work.

Table 1 Standard symbol fonts for facilities and activities (NMALMD, 1997)

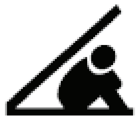
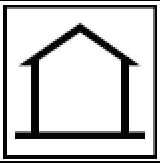
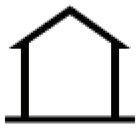
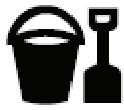
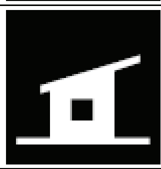
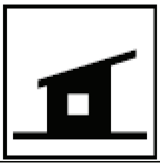
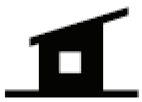
Subject/tema	**Negative symbol with frame**	**Positive Symbol with frame**	**Positive symbol without frame**
Primitive shelter			
Tourist hut with no services			
Playground			
Emergency shelter/Building			

Table 2 Standard symbol fonts for nature areas (NMALMD, 1997)

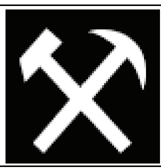
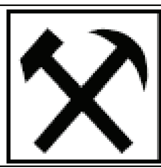
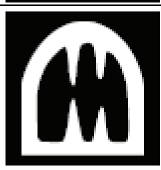
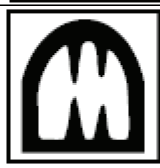
Subject/tema	**Negative symbol with frame**	**Positive Symbol with frame**	**Positive symbol without frame**
Mine			
Grotto			

Table 3 Standard symbol fonts for service and transport (NMALMD, 1997)

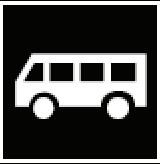
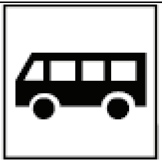
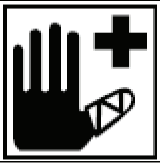
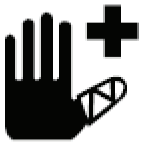
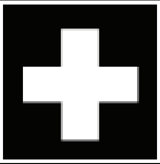
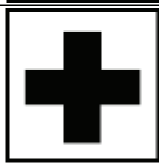
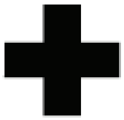
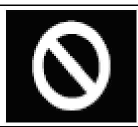
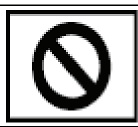
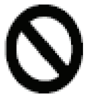
Subject/tema	**Negative symbol with frame**	**Positive Symbol with frame**	**Positive symbol without frame**
Bus stop			
Drinking water			
Danger			
First aid station			
Hospital			

Table 4 Standard symbol fonts for supplementing symbols (NMALMD, 1997)

Subject/tema	**Negative symbol with frame**	**Positive Symbol with frame**	**Positive symbol without frame**
Prohibited			

In Table 1 ,Table 2 , Table 3 and Table 4 all symbols are depicted as proposed in the Norwegian standard, but this may not be the optimal in this work. Maybe some of the symbols will get a new meaning or new symbols must be created to illustrate the correct meaning. Although this is only a portion of the symbols in the standard, not all of those symbols will be considered in the further work. For more about color and directive from the Norwegian map authority, see (NMALMD, 1997)

2.4 SETTING UP A GEOGRAPHIC INFORMATION SYSTEM (GIS)

Dependent on what kind of geographic data that exists, on must choose an appropriate drawing or GIS software for presentation, analysis and design. In this chapter, two different software will be considered with a view to possibilities and drawbacks for each of them; ArcGIS Pro 9 and MicroStation V8. One will mention two references to similar system that are established for environmental mapping.

2.4.1 Selection of software

ArcGIS Pro 9 is an ESRI[6] GIS software and is a integrated collection of products that can be used to build a complete GIS for a organization or a project (ESRI, 2006). ArcGIS consists of many software products like for instance ArcView, ArcReader, ArcCatalog and ArcToolbox. ArcReader and ArcView are both a part of ArcGIS Desktop together with ArcEditor and ArcInfo. All those products can be run on standard desktop computers and are used to create, import, edit, query, map, analyze and publish geographic information. (ESRI, 2006). Formats of GIS data that is supported in ArcGIS are shape files, coverage, raster and geo-database. Coverage and shape files are file-based models and they employ a geo-relational data model. Vector data is stored and unique identifiers are used to link features to attributes. In the geo-database data model, features are stored as rows in a relational database table. The rows contain both the coordinates and the attribute information of the features. (Crosier *et.al.*, 2002).

A great deal of geographic data is available in shape file format, also of geographic data from Zimbabwe. Shape files stores features belonging to a single feature class. They are stored in folders, and consist of a set of files of vector data. Each folder consists of a .dbf, .shp and .shx file (Crosier *et.al.*, 2002). Shape files can be used for mapmaking and some kinds of analysis.

An advantage with ArcGIS is that it is a user-friendly program if one has the necessary input files. Lots of analysis and design alternatives are possible. A disadvantage is that one can not do anything if information or data are not complete, all information and files must be given to get accurate design of maps. The maps can not get a better accuracy that the input files. It is important to have good enough information on the input data to reach wanted precision.

MicroStation V8 is a CAD[7] application that is used for infrastructure design, construction and operations. MicroStation is an advanced design program that can be used for a wide range of tasks. It is a design platform suited for 3D modelling, data versatility, workgroup productivity and application development among more. MicroStation has multiple raster image support, and accepts aerial photographs, satellite imagery, scanned maps and drawings among other things. It supports a wide variety of deliverable file formats, and data exchange and file translation is well developed. (Bentley Systems, 2003) MicroStation has solutions for geospatial industry that can be used for high-precision cadastral mapping, end-to-end design, documentations and engineering design of infrastructure project. (Bentley Systems, 2006)

MicroStation was primary used in the engineering and architecture fields for construction drawings, but today it has evolved to include advanced modelling and rendering features, and

[6] ESRI stands for Environmental Systems Research Institute, Inc. (ESRI, 2006)
[7] CAD stands for computer-aided design and refers to the use of computer systems to design detailed two- or three-dimensional models of physical objects (All-Free-Info, 2006)

specialized environments for mapping can be provided. (Wikipedia, 2006). It is an advanced program with many possibilities. One has lots of opportunities for manipulations and presentations in MicroStation. It is possible to convert formats, so that files can be analysed in other programs after manipulations or construction. The drawback is that it is not intuitive and easy to use; one has to use much time to get to know all possibilities and functions.

MicroStation and ArcGIS are the only programs evaluated here for presentation, analyses and manipulation of maps. It may be necessary to use other programs or methods if the programs discussed here is not well adapted for the intended use. Also it is likely that one has to use other programs to convert and prepare that data one want to use in MicroStation or ArcView.

2.4.2 Using a GIS to indicate contamination

GIS is a powerful tool to indicate, present and analyse pollution or other things over large areas. GIS is a software program that allows one to combine location information with descriptive tabular information.(Misiti *et.al.*, 2002) That can be an attractive capacity when one want to monitor or simply map contamination. Many systems are developed for specific areas, or range of applications. In this part, two examples on similar systems will be presented to show possibilities and limitations on GIS systems for contamination and environmental use. A system developed for the Florida Department of Health and a system developed for modelling environmental contamination from mining activities in Bolivia.

The Florida Department of Health has developed a system that locates and identifies petroleum-contaminated facilities and surrounding portable wells by using GPS, GIS and databases specially evolved for the purpose. The primary purpose for the well surveillance project was to identify potentially contaminated drinking water wells and assist in getting those wells remediate if necessary. They used a Geographic Information System (GIS) database to generate high resolution map, conduct spatial analysis and provide a tool for remediation and risk-based assessment. (Gordon, 2003)

The Florida Department of Health uses ArcGIS to construct well survey maps. First, GPS coordinates that were identified in the field were electronically submitted as a data file to a central e-mail address (GLOBAL), where the quality, formatting and content where assured for completeness and accuracy. The GPS file contained latitude and longitude (in WGS1984) coordinates, demographic information like name, address and owner, and optional information like date, comments, and well details. All was done electronically and never manually edited or entered in the database. Then the GPS data file was imported into Microsoft Access facility or a well table that were directly linked to ArcGIS. When the tables were linked to ArcGIS, facilities could be searched and located on street maps, digital orthophotos or to other spatial information, and analyses run based on contamination levels or well locations. They used the system to identify wells around a leaking with buffer analyses, they monitored to evaluate the potential for spreading plumes in ground water near drinking wells and they used the system to interpret the movement of petroleum contamination in the ground water. (Gordon, 2003)

In Bolivia, an environmental information system (EIS) was developed to support the management of existing and future mining activities for the Bolivian government. The foundation for the EIS was a GIS database that was provided with basic GIS functionality by ESRI's ArcView GIS software. And to supplement the basic GIS functionality, environmental modelling tools were made for prediction of concentrations from metals in air, surface water and ground water.

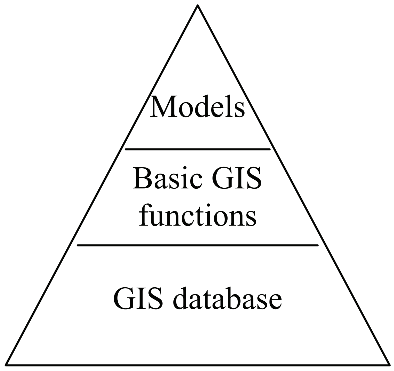


Figure 4 Environmental Information System (EIS) from (Hellweger *et.al.*, 2006)

The models were fully integrated with the graphic user interface of ArcView, and they were made in FORTRAN code that could be executed off-line. ESRI's ArcView GIS software was chosen as the conceptual view of a GIS, and the user interacted with a database through that software. ArcView were chosen because it was a powerful and easy-to-use software, and it provided the basic functionality like editing, zooming and identifying features. (Hellweger *et.al.*, 2006). To learn more about each of the models assigned to the GIS, see (Hellweger *et.al.*, 2006).

Both those systems presented above are much like the system needed for mapping of pollution from mines in Zimbabwe. The ArcGIS package from ESRI was used in both cases because it was easy to use and has lots of possibilities. Although the primary goal for a GIS in Zimbabwe is to map the situation, a GIS system may have profitable functions for later analysis and work. It may be an idea to look in a long perspective and try to identify prospective requirements for such a system. The examples showed that many possibilities lies ahead, and it is possible to customize a product that has those modules one want for mapping, identifying and analysis.

GIS makes it possible to have a dynamic approach to the situation or problem. Background information like land use, topographic features and expansion of buildings and industry is constantly changing and evolving. GIS will make it possible to give a "snap-shot in time". To have up-to-date values of contamination. To identify changes of water quality in early stages may be important for rehabilitation and information to locals. A GIS can help to have current information about infrastructure, detailed land use, geology and ground water together with the actual data on contamination. (Misiti *et.al.*, 2002)

CHAPTER 3 METHODOLOGY

3.1 EQUIPMENT USED TO MEASURE WATER QUALITY

Some laboratory equipment and a GPS was the only kit available for fieldwork. A Dr. Lange Lahsa 20 was used to take different samples of the ground water and the river flowing through the area. The Dr Lange Lahsa 20 could analyse for the content of sulphate and cobber in water. Analysis of sulphate and cobber was not necessary to take every week, it was taken only once because of the costs of running the analysis. The analysis contributed to a better understanding of the contamination and for determination of potential sources of contamination. For more information see (Tobiassen, 2006).

Figure 5 Equipment used for water samples and GPS positioning

Conductivity, temperature and pH were measured with a pH-metre, WTW pH/cond 340i, displayed in Figure 5. The pH-metre was a small and plain measuring instrument that was easy to bring and had the advance that one could do the analysis in situ[8]. That made it possible to carry out the same measurement at the same places each week. This kind of monitoring gave a good picture of the situation as regards changes over time. The GPS used for fieldwork and mapping of sampling points was a Garmin GPSMap 60CS.

[8] In situ means that the measurement can be done in the field. One does not have to bring samples back to a laboratory to do the analysis.

3.2 PREPARING A SURVEY

3.2.1 Considering different aspects for preparing a questionnaire

It's a time-consuming work to make a good questionnaire. The questionnaire as a whole must be designed in a logic and sensible manner, with a good structure and each question must be evaluated carefully. The guidelines in *2.2.1.3 Evidence for good research* must all be implemented into the questionnaire, so that quality will be implemented and correct conclusions may be drawn. Most of the relevant data and symbols for the questionnaire will be found in the literature described under the *2.3 symbolization*. But since literature is not very well adapted to Africa and Africans, it is essential to get to know the people around in the rural areas so that one can get a good adapted questionnaire.

In this project no indirect or secret motivations was known, and there was no reason to believe that there was necessary to an indirect approach with disclosure. A high degree of directness could be applied. The amount of structure was high, all respondents were asked the same questions in the same sequence. With those conditions, the analysis-process could be implemented straight forward and generalized to a larger population when an appropriate sample was made. The first draft to the questionnaire worked as a pilot, and a selection of a few people were asked to go through the survey, both resident at the mine and people with a university background. That will improve the questionnaire in ways that one person alone can not do – an insurance that questions are well formulated and a good design of the questionnaire.

To insure a good design of the questionnaire, the following components were considered:

- **The respondents**
  To insure that the questions were well formulated and asked in an unambiguous, precise way, it was an operative contractual assumption to know how is the respondents and who should be asked to insure a good and representative sample. Since the duty of the map was to illustrate and show where water are safe and where water are not safe to drink or use for farming and irrigation, those bringing and using water was the target group. An appropriate sample of those people should be asked to complete the survey. The knowledge level for such a sample group is not known, but from experience in the field of concern, some presumption may be drawn. Experience showed that people were not familiar with maps, and the survey may be the first experience of a map for some of the respondents. That means no prior presumptions from western knowledge of maps are good or true presumptions in this context. It may be good solutions and ways of expressing things, but it should be tested first to insure the quality. With no basis or knowledge-base, it is hard to figure out where to start! One can not take for granted that the usual perspective for maps is appropriate for people that have no experience with that kind of perspective. The area to be mapped is characterized as a flatly terrain, with no mountains or lookouts. So the inhabitants have probably never seen their own area from above. Also the vegetation changes drastically during the year, from very green, fast growing and vigorous under the rain season, to totally desiccated, dried out during the dry season. This has impact on how the study participants recognize their own area.

- **Form of the questionnaire and administration**

Lots of bearings must be considered for administration of a questionnaire carried out in Africa since access to facility is not as easy as in Norway. Facilities as paper, computers, printers and power or batteries, all makes constraints to the administration. This will be discussed further in next section, *3.2.2 Choice of method for administration.*

- **Information to the study participants**
  The first thing one must do is to tell who the researcher is, from which institution/university and why the researcher disturbs. To motivate the respondents and to make them complete the survey, some background information may be necessary. To tell people that it is to improve their living quality, and to help them prevent illness because of the water. A motivation may be to explain what may happen to them if they drink heavily polluted water, and how a map can help them preventing that.

- **The questions**
  The major question is what kind of questions is most appropriate? Open-ended questions will give the respondents an opportunity to think without restrictions and without predefined alternatives. The difficulties with those kind of questions is that if hundred people were asked about what symbol or illustration pictures danger best, one would probably get hundred different answers. It would be a very difficult job to analyze and interpret those kinds of answers. With close-ended questions, the process of analyze and interpretation will be easier, but then the answers will be restricted to those predefined alternatives given by the researchers. With close-ended questions, the researcher must have good knowledge about the area of interest so that good questions and answer-alternatives can be made.

- **Structure and layout**
  To give the questionnaire a good structure, it might be appropriate to split it up in different parts. In each part of the survey similar question will appear, and it will be easier for the participants to understand the questions. The layout should be as easy and simple as possible; to make sure that it would not be a disturbing effect.

- **The contents of the questionnaire**
  What kind of information is interesting and in what way should the questions be formulated. General information about the respondent will be interesting, like gender, age occupation and so on. Their understanding of maps will be interesting to get an overview of their map knowledge. It will be an important part since it will influence in what way information should be given. Their choice of appropriate colours and symbols should be evaluated. This will be discussed further in a later section.

3.2.2 Choice of method for administration

When it comes to the administration and form of the questionnaire, some limitations must be considered as mentioned in a previous section. First of all, it is almost impossible to print at the University of Harare due to lack of toner and paper. If the questionnaire must be printed, that means much paper must be used. And that’s kind of waste, in a country where people fight and struggle to get food. To administrate the questionnaire over e-mail is impossible; people don’t have computers or contact-information.

One solution may be to print the questions to be asked in one paper and then make an lamination of the questionnaire, so that all respondent can be exposed for the same questionnaire, and answers are written on a separate sheet, book or even directly onto the computer (laptop). This solution claims that one must find a printer printing colours – good colours. Since a major part of the questionnaire is dependent on choice of appropriate colours.

The solution with minimum of cost associated with it, is to make a questionnaire on the portable computer developed as a kind of presentation (e.g. PowerPoint), and then bring the portable computer around to the respondents and show the questions on the computer, while the answers can be written on a sheet, in a book or even on the computer. This solution has minimum of costs associated with it, except that the researcher must do the questionnaire face-to-face, bringing a computer around. That may be time consuming. One big drawback is the lifetime on batteries; one cannot expect to find power at the places being visited.

To get a better idea of advantages and drawbacks of different solutions about distribution, a table may give a better overview.

Table 5 Short overview of different alternatives for questionnaire form and distribution

Topics to be evaluated	**Regular paper-questionnaire**	**One laminated questionnaire to all respondents**	**Distributed via mail/ e-mail**	**Questionnaire on portable computer**
Distribution to respondents	Possible if researcher or other visit respondents	Possible if researcher or other visit respondents	Not possible. No contact information exists	Possible when researcher or other visit respondents
Printing facilities	Expensive and difficult to get enough paper and/or toner	Depends on colour-printing facilities. One copy of questionnaire may be possible…	Omitted	Not affected.
Administration possibilities	Omitted	Face to face. Researcher or helper	Omitted	Face to face. Researcher.
Security	Omitted	OK	Omitted	Expensive equipment may be a vulnerable target
Focus of the respondents, disturbing factors.	Omitted	On questions. May be disturbed by white researcher. Everyone is familiar with paper.	Omitted	Focus on portable computer, a new experience. White researcher. Will probably get used to it after a few questions
Questionnaire offset	Omitted	Language. May be necessary with translation to shona, and a translator.	Omitted	Language. May be necessary with translation to shona, and a translator.

In summary, one can see that the only administration solution will be to visit the respondents' face to face, mail or e-mail distribution is impossible due to contact information and postal communication or computer facilities. The best solution seems to be a one copy of laminated questionnaire to all study participants, where answers can be written on a separate sheet. That solution depends on the feasibility for colour printing, that's the only drawback that needs to be investigated. To make a questionnaire on the portable computer may be an alternative solution, but some drawbacks need to bee considered then. First of all, a portable computer is extremely postponed to robbery. Calculated with a salary at the mine, a portable computer is worth 2.7 annual salaries, i.e. MUCH money for local inhabitants. But an even more possible drawback is that a majority of the study participants has probably never seen such an electronic devise, and focus will be on the fascinating computer, rather than on the questions being asked.

3.2.3 Methods for generating the questionnaire

The questionnaire was generated into four parts. Part one about the study participants and part two about their comprehension of maps. Part three and four concentrated on symbols and colours of features. In the first place, the survey was supposed to only concentrate about symbols and colours, but after a lot of evaluation, it seemed unreasonable to only concentrate about symbols if the participants never had seen a map before. With that in mind, the parts of symbols and colours could not be as close and in-depth examined as first planed. It would only give an indication of how locals interpret symbols and colours in relation with a map. Only those things relevant to the participants will be investigated. The questionnaire that was carried out is attached as Appendix 1 .

3.2.3.1 Part one of the questionnaire

The first part was designed to obtain information about the respondents. Most of the questions of interest could be asked without worrying of offending or making the participants feel uncomfortable. It was important to make the questions in such a way that the participants would not feel that they were stupid or inadequate. That's why one would ask the respondents of which age-group they belong to instead of they're exact age. It can be embarrassing not to remember or know their exact age.

The aim of part one was to get an overview of the participants and make it possible to categorize them in different age groups, gender or others classes in the analyzing process. If it would be impossible to draw conclusions from the survey as a hole, it could still be possible to draw conclusions from a subpart of the respondent. Most of the question was made as close-ended questions. That would make it easier to answer, all the participants had to do was to recognize or identify the alternative most appropriate for them, mostly yes or no in the first part. Question 3 was asking about their occupation and constructed as open ended. A short definite answer was expected. That was easier for the researcher than investigating all possible and probable working alternatives. Question 9 was about how to orientate in the terrain. It was included to get an understanding of their relationship to the local area and of general interest. It could help to get a better understanding for their responds and their interpretation. The question would suit better as an open-ended question, where they could answer with own words and statements. But to make sure everyone understood the question and to help them identify different answer possibilities, it was made as a close-ended question.

3.2.3.2 Part two of the questionnaire

The aim of the part two was to explore how familiar the participants were with maps, and if they could interpret them. It consisted of four maps from the locale area around Iron Duke Pyrites where the participants lived. The participants were asked if they understood the map and knew where it was from. The simplest form of a map was a drawing of the area, much like a drawing with major roads, houses and rivers only, without describing text and legend. Then the same drawing appeared with names of areas and houses together with reference to a coordinate system and a legend describing the different features. Those two maps were taken from a drawing made by a student at UZ (Ravengai, et al., 2001). The student had done a project at IDP before and had sketched a map over the area.

The two last maps were taken from the same source, a topographic map made by the department of land survey at IDP. They did not have the maps in digital form, and a scanner was not possible to obtain. It was based on a picture taken from the topographic map with an Olympus 500E mirror reflex camera with wide angle lens. Then the picture was taken into image processing programs to make them more legible, and to adjust colours tones and contrasts. The topographical maps had all features, like houses, roads, water, contours, scale and so forth. Map number three was depicted without outlining anything while map number four was depicted with roads, river and houses outlined.

A map in another perspective would be convenient in this part of the survey, but unfortunately it was impossible to find this kind of map. To draw such a map was difficult this part of the year, when the area was so vigorous and indefinite because of bushes and forests. One could not get an overview picture over the area.

3.2.3.3 Part three of the questionnaire

Part three consisted of close-ended questions of what symbols the respondents found most appropriate for different features. The alternatives were gathered from standard symbols developed by The Norwegian Mapping Authority; from pictures taken of signs and posters around the area of interest; and from the symbol library found in programmes like ArcGIS pro 9 and Microsoft Office Visio 2003. Some of the features were drawn in drawing programs, to include all thinkable alternatives that could be important to include. Since close-ended questions had the drawback that alternatives could be forgotten, one of the alternatives was for all questions "*don't know*" or "*others*". In that way, the participant could indicate that he or she found none of the alternatives appropriate, and they could include they're own drawing or sketch of what they felt were missing.

3.2.3.4 Part four of the questionnaire

The last part was about colours, what colours the participants mean was most appropriate for features like water, roads, danger and so on. Picture was taken of the colour of feature they were familiar with from their own living area. The colour from those pictures was compared to colour schemes to find the best alternative most comparable to the real colour. Figure 6 illustrates pictures and choices of color for river and road.

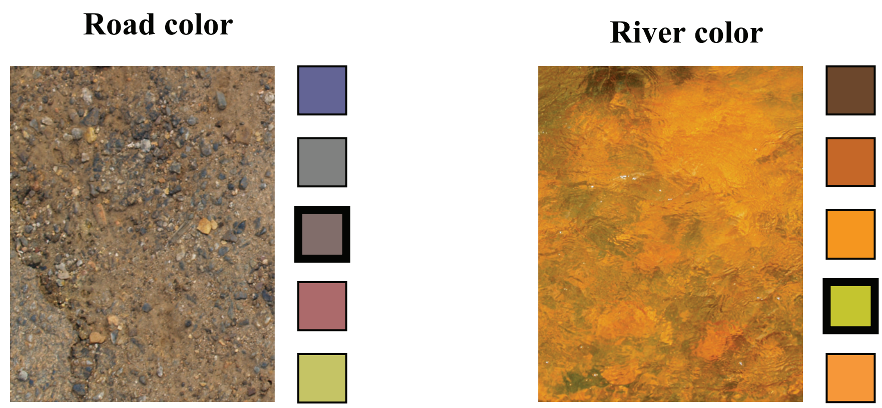


Figure 6 Choice of colours for road and river

The choice of colour of river is based on the colour of the water and not the ground which is more like orange as can bee seen in Figure 6.

3.2.4 Methods for analysing the results from the questionnaire

50 different people from around Iron Duke Pyrites were asked in the survey of the researcher and a translator. Each respondent were asked face to face, a translator asking each questions, and the researcher collecting the answers in a sketch book adjusted for that purpose. The results from the survey were stored in a excel book before it was taken to further analysis. Two statistical analyze programs were considered, SPSS and MINITAB 14. Both were well known and recommended. SPSS was the "*Statistical Package for the Social Sciences*" and included a comprehensive set of tools that could be used to accomplish a wide variety of data analysis tasks specially adopted for social science researchers. (Einspruch, 2005). MINITAB 14 was a statistical program that helped the researcher to create graphs, generate statistics, procedures and reports and assessing quality (MINITAB, 2003).

Since the survey was an attempt to understand the locals and their understanding of a phenomenon, and not very technical in its nature, SPSS were used as the statistical program. To transfer all data from excel to SPSS, one had to convert all alphanumeric values to numbers so that SPSS could accept the values (Einspruch, 2005). Level of measurement assigned to most values was "nominal", except for age which was assigned to "ordinal". Variables measured on a nominal scale had values that could not be ordered in a meaningful way. Variables measured on an ordinal scale had values that could be ordered from smallest to largest, but the numeric distance between the values was not meaningful (Norusis, 2005). To make it easier remember and to have a good structure, a codebook were created.

When all data were in SPSS, it was easy to get descriptive statistics from the survey. To get a better understanding of the data from the survey, and to debug the data, frequencies of all the questions were useful and generated. When one could see the frequencies of all alternatives for each questions, an overview emerged. Unforeseen results emerged and one could be able to detect derogation and errors. Empty boxes in the Data Editor were detected from the descriptive statistics as "*Missing System*". It told which records that had missing boxes, so it was easy to go into the Data Editor and correct the input data. The descriptive statistics are attached as Appendix 4 and the answers from the questionnaire are given in Appendix 3 .

3.2.4.1 Statistical analysis evaluated for the data sample

Much time and effort were used to try to find tests or statistical analyses one could employ to the data set. The main objective for the questionnaire and dataset was overall mapping and identification of Africans understanding and comprehension of maps and map symbols. To see if they had the same understanding and interpretation as Norwegians and if same rules for colours and symbols could be used. A good picture of the results emerged from the descriptive analyses run in SPSS. Insightful information was detected and illustrated in graphs and tables.

Early in the process before constructing the survey, lots of suggestive hypothesis were formed as interesting research basis. One of them was:

H_0: “It is not a difference in interpretation of maps between Africans and Norwegians”
H_1: “There is a difference in interpretation of maps between Africans and Norwegians”

To do analysis and test that hypothesis, one must have a control group. A control group would be the group one is testing the hypothesis against. An appropriate control group would be a group in Norway that had completed the same survey as the survey carried out in Zimbabwe. Because the researcher was in Zimbabwe and had limited resources, an identical survey to a control group in Norway was impossible. Such a survey would be a waste of time, since the answers from a Norwegian control group would be known. It is something most Norwegians agree upon that water is depicted as blue in maps. To execute a questionnaire, where most of the answers are known prior to the survey was not useful.

A control group was not an alternative in this case; one could test the data set from the study participants against the known Norwegian standards. Like water is blue, danger is red, safe is green and so on. But with the Norwegian standards, one did not have the control group most of the tests require. A one-sample t-test requires only one sample, but one needed a population with a known mean. A population with a known mean did not exist. The other t-tests required at least two sample groups, One-way analysis of variance required at least three groups.

Another suggestion to an interesting hypothesis was:

H_0: “The study participants find blue as the most appropriate colour for water in maps (same as in Norway)”
H_1: “Blue is not the most appropriate colour for water in maps among Africans (Different from Norwegian maps)”

Other similar hypothesis could be made with other features such as danger, crops and safe. With such a hypothesis one has two groups of variables one would like to compare or investigate; blue and not blue. The different colours of blue could be merged into one variable, and all the other colours could be merged into another variable. Some test could be possible to run with that hypothesis, but a much easier way to investigate this hypothesis is to look at the graphs and frequencies and add up with count or percentage. Then one will see how many found blue most appropriate and how many did not find blue appropriate. One would not be able to tell if there was a significant difference, but what difference would that do in a mapping stage where the overall goal was to get an overview and a better understanding of Africans interpretation of map.

Most of the test presented in *2.2.4 Analysis of answers from a survey* required that the level of the data were at least ordinal. That was a problem in this situation since most of the data were nominal level. A test recommended for data at nominal level was chi-square test that was used to test if categorical variables were independent. Chi-square test was possible for the last hypothesis proposal. Viewed against the background of all possible statistical tests and what they examine, the conclusion was that in this stage of the research no such test gives useful and more insightful information than was already gathered through the descriptive statistics.

3.3 METHODS FOR SETTING UP A GIS

3.3.1 Data basis and acquisition

To be able to make a map over the area of Iron Duke Pyrites, it was of primary importance to get basic map data from the area. It was not a part of the task to make a map from start to end, but to use existing geographic data from the area. Lots of energy was used to try to get the data one needed, all kinds of maps that could be found and shape files over Zimbabwe. After weeks with searching, one got hold of shape files from the University of Zimbabwe and from the Zimbabwe National Water Authority (ZINWA). Geological maps over Zimbabwe were also provided. Most of the maps provided was in JPEG-format, and it was poor accuracy, with little additional information about reference system, legend, when the map was made etc. It was not good to use the data source when one don't know anything about the accuracy, if the data have some sources of error or have been manipulated.

The shape files given from the University of Zimbabwe and from ZINWA, did not have any information about reference system. It was used lots of time to try to get that information from people working with ArcGIS and shape files. No one could tell what reference system they used, and they had little understanding for the need of such information. To try to get information from the shape files given, ArcCatalog was used, and one looked in each of the shape file to see if information about coordinate- or reference system were given as metadata. There was no place such information were given, and the .shx- file was missing for all data. The .shx- file is the extension to the shape entities, called file extension information. It is possible to make those extension files if they are missing, but then one need to know what reference- or coordinate-system of the shape files. The coordinates given in the shape files indicated that it may have been a local coordinate system used, not WGS1984.

At the mine, the department of mapping and surveying had made a topographic map over the area manually. They had used a local reference system for the area, and used cartographic instruments like levelling and distance measurements. Because there was no scanner available, the only possibility to get a copy of the map was to take pictures of it. An Olympus E500 mirror reflex camera was user with a wide-angle. That kind of creative solution gives some sources of errors. One gets errors from the projection of the camera, and it is difficult to hold the camera in a good position over a big map. Different pictures were taken, some pictures from the whole map, while other pictures was only from parts of the map. All together, it gives a good basis for further analysis and design of a map for the area of interest. Together with the samples and GPS-points taken in the area, it will be possible to illustrate the pollution situation for the local inhabitants. For a GIS-tool that can be used for later analysis and storage of information, one needs good and accurate shape files or other map data over Zimbabwe. With that in basis, the pollution mapping can be expanded to all mines and areas of Zimbabwe. That will give very good overview of the water quality situation of Zimbabwe.

3.3.2 Software evaluation for implementation

As described earlier, and as a part of the task for this thesis, two software programs should be evaluated, to se which one is best suited. MicroStation V8 and ArcGIS Pro9 were both evaluated. It was evaluated with a view to this project and the work that must be done for the project and software was evaluated with a view to further monitoring of the contamination of the mine by the mine administration and other projects that work with the current problem of contamination.

3.3.2.1 Software for commissioning this project

Since the data basis was less than planed, and other solutions had to be evaluated, both MicroStation V8 and ArcGIS had to be used in the process of planning a geographic information system and making maps for the local inhabitants.

The preliminaries for a GIS of contamination had to be done in a range of software, so that the geographic basis became satisfactory. Software programs that had to be used for implementation were among others Korus, MapSource, MicroStation, ArcMap, and Microsoft Office Access. CHAPTER 4 IMPLEMENTATION will describe how each program was used to make the geographic map basis.

3.3.2.2 Software for further monitoring of the contamination

Both MicroStation V8 and ArcGIS were evaluated for further monitoring of the contamination and for the possibilities to make a geographic information system. It was important to choose an easy-to-use-program, because the computer and GIS skills to the intended users were not very good. MicroSation V8 is a program that has lots of possibilities and functions, but it is not easy to use for non experienced users. MicroSation is not adapted software for GIS although it has functionality that makes GIS analysis and tasks possible. ArcGIS is more user friendly and is relative easy to use. It is big and complex software that has lots of functionality, but it is not necessary to know about everything to use it. To use simple functions for monitoring it is easy to learn. ArcGIS must have a geographic map source to give reasonable results, shape-files is easy to use and available for most areas. It was not time and resources to get shape-files for this project, but for later monitoring, it will be possible to get reach of a good geographic data source.

With shape files and a GPS for point determination, ArcGIS is good software for illustrating and analysing the contamination over large areas. Functions like panning, zooming and scaling are easily accessible.

3.3.3 Organize data of ph and pollution into a database

For great amounts of data it is a good idea to establish a database for storage, editing and processing. The database must support spatial data, since all the data in this project has a spatial property. Much can be said about definition of a spatial database system and what such a database system should support, it will not be discussed in this thesis, but for more information, see (Güting, 1994). Instead the focus will be on software systems that support spatial data in their database system. It must be a software system that is available for the intended user. It means that it is not attended with heavy expenses or difficult to use. The best solution is a database that is supported by MicroStation or ArcGIS by the fact that that software is considered in the geographic information system in this thesis.

ArcCatalog is the database handling software that comes with the ArcGIS package. ArcCatalog requires that one has the software from ArcGIS. That is expensive, and one can not expect that the mine has access to such software. Microsoft Office Access is a database handling software that is a part of the Microsoft Office Package. The administration at the mine has access to Microsoft Office, and one can assume that they have Microsoft Access as well. Microsoft Access supports creation of tables, reports, forms and queries. It is not well adapted for creating graphs or diagrams, but it is possible to open tables created in Access into Microsoft Excel or other. It is easy to import tables from Microsoft Access into ArcGIS.

Microsoft Access will be used as a database for the data of contamination in this project, primarily because it is the one software the mine has access to.

The mine had large amounts of data about the contamination stored in books and bindings at the mine. The first task for the persons working in the administration was to get the data into digital form. They had some data in Excel sheets, and they extended those sheets with the data they had stored in books. They forwarded all data they got into digital form. Most of the data had random layout, and no standards were used. It was a large job to get all data into Access and to standardized formats. The focus was not to convert all data into Access and a standardized format. One chose to convert enough data so one could display the results in ArcMap and to find standard on how the data should be implemented. To convert the data into standardized forms was a job for the mine, and manuals were created to simplify their work and to force them to store the data in a fixed format. A manual for Microsoft Access is attached as Appendix 5 .

3.3.4 Methods and design for Database handling

For the time being, Microsoft Office Access is chosen as the software for database handling. Microsoft Access is easy to learn and use for key-entry of new measurements, and can be imported to ArcMap for display.

The actual design of the database had many alternatives, and must be considered. A database could consist of many tables. One table would give the name and the coordinates on all sample locations. One possibility was to add ph-, temperature and conductivity values in the same table, but since those measurements should be taken every week, which would be a poor solution. Then it would be a table like illustrated under:

Table 6 Proposal to database table I

OBJECT ID	NAME	LONG.	LAT.	DATE	TEMP.	PH	COND.	DATE	TEMP	…
1	YJR1	longitude	latitude	…	…	…	…	…	…	…
2	YJR2	…	…	…	…	…	…	…	…	…

The Table 6 would be a long and a difficult to follow table with four new columns for each new measurement (week). The columns would be difficult to name, and one would have to deal with column-names like temp1, temp2, temp2 and so on. Each column must have a unique name.

A simplified solution would be to keep the table with sample-names and coordinates alone, and make new tables for temperature, pH and conductivity. The table with names and coordinates needs a primary key[9] and the name it self can be a primary key, or one can create an object id column that assigns a unique number for each sample-point. The longitude and latitude columns are composed by the WGS1984, zone 36S coordinates given by the GPS-positions.

Three alternatives were considered for design of tables indicating temperature, pH and conductivity. Three variables had to be included to give complete information; NAME, DATE and measurements (TEMP./PH/COND.) The alternatives are illustrated in the following tables:

[9] Primary key - forkalr

Table 7 Proposal to database table II

pH.db				
SAMPLE	**Date1**	**Date2**	**Date3**	**…**
YJR1	pHvalue	pHvalue	…	…
YJR2	pHvalue	…	…	…

Temp.db				
SAMPLE	**Date1**	**Date2**	**Date3**	**…**
YJR1	temp	temp	…	…
YJR2	temp	…	…	…

Table 7 illustrates the possibility where one table for pH, one table for temperature and one table for conductivity are created. Each column is a new measurement-date and one row is one sample point. This is a good alternative, one need three tables and the columns expands for each week a new measurement is taken. It is easy for administration; three tables must be opened and updated.

Table 8 Proposal to database table III

YJR1.db			
Measurement	**Date1**	**Date2**	**Date3**
Temperature	temp	temp	…
pH	pHvalue	…	…
Conductivity	cond	…	…

YJR2.db			
Measurement	**Date1**	**Date2**	**Date3**
Temperature	temp	temp	…
pH	pHvalue	…	…
Conductivity	cond	…	…

Table 8 is the alternative where one table is created for each sample point. Every table has three rows where one row is for temperature, one row is for ph-values and the last row is for conductivity-values. One column is one date, and a new column will be set up each week. This solution requires as many tables as there are sample points.

Table 9 Proposal to database table IV

Date1.db			
SAMPLE	**pH**	**Temperature**	**Cond.**
YJR1	pHvalue	temp	cond
YJR2	pHvalue	…	…

Date2.db			
SAMPLE	**pH**	**Temperature**	**Cond.**
YJR1	pHvalue	temp	cond
YJR2	pHvalue	…	…

Table 9 is the last alternative. With this alternative, a new table must be created for each date or new measurement. The sample points are listed down the rows and the columns consists of pH, temperature and conductivity-values. This alternative need as many tables as sampling dates and will be expanded each week when a new measurement is taken. This alternative may give lots of redundancy when each table must be created again every time a new measurement is given.

Table 8 was a poor solution since it requires that the administration must open one table per sample point. It was time consuming and not a good solution for those doing the work. Table 7 and Table 9 were better solutions. Table 7 gave many empty cells when not all sampling points were taken. Some of the boreholes were empty of water, and was not used for collection of samples every week. It was primary the sampling points along the river that were taken every week. That gave many empty cells in the three tables. Table 9 made lots of superfluous work since a new table had to be created from scratch every time a new measurement was taken, this work could be reduced with good preliminaries of the database. A standard table could be created and copied every time a new table is needed. Much is handed over to the administration at the mine with the last solution, and it is more likely that a mistake will be done. To make sure the database system was as easy as possible, the solution illustrated in Table 7 were used. In case of prospective expansion of water samples, new sample points could be added on the three tables, or new tables could be created for other analysis, like amount of cobber etc.

CHAPTER 4 IMPLEMENTATION

4.1 LOCALIZATION OF WATER QUALITY SAMPLES

Early in the process of getting an overview of the area, samples were taken along the river at 10 points, and the samples were analyzed for copper and sulphate. Figure 7illustrates where the sampling points along the river where taken.

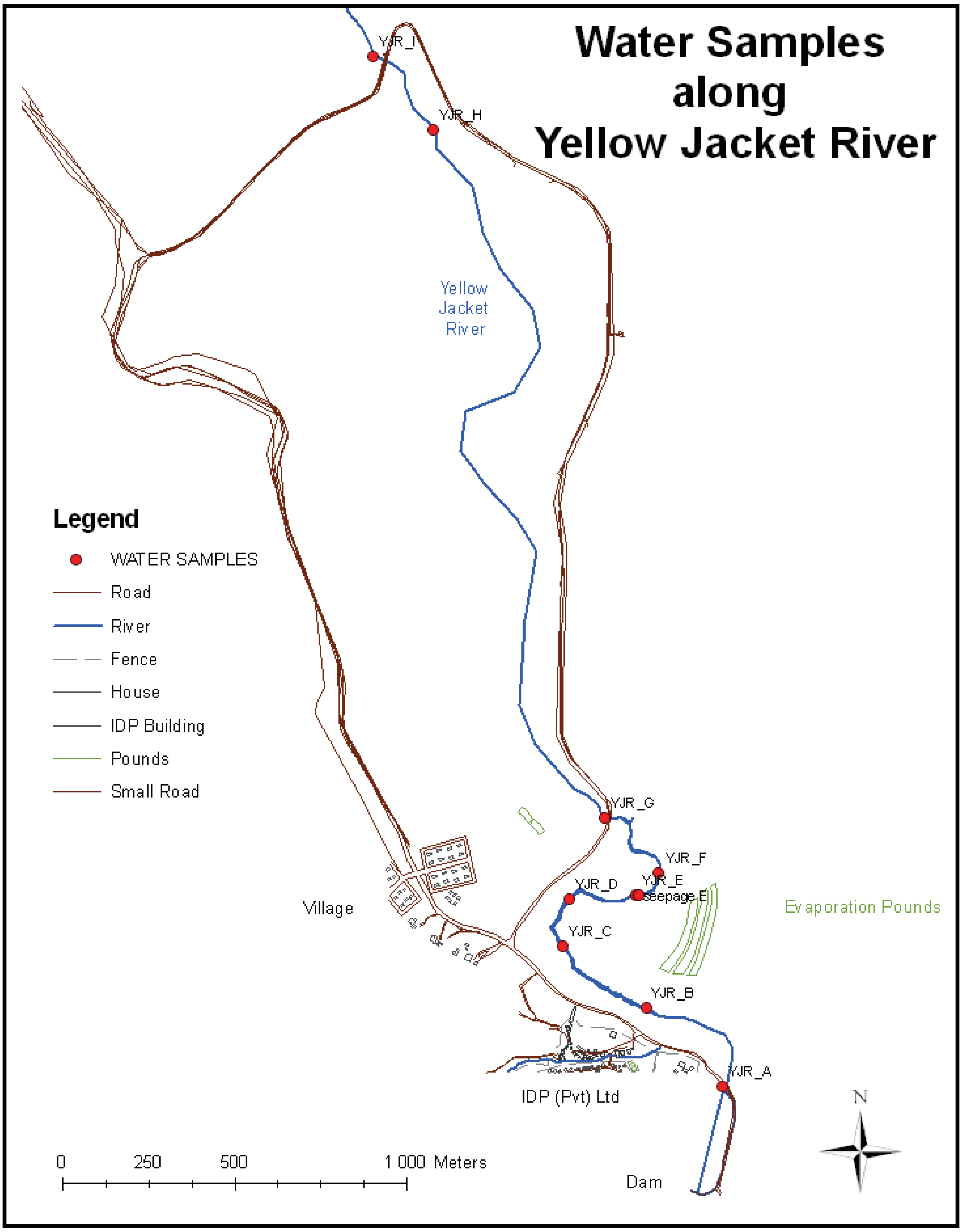


Figure 7 Map that indicates where the water samples along YJR has been taken

Samples of the ground water were collected from boreholes made by Mr. Blessing Tafisa from IDP, and the Norwegian student Bård Tobiassen. An illustration over the different points for measurements is given in Figure 8.

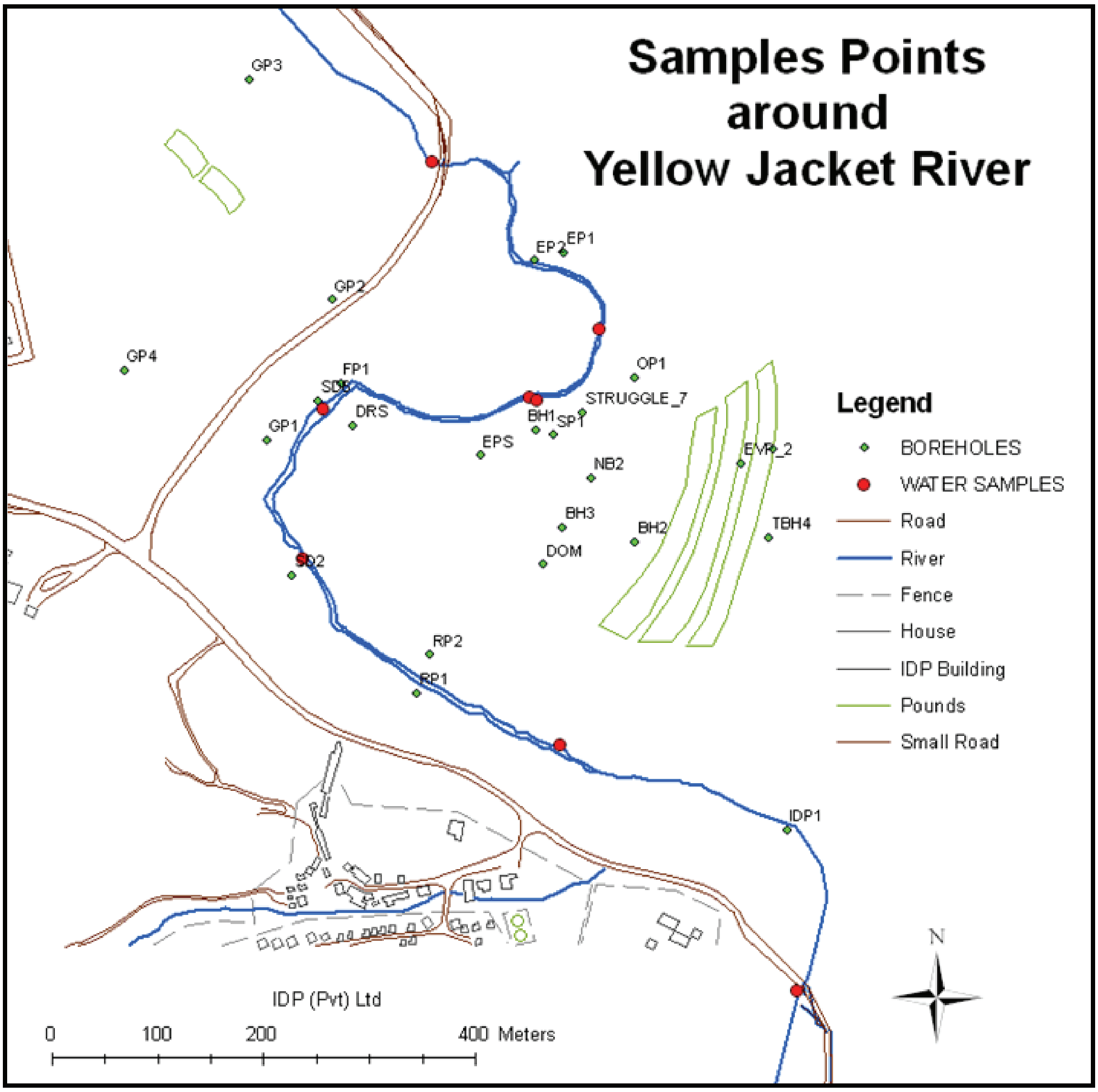


Figure 8 Map over IDP showing most of the boreholes

To get an accurate position of the measured points, GPS[10]-positions were taken for each point along the river and for all boreholes around the area. GPS don't give very good positions absolutely, but relative to each other, they give good enough results. When all points were taken the same day, within 2 hours, and it was a sunny day without clouds, the positions were acceptable relative to each other. There was no chance to check the absolute position of the points. The mine had never used a global reference system and did not have any known points with accurate coordinates.

[10] GPS stand for Global Positioning System

Figure 9 Training mine administration workers in usage of GPS

Samples of conductivity, pH and temperature are still taken by the mine for monitoring. That will make it possible to look for trends over a longer time-perspective.

4.2 CARRYING OUT THE SURVEY

4.2.1 Carrying out a pilot questionnaire

When the first version of the questionnaire was ready, some participants were asked to come with feedback on a pilot of what was good and what needed to be improved. Two people from the mine were asked, two students from Norway and the teaching supervisor in Norway. A few of the questions were a bit confusing, and some changes were made. One found question 8 confusing, and changes were made from "*How do you recognize where you are?*" to "*How do you recognize where you are, and orientate in the terrain?*".

In part 2, some of the pilot-participants found the formulation of the questions a bit indefinable. Confusion of what to answer could be a problem when the questions together with the maps were asked as " *Do you know what this is?*". The participants may answer everything from picture, a map, map over IDP etc. To direct the answers in the direction of interest, the questions were changed to "*Do you know where this is*?". It is more interesting to find out if the respondents know where the area of the map is from, and the new form of the question will lead the respondent in right direction of desired answers.

In part 3 and 4, it was no feedback of the symbols and colours depicted. But one of the pilot participants thought that it could be interesting to see if it was possible for the respondents to grade the symbols in a scale like "*not appropriate*", "*appropriate*" and "*very appropriate*". That was a good idea, and alternative ways of implementing that proposal were explored. It was very important to keep the questionnaire as easy as possible without confusing questions of tasks. The result were that the question for part 3 and 4 got extended from "*Which of the following symbol alternatives do you find most appropriate for describing the following terms?*" to "*Which of the following symbol alternatives do you find most appropriate* ***and least appropriate*** *for describing the following terms?*". It could be difficult to grade all the symbols depicted in the questionnaire, and it would be very time-consuming if all alternatives should be graded from least to most appropriate. With the new question, more information could be drawn from the questionnaire, and the most important and interesting information could still be intercepted.

4.2.2 Carrying out the questionnaire at IDP

The choice of administration of the questionnaire was to print one copy in colour, and use that one to all participants. The Royal Norwegian Embassy in Harare assisted with printing of the questionnaire.

Instead of translating the questionnaire into shona[11], a translator from the IDP carried out the questionnaire in shona for those respondents that did not speak or understand English. This was a more satisfactory solution than translating the questionnaire, since those how did not understand English, most probably did not read either. Most of the respondent had no trouble understanding the questionnaire, and all people that were asked if they wanted to take part, wanted to participate in the survey. The translator from IDP lived in the old village in the area, and knew most of the people living and working at the mine. He had been a teacher before, so he had a pleasant approach to the participants and he was very patient and understanding towards the respondents. After the questionnaire was carried out, he explained those maps the respondent did not understand and helped them orientate in the maps. That was very informative and instructive, and many of the respondents learned something from the survey.

The questionnaire was executed by the researcher and a translator. One and one study participants were asked the same questions in the same order. One and the same copy of the questionnaire was basis for all respondents because of the problems with paper, printing and ink. No one was allowed to draw or to mark on the questionnaire. The researcher entered all answers in a diagram, and all questions were framed in a way so it was easy to gather the answers. If the study participants had suggestions or ideas not covered by the questionnaire, he or she got the opportunity to illustrate thoughts and ideas. The translator read the questions in English to all participants and translated into shona if the participants did not understand English. In that way, one made sure that the study participants got the chance to understand the question in its true form and one would not get mistakes due to translations if the participants had good knowledge of English.

[11] Shona is the most widespread local tribe language spoken in Zimbabwe, together with Nbele.

Figure 10 Questionnaire carried out by researcher and translator

One aberration from the questionnaire was that the translator forgot to ask the participants of which symbols and colours they found least appropriate of the alternatives, when the missing questions were detected, the best thing to do was to leave out those questions, since the questionnaire was long and time-consuming as it was without asking those questions.

4.3 IMPLEMENTING A GIS

4.3.1 Preparing GPS point file

The GPS-positions from the Garmin GPSMap 60CS were transferred to a computer into the programme Garmin MapSource. It was stored as an ordinary tabulator divided file (text file). Korus were used to make the points readable for MicroStation. In Korus, the text file was converted to a Script file. A mix-file was created and imported into Korus that described how all data should be read in the Script file.

4.3.2 Using MicroStation V8

Since the shape files were not complete, one had only pictures of the local topographic map and GPS-points as input to MicroStation. There were two alternatives to make the picture and the GPS-points correct relative to each other. One could snap the GPS-points to the correct positions on the picture, and adjust so the GPS point got the right positions relative to the picture. That was not easy, and the results was not satisfactory because the GPS points had good position relative to each other, but the picture had to much screw because of the wrong projection, caused by taking the picture.

The other and more satisfactory solution was based on the picture and the local grid in the picture. The grid was based on a local coordinate system, and had known longitude and latitude between each square. Based on that gird, a new grid was drawn with the same distance between each longitude and latitude. Then the picture and the grid were wrapped to fit each other. The picture and the grid got dislocated and the distortion made by the projection from the photographing got reduces. With the new picture as a background or a basis, the GPS-points could be opened. The GPS-points was set to the active level, with the coordinates form WGS1984 as default, then the picture were imported as a reference or background. One could move and adjust the picture so that the GPS-points appeared on the right positions. Because the picture had grids with known distance, one did not have to worry about getting the right scale in proportion to the GPS-points, since it was the same scale on the picture and the points. That made the basis for drawing a new and simple map.

New levels or layers could be added with different appearances. New levels were made for road, river, house, mine/public buildings, pounds and fence. With the picture as background it was easy to draw the new features, and they got the same coordinates (WGS1984, zone 36S) as the GPS-points, since the GPS-points made the default reference system. Illustrated under:

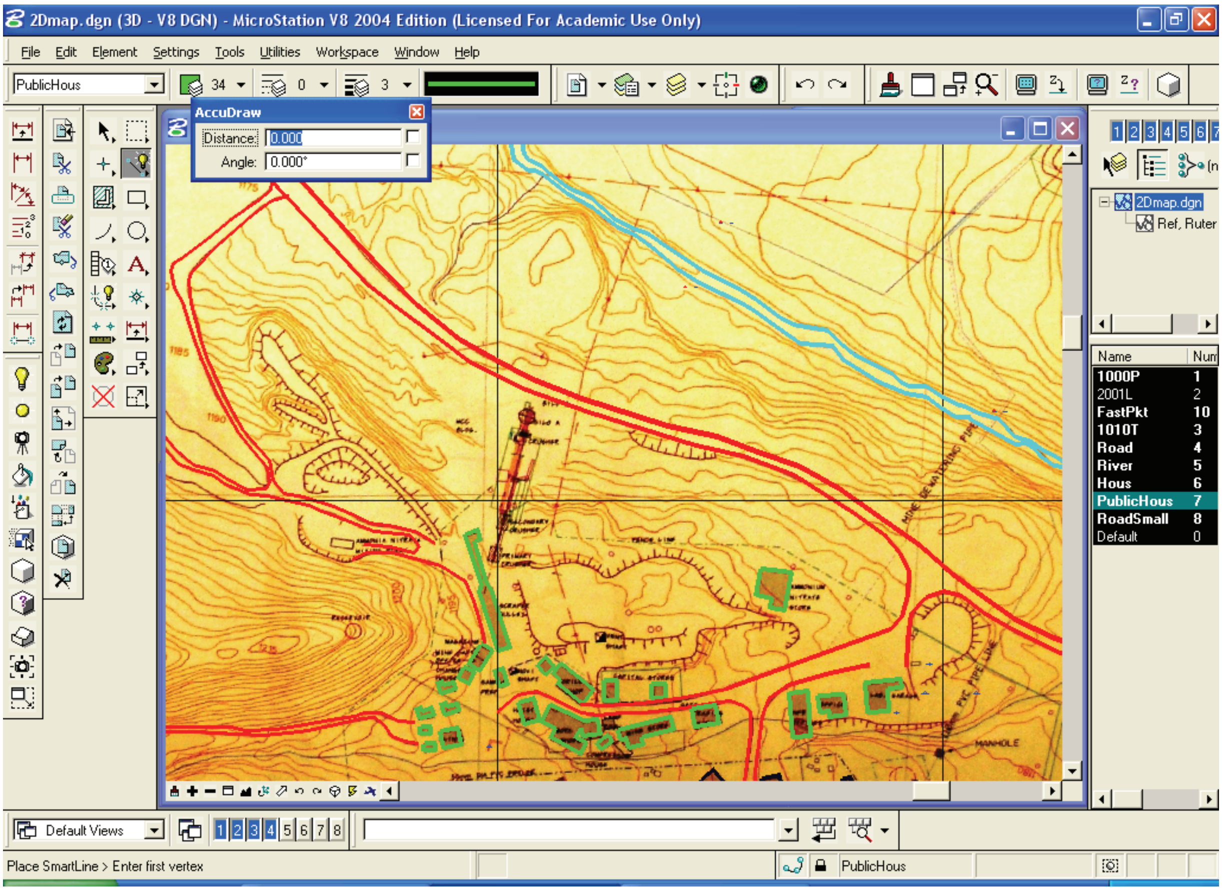


Figure 11 Print screen from drawing map features in MicroStation V8

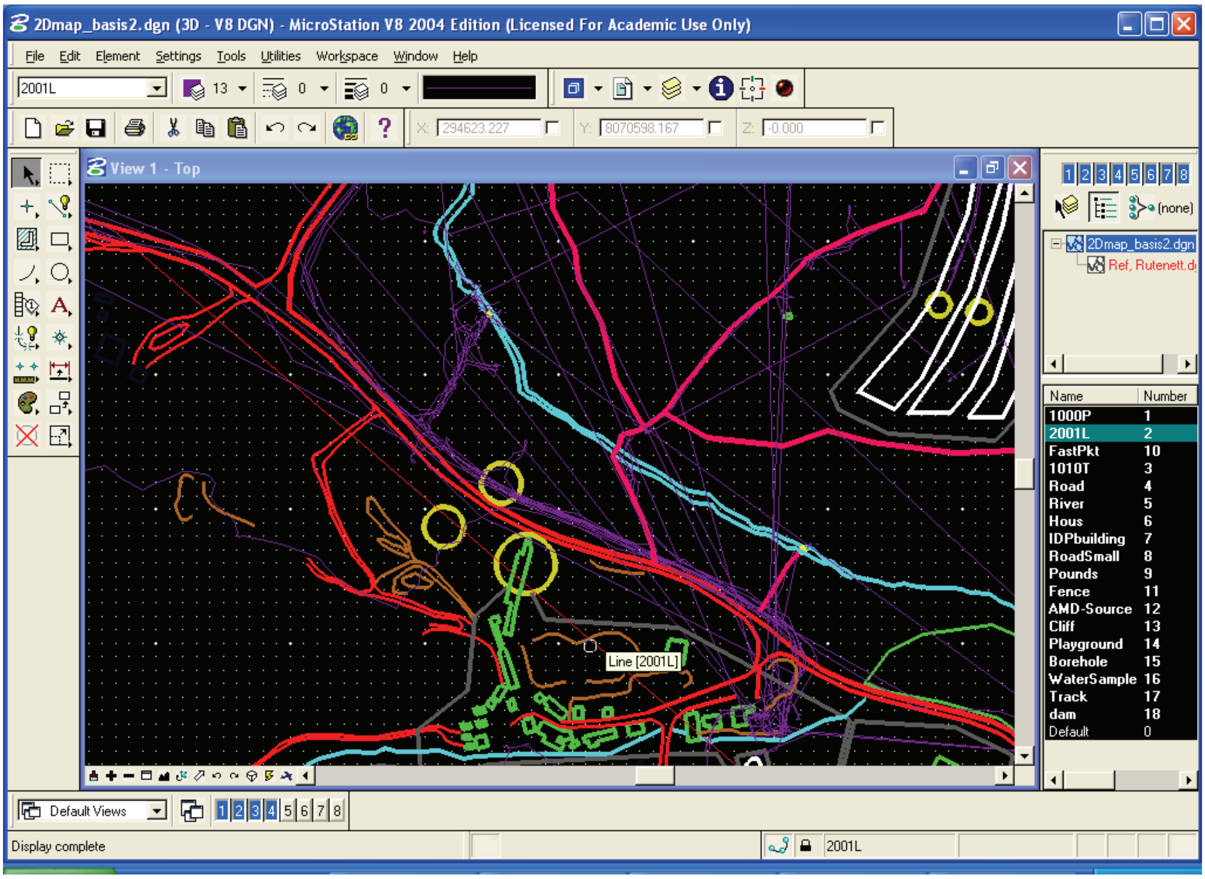


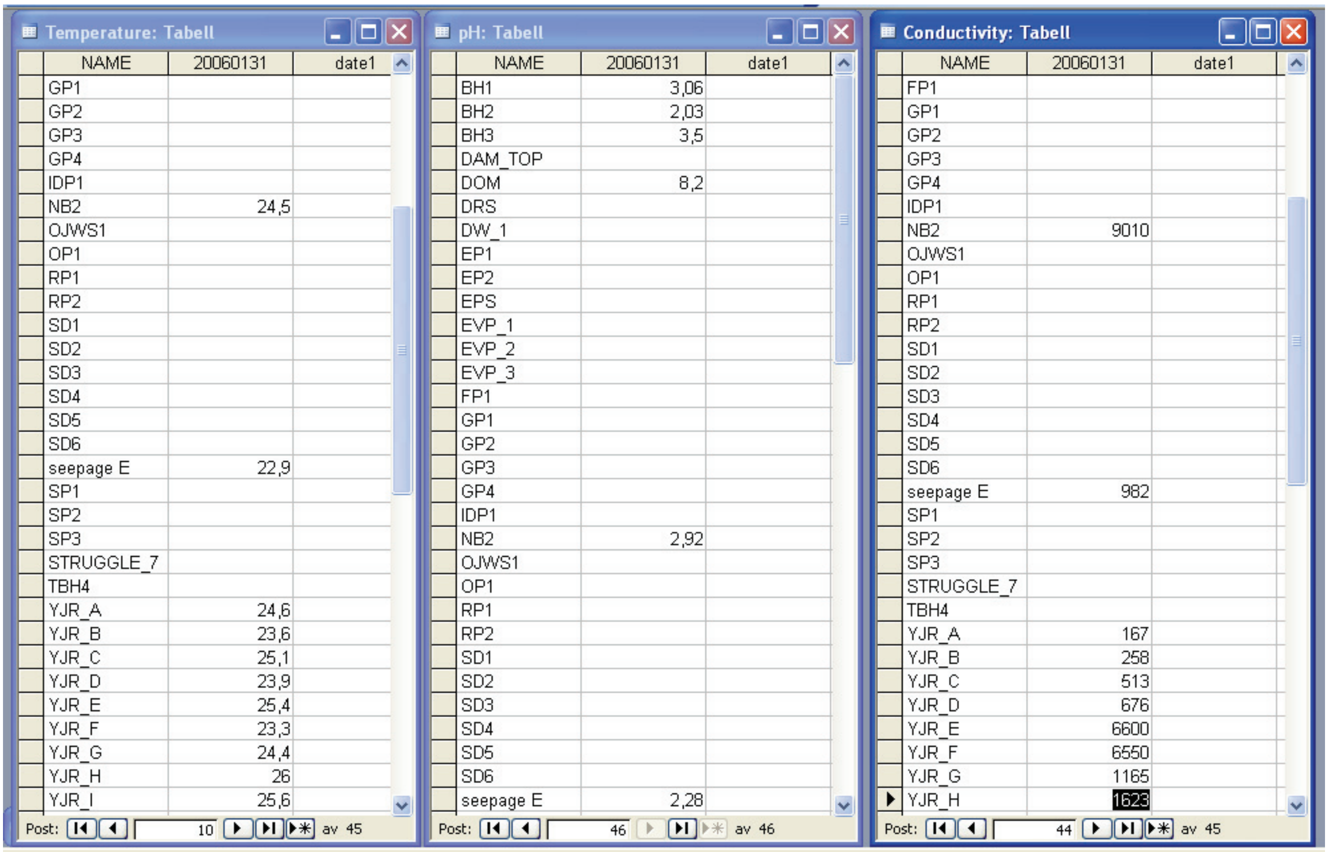
Figure 12 Print screen from MicroStation V8 displaying all available layers before export as .dng-files

Figure 11 demonstrate the process of making feature-layers in MicroStation V8, a river, some houses and roads are designed so fare. When all levels were drawn, one could arrange and regulate the appearance of each level. Figure 12 illustrates all layers finished drawn in MicroStation V8. When all features were implemented, one and one feature was exported as .dgn-files for additional processing in ArcGIS pro 9.

4.3.3 Set up a Database with Microsoft Access 2003

It was not of primary concern to establish a database for this project. For such a small area that was mapped, it was not necessary with a database, but with a view to extend this work to other mining areas around Zimbabwe, a database may be necessary. Microsoft Access was used to establish a standard for a database that could be implemented into ArcMap.

As described *in 3.3.4 Methods and design for Database handling*, different realizations of database tables were evaluated. Two of the alternatives were implemented, but only one would be used for further work by the mine. The tables from Microsoft Access 2003 that would be used are illustrated under:



Temperature: Tabell

NAME	20060131	date1
GP1		
GP2		
GP3		
GP4		
IDP1		
NB2	24,5	
OJWS1		
OP1		
RP1		
RP2		
SD1		
SD2		
SD3		
SD4		
SD5		
SD6		
seepage E	22,9	
SP1		
SP2		
SP3		
STRUGGLE_7		
TBH4		
YJR_A	24,6	
YJR_B	23,6	
YJR_C	25,1	
YJR_D	23,9	
YJR_E	25,4	
YJR_F	23,3	
YJR_G	24,4	
YJR_H	26	
YJR_I	25,6	

Post: 10 av 45

pH: Tabell

NAME	20060131	date1
BH1	3,06	
BH2	2,03	
BH3	3,5	
DAM_TOP		
DOM	8,2	
DRS		
DW_1		
EP1		
EP2		
EPS		
EVP_1		
EVP_2		
EVP_3		
FP1		
GP1		
GP2		
GP3		
GP4		
IDP1		
NB2	2,92	
OJWS1		
OP1		
RP1		
RP2		
SD1		
SD2		
SD3		
SD4		
SD5		
SD6		
seepage E	2,28	

Post: 46 av 46

Conductivity: Tabell

NAME	20060131	date1
FP1		
GP1		
GP2		
GP3		
GP4		
IDP1		
NB2	9010	
OJWS1		
OP1		
RP1		
RP2		
SD1		
SD2		
SD3		
SD4		
SD5		
SD6		
seepage E	982	
SP1		
SP2		
SP3		
STRUGGLE_7		
TBH4		
YJR_A	167	
YJR_B	258	
YJR_C	513	
YJR_D	676	
YJR_E	6600	
YJR_F	6550	
YJR_G	1165	
YJR_H	1623	

Post: 44 av 45

Figure 13 Print screen of tables giving pH, temperature and conductivity values from Microsoft Office Access 2003

The NAME is used as primary key on each of those tables since the name of sample points is unique for each point. Figure 13 shows the tables the administration at the mine must update. The cells to those sampling points that were not measured are empty. Together with those three tables is a fourth table giving objectid, name, longitude and latitude.

4.3.4 Using ArcGIS pro 9

The .dng- files created from MicroStation V8, were opened in ArcMap. When the drawing files were added to ArcMap, they had no information about reference system or coordinates. The data source (reference system) had to be specified as the same reference system used in MicroStation, where coordinates were assigned to every feature. The coordinate system was a predefined projected coordinate system in ArcMap. It was stored as WGS1984, UTM, zone 36S. All layers had to be assigned that coordinate system, so that analysis and editing could be done.

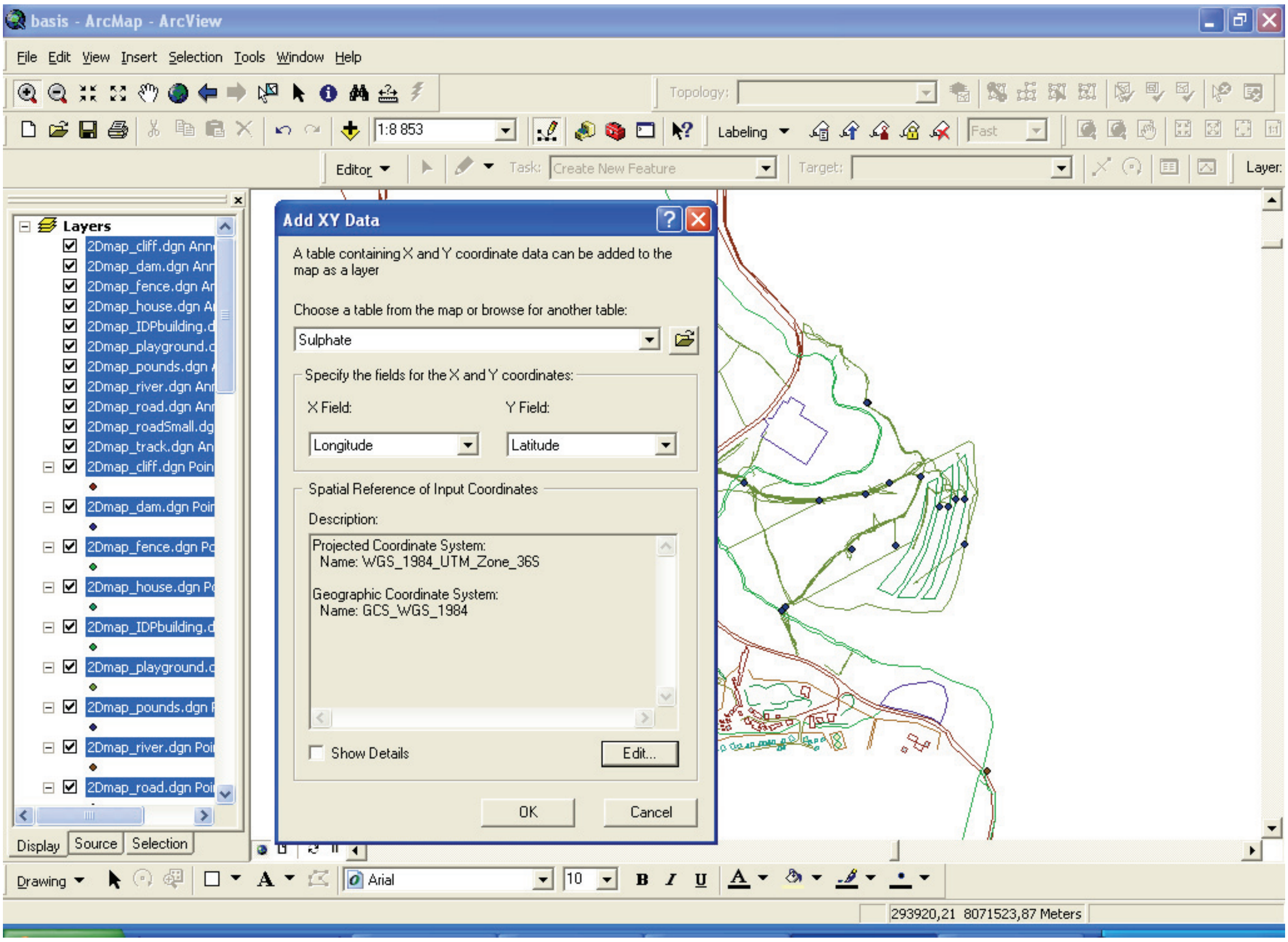


Figure 14 Print screen of ArcMap that illustrates all data basis when it is taken in as .dng-files and tables from Access

When all layers were imported into ArcMap, one could import data from the Microsoft Office Access database. The data were imported from Tools → Add XY data…A window emerged and one had the opportunity to find requested files and to specify the fields for the X and Y coordinates. One had to assign the same coordinate system (WGS1984, UTM, zone 36S) to the database-files. When all data was imported, one could start to design maps that were adapted to each user group.

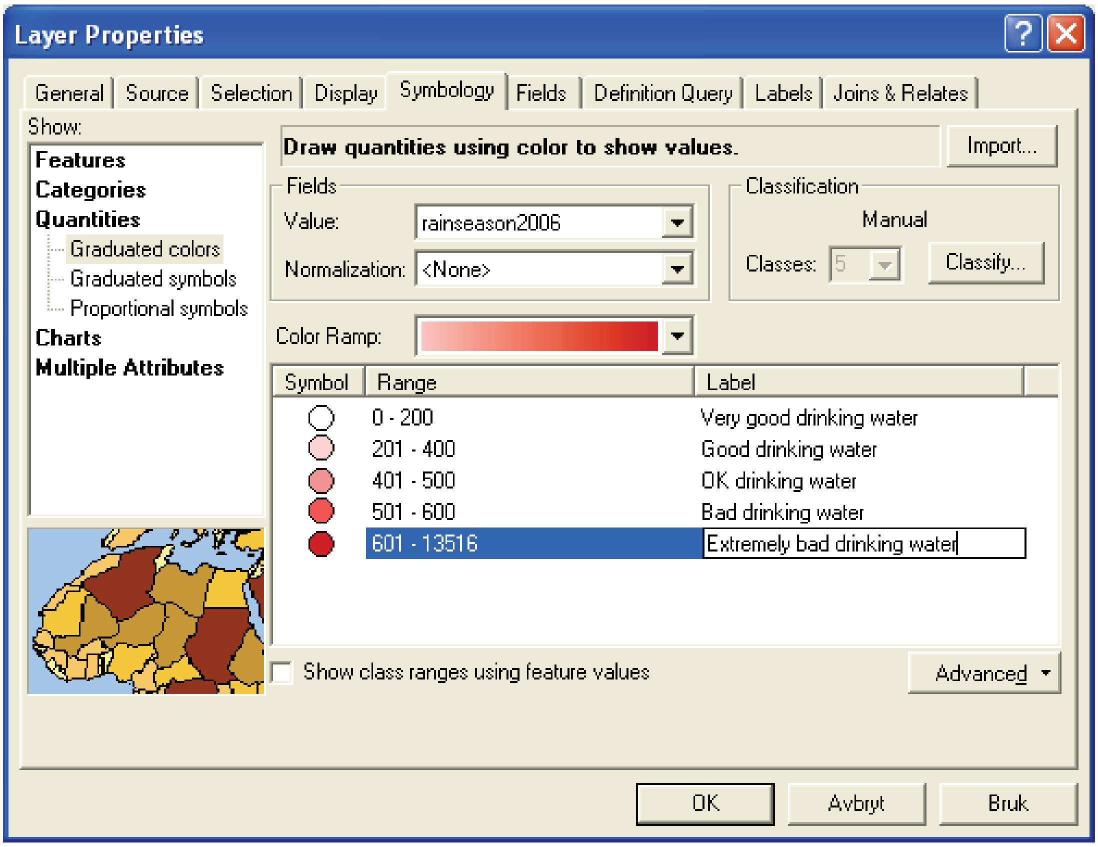


Figure 15 Window that classifies sulphate values for display in ArcMap

Simple and easy to understand map basis was the primary factor for maps to the inhabitants around YJR. The basis for a map to the inhabitants at Iron Duke Pyrites (Pvt) Ltd, were evaluated from a map showing sulphate values in the area. The process of classifying sulphate events are showed in Figure 15.The values were based on the standard recommendation from Zimbabwe National Water Authority (ZINWA),Appendix 2 .

CHAPTER 5 RESULTS

5.1 RESULTS FROM THE WATER QUALITY SAMPLES

The pH results gives unreliable values since pH changes rapidly to external factors, as mentioned in *2.1 mapping of drinking water quality*. Sulphate gives a better indication since it does not change so rapidly. Sulphate is not very dangerous itself, but it is a very good indicator of the contamination potential for heavy metals. The sulphate values are based on measurements on conductivity. Conductivity and sulphate is correlated. For more information about the correlation and transformation between conductivity and sulphate, see (Tobiassen, 2006)

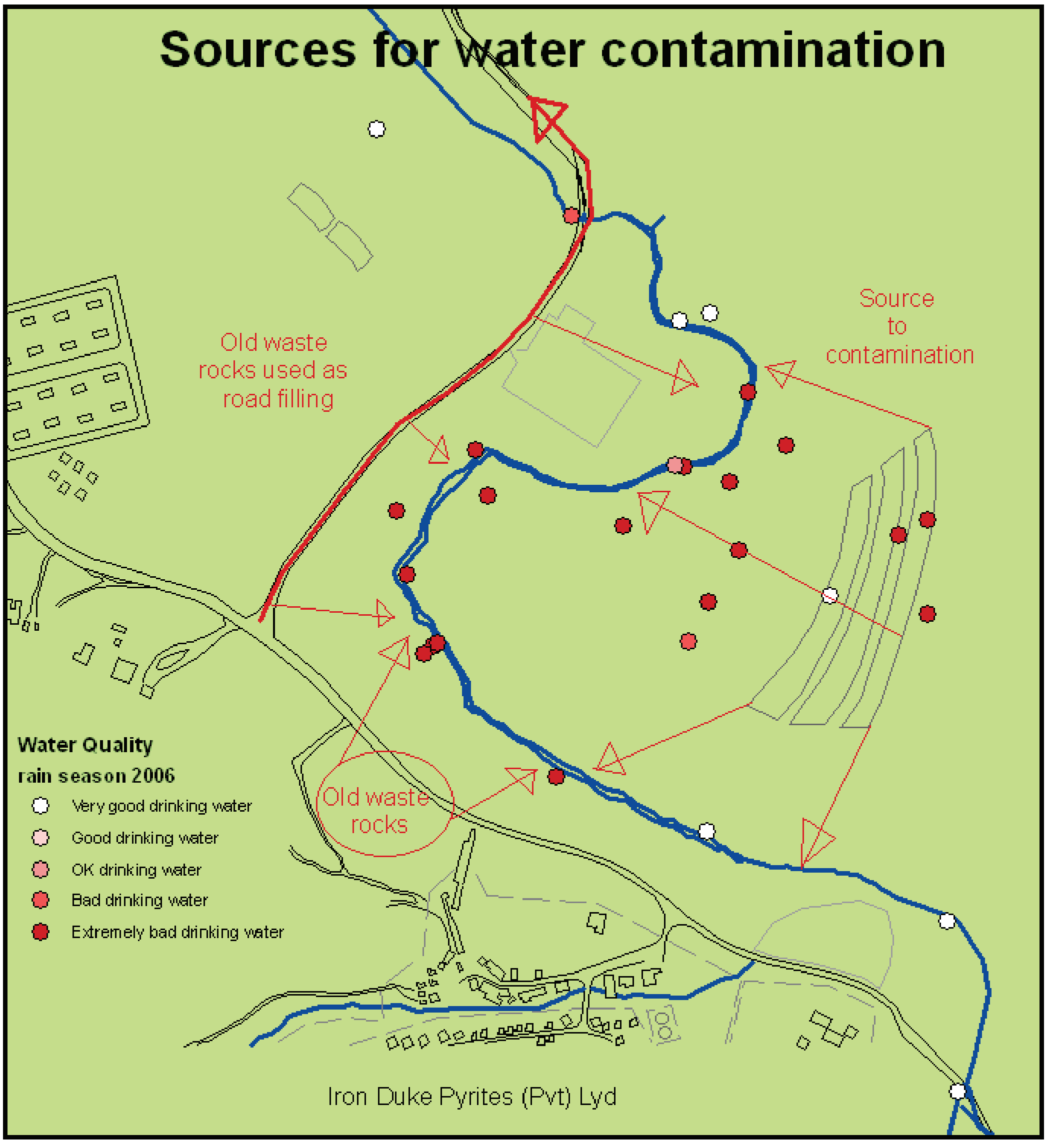


Figure 16 Illustration showing contamination sources and direction of ground water contamination from those sources

The arrows in Figure 16 are based on analysis of the measurements, and indicate the flow of contaminated groundwater. It is found from topographic features and analysis of the area. For more about ground water flow and analysis of the ground water, see (Tobiassen, 2006).

5.1.1 Monthly water quality samples during 2005

The mine had taken regularly water samples during 2005. Monthly average from weekly samples of pH gives good indication on how the contamination varies during a year. The pH variation is illustrated in Figure 17 and Figure 18

Figure 17 pH-values along Yellow Jacket River measured during 2005

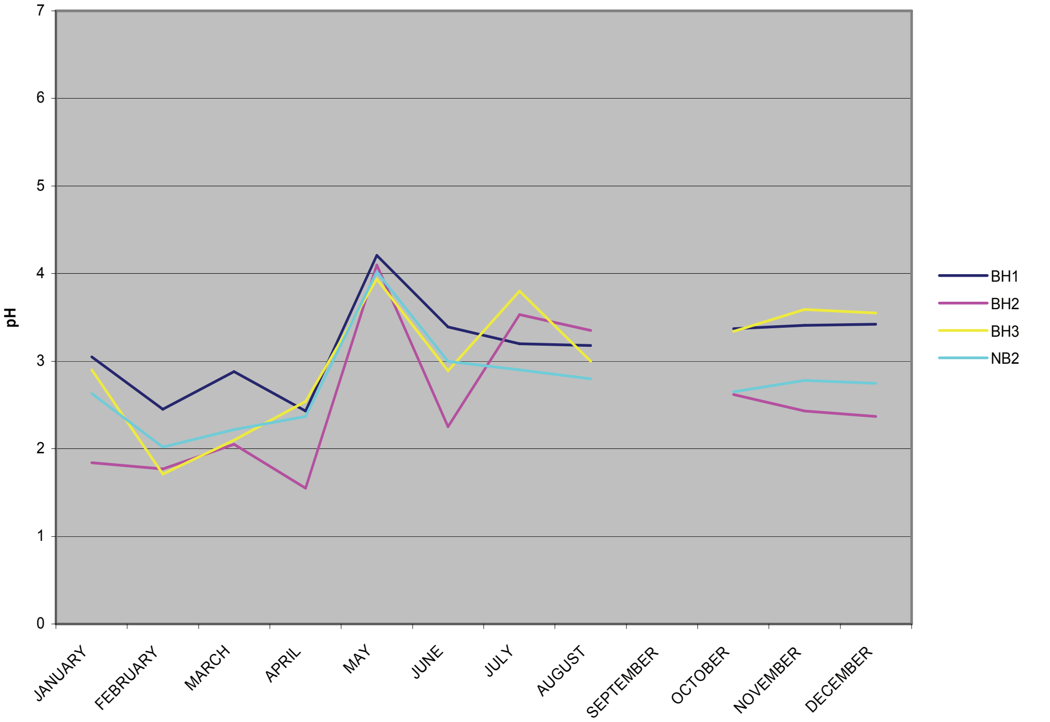


Figure 18 pH-values of boreholes measured during 2005

The figures indicate that pH was at a minimum in February 2005. February was a wet month in 2006, so late January were presumed to have the minimum pH values in 2006.Water samples were taken the 31st of January 2006 by the researchers. Those samples are presumed to give a good indication on worst case scenario and will be illustrated in the following section.

5.1.2 Water quality measurements during the fieldwork 2006

The worst case scenario for the contamination and pollution in the Yellow Jacket River is just before the rain season, before the dam above IDP flows over. The water samples taken in the end of January, is therefore representative as a worst case scenario. Figure 17gives good indications that late January and February has the lowest pH values during the year.

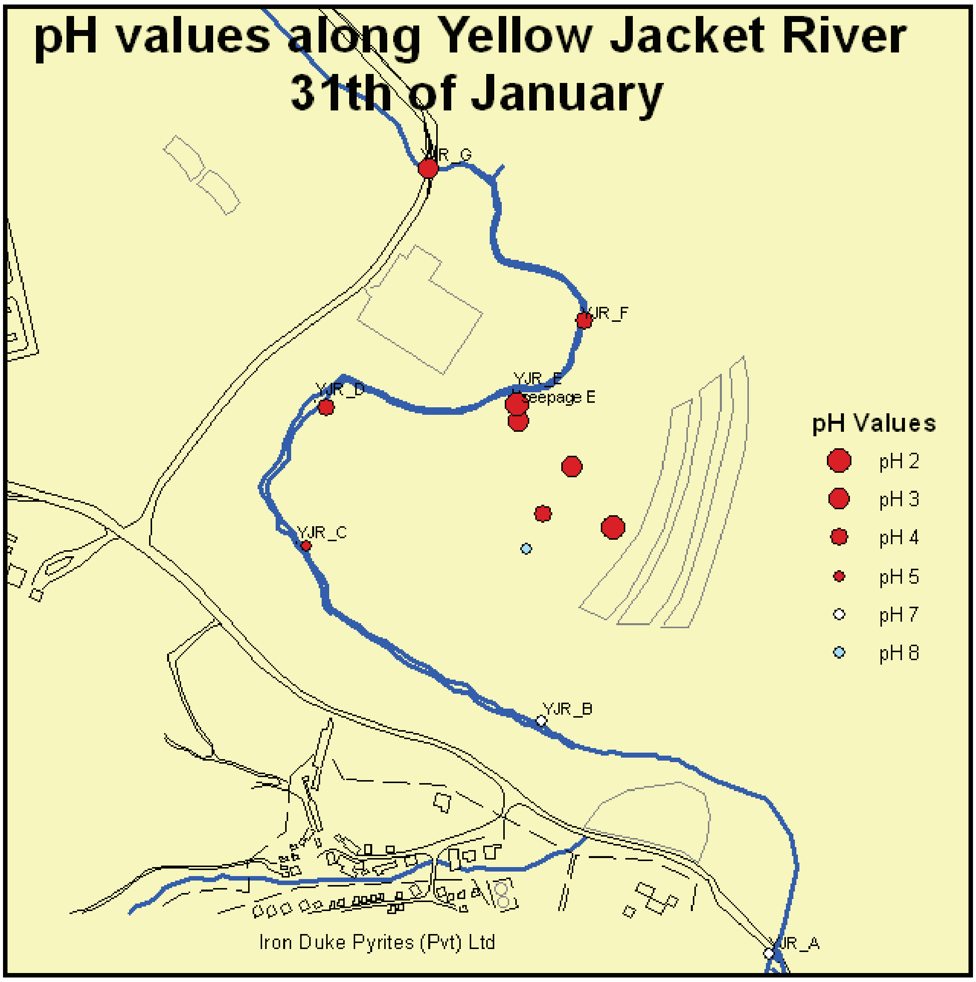


Figure 19 pH values at YJR illustrated on a map from 31st of January

Figure 16 and Figure 19 gives a good picture of pollution at IDP. It indicates that most of the area downstream of sample point YJR_A is polluted, both the ground water and the river.

5.1.3 Influence from Yellow Jacket River into Mazowe River

Yellow Jacket River runs into Masowe River. Mazowe River is one of the largest rivers in Zimbabwe next after Zambezi River. Some kilometres downstream from where YJR runs into

Mazowe River, is Glendale Waterworks. Glendale waterworks supply drinking water for Glendale and produces drinking water on bottles that is sold in stores in Zimbabwe.

Table 10 Water quality in Mazowe River taken 7th of March 2006

Sample Point	pH	Conductivity [µS/cm]	Temp [°C]	SO4 [g/l]
V-Notch in YJR	6,7	251	23,8	0,0920
Mazowe River before confluence with YJR	7,85	467	21,0	0,0415
Glendale Waterworks	7,1	362	23,80	0,0542

V-Notch in YJR is the last water sample point along YJR before it runs into Mazowe. Glendale Waterworks is water from the Mazowe River in Glendale.

5.2 RESULTS FROM THE QUESTIONNAIRE

5.2.1 Results from part 0ne

The frequencies of all answer alternatives are given in Appendix 4 There one can see how many chose each alternative in count and percentage. The age distribution was not very good distributed, but represents the population well. The median age in Zimbabwe is 19.9 years and the age structure is distributed like:

37% is between 0-14 years, about
59% is between 15-64 years and only
3.5% of the population is over 65 years old (FACTBOOK, 2006).

That tells that the distribution form the survey reflected the age structure of the population well from Appendix 4 . Also the male-female distribution was relative good divided in the survey with 46 % males and 54 % women asked. The main occupation among the inhabitants was "*mining*" and "*housewife*" with respectively 30 % and 34 %. 24 % were students, 6 % were teachers and one respondent was "*bookkeeper*", one was in the "*mine administration*" and one of the study participants did "*nothing*".

The frequency statistics showed that question 4 "*Do you get drinking water?"* had unique answers, all the 50 respondents fetched drinking water, and all fetched the water from a tap. Only 20 % or 10 respondents had farming animals (in question 5), while 96 % had some kind of crops belonging to them (question 6).

Most of the study participants had seen a map before; only 5 respondents had never seen a map, while the 45 remaining had seen some kind of map. The results from question 8 showed that 60 % of the inhabitants around Yellow Jacket River used rivers, trees, buildings or roads to orientate and recognize in the terrain. 34 % used mountains fields or valleys when they orientated while one participant used sun, stars and the moon for orientation. Two respondents answered that they did not orientate.

5.2.2 Results from part two

Question 7 from part one indicated that 45 of 50 study participants had seen a map before. With that in mind, the following results were given from part two where the participants got to see four maps over the same area.

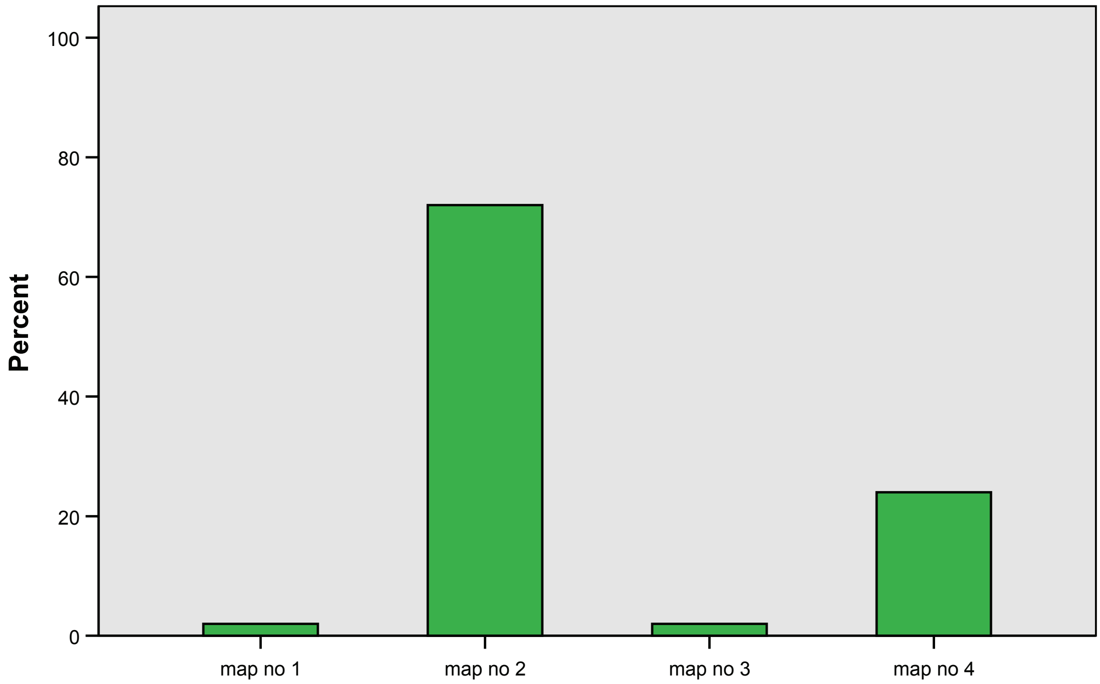
The results from first map with no labels or text showed that 32 % knew where the map was from, while 62 % did not have an idea of where the map where from. 6 % had some idea where the map where from, but was not certain that he or she was right. The second map was the same sketch as the first map, but legend, text and information about coordinates and direction were given. 78 % recognized the area of the second map, while 18 % had no idea. Only 4 % was unsure about the area of the second map. Question 11 asked if the respondent could point out a known feature in the area on the second map (the gate to IDP administration building). Almost half of the respondent could point out that feature on the map, while a quarter of the respondent could not point the feature. 8 respondents did not know what area the map illustrated, and did therefore not answer that question.

The third map was a topographic map made by the mine. 62 % recognized the area of the topographic map, while 38 % did not recognize the area. On the same map as 62 % recognized as the area over IDP, only 8 % could point on the main gate to IDP, 2 % (one respondent) pointed more or less the right area of the gate while 56 % could not point the gate. 34 % did not answer that question.

In the appendix two different percentages are given. The column named "percent" gives all the percentage with the condition that all 50 respondents are in, e.g. *X out of 50*. The column named "valid percent" gives the percentage of all respondents answering the question. For question 13, that means *X of 33* respondents.

The fourth and last map was the same topographic map as the third map, but with some features emphasized. 64 % recognized the area of the fourth map, 2 % had some idea while 34 % had no idea. The answers from question 15 tells that 26 % of all the participants could point the same feature on the fourth map, 4 % could point the feature more or less while 38 % could not point the feature and 32 % did not answer that question.

The last question in part two asked the participants which map they found easiest to interpret. The results are illustrated here:

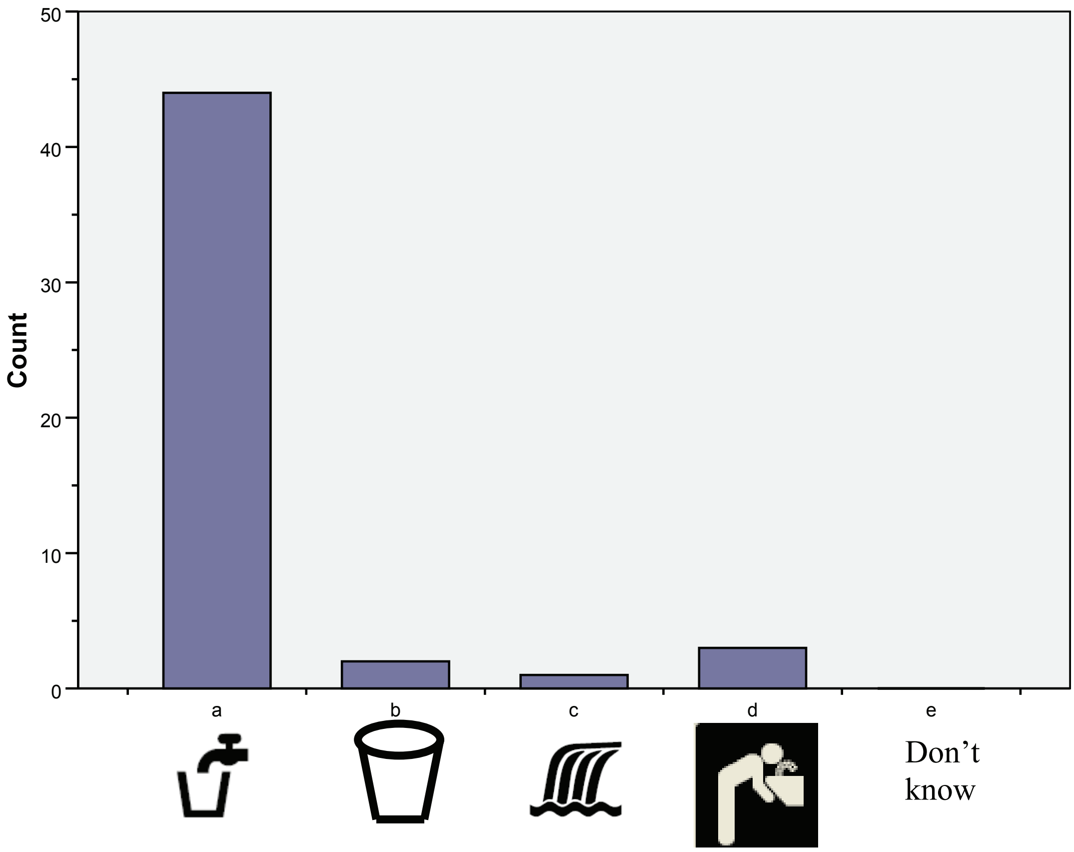


Graph 1 Graph showing which map the respondents found easiest to interpret. Generated from SPSS.

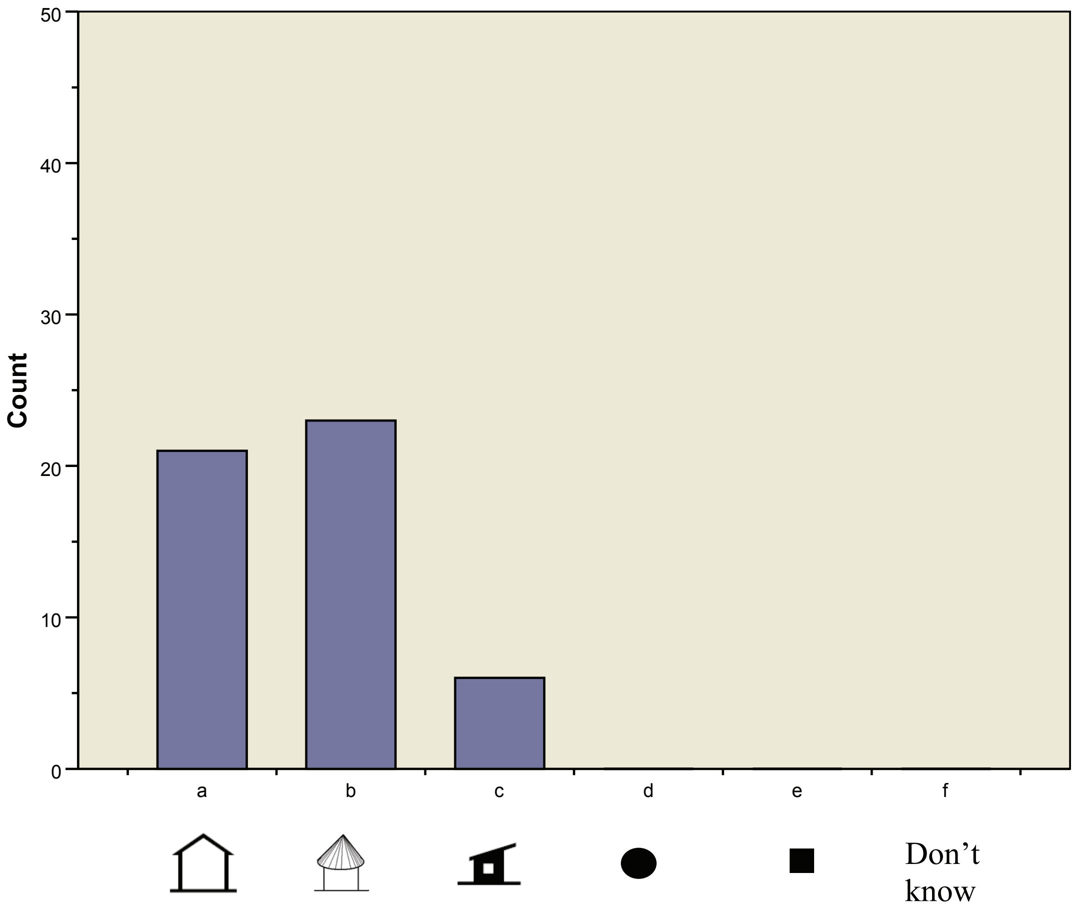
Graph 1 show that most respondents found the second map easiest to interpret.
This is in accordance to the other questions relating to understanding of maps in previous paragraph where most participants knew where map no 2 was from and could point out the known feature.

5.2.3 Results from part three; symbols

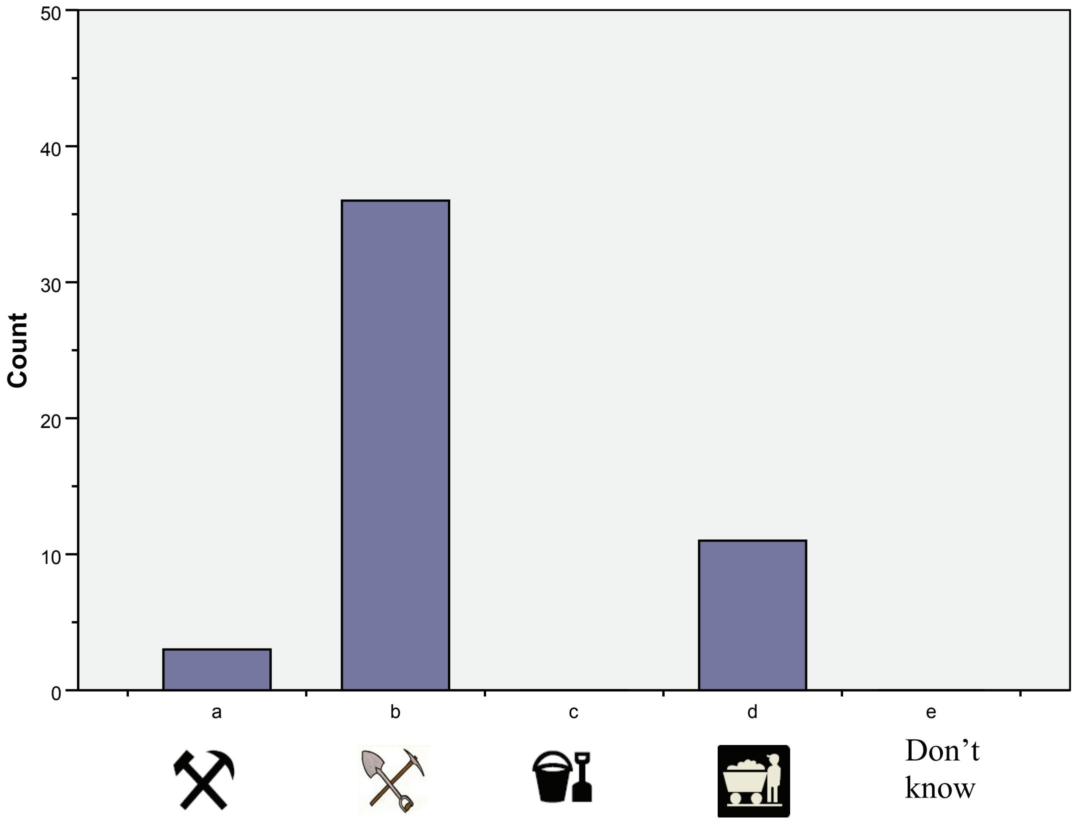
The descriptive analysis from SPSS gave the following results for map symbols (part 3 of survey). The results are given in graphs with the frequency (count) as y-axis and the different alternatives along the x-axis, denoted with a, b, c, … as in the survey. The symbols are depicted under each bar to give a more intuitive and easier understanding of the graphs. More accurate statistics can be found in Appendix 4 .



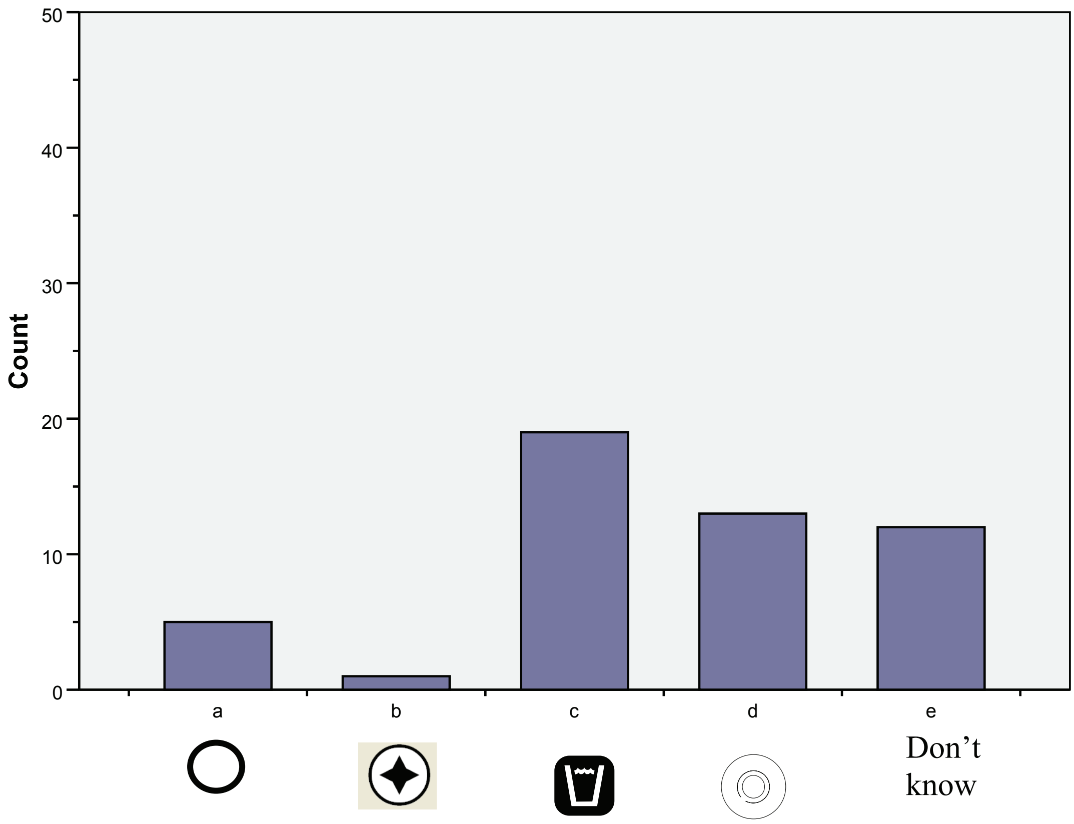
Graph 2 Graph over count of responses for drinking water symbols



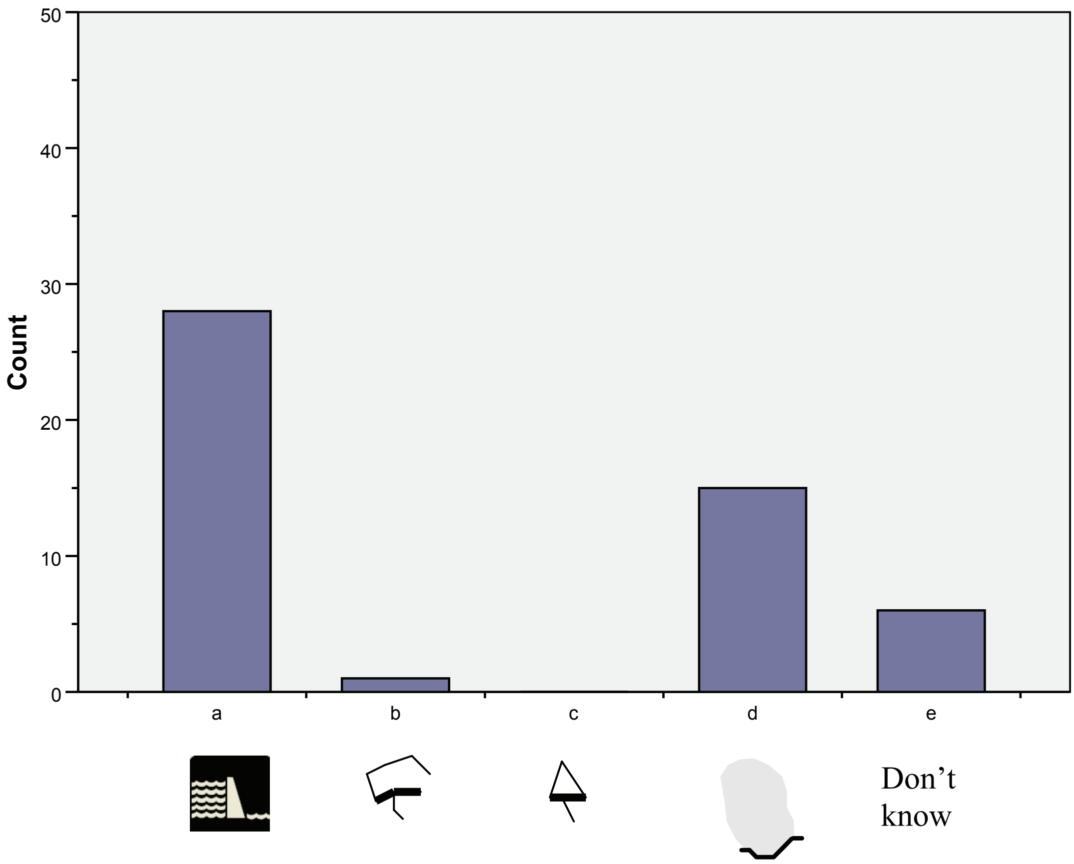
Graph 3 Graph over count of responses for house symbols



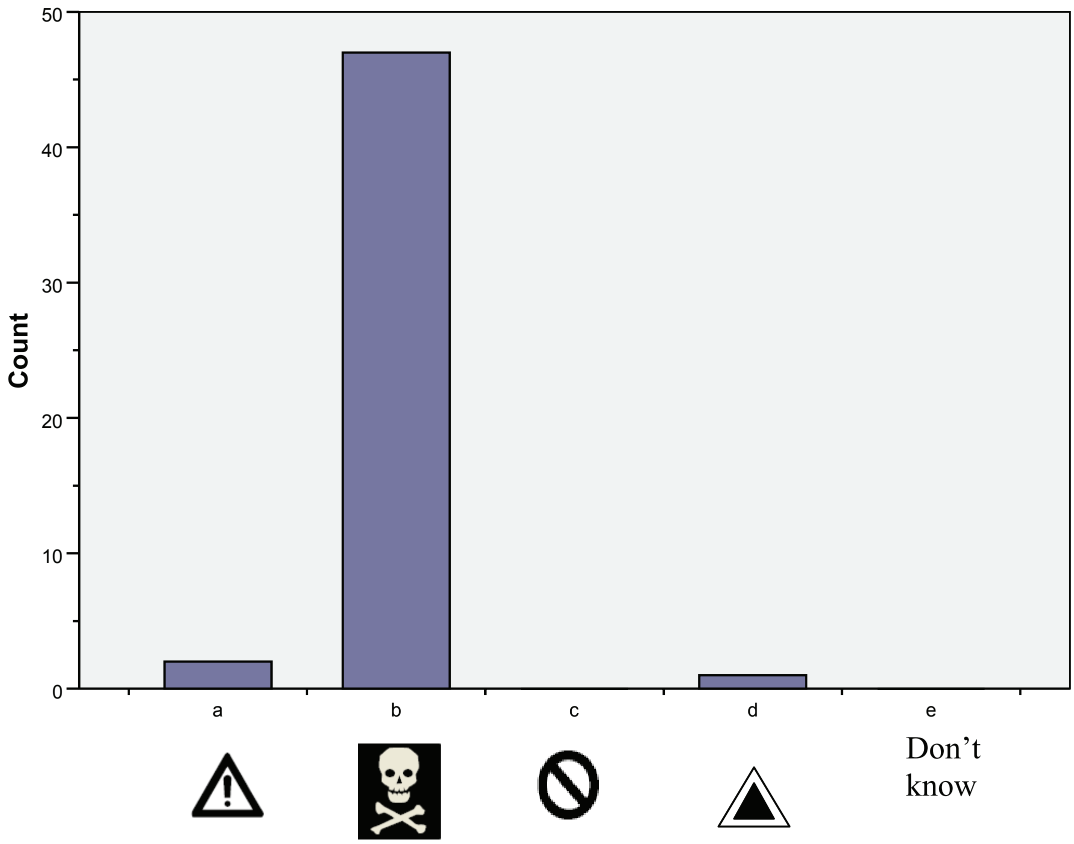
Graph 4 Graph over count of responses for mine symbols



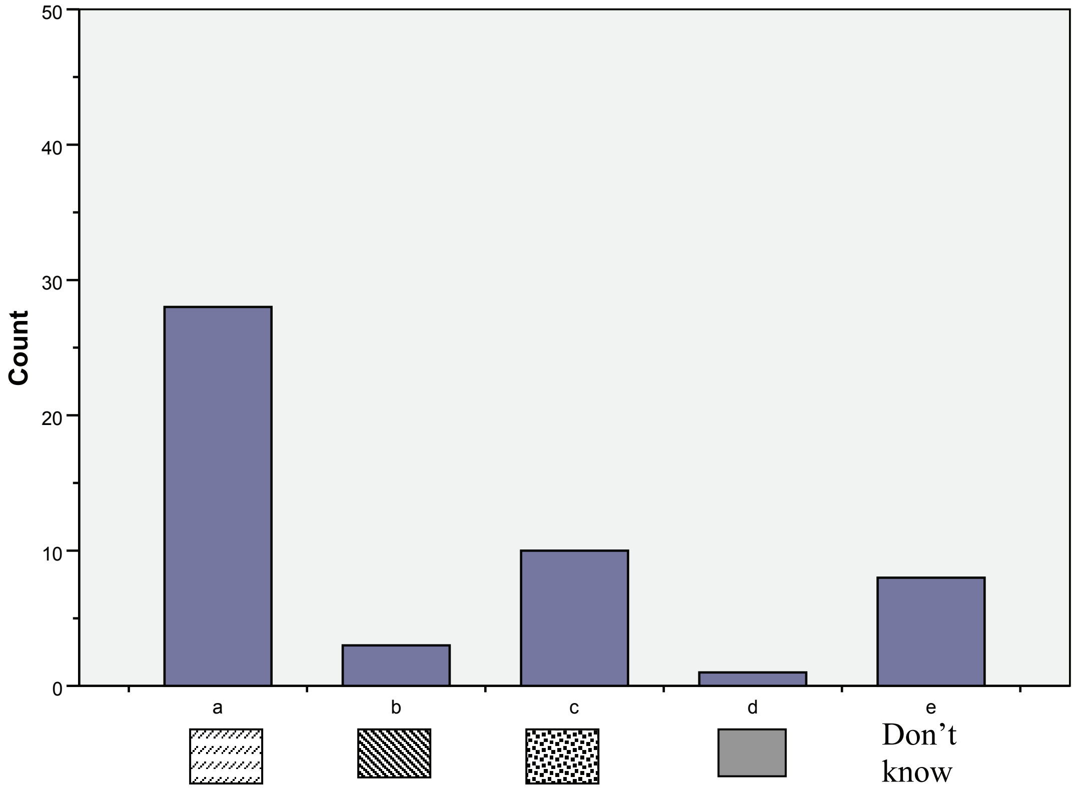
Graph 5 Graph over count of responses for well symbols



Graph 6 Graph over count of responses for dam symbols



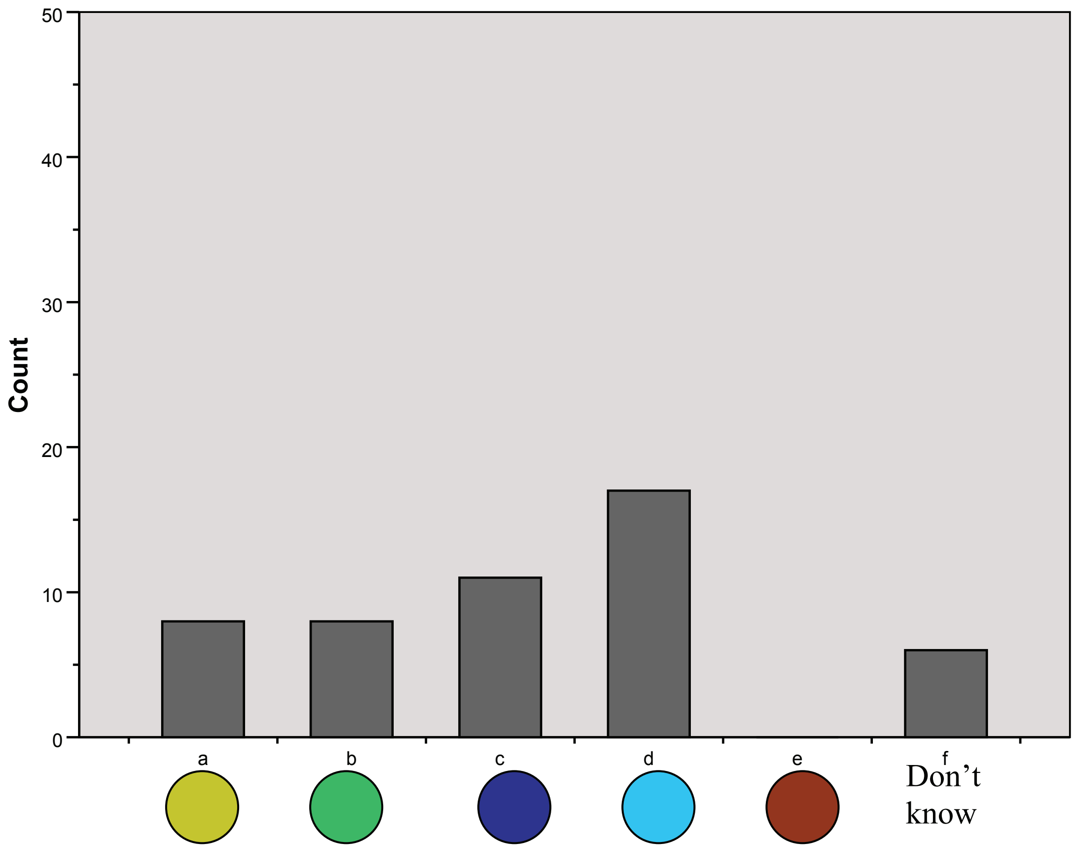
Graph 7 Graph over count of responses for danger symbols



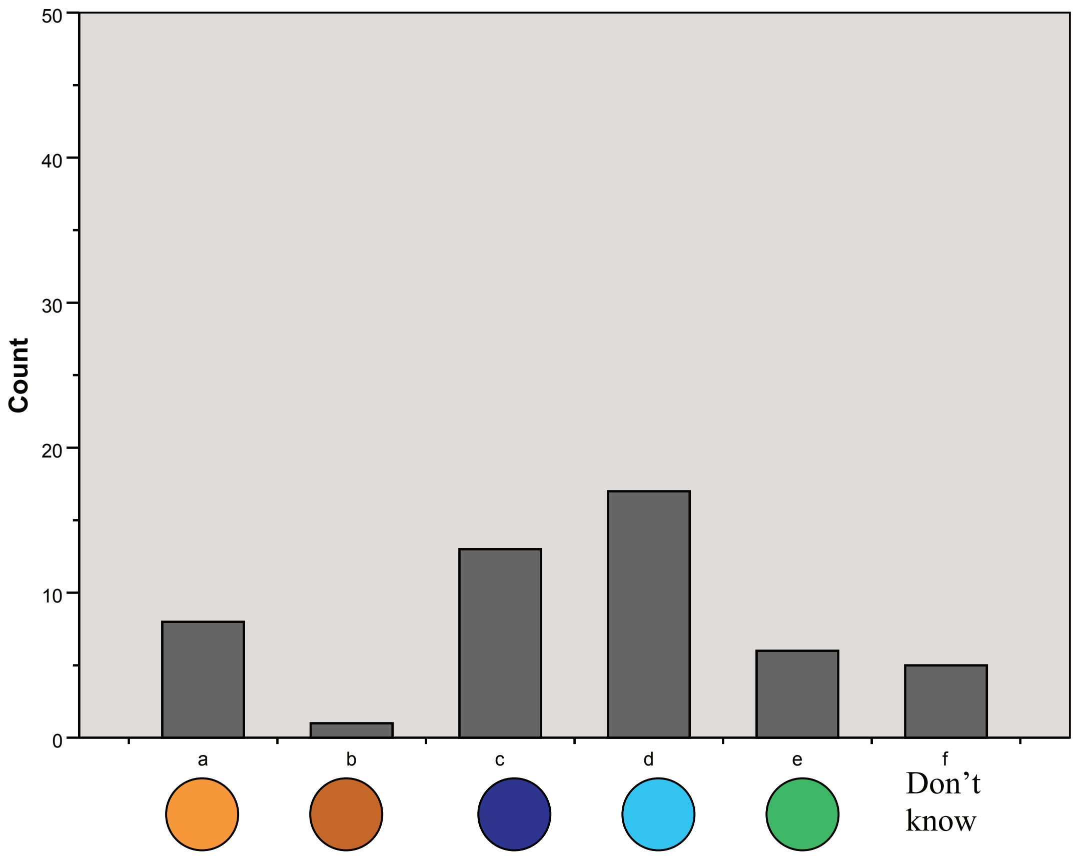
Graph 8 Graph over count of responses for crops symbols

5.2.4 Results From part four; colours

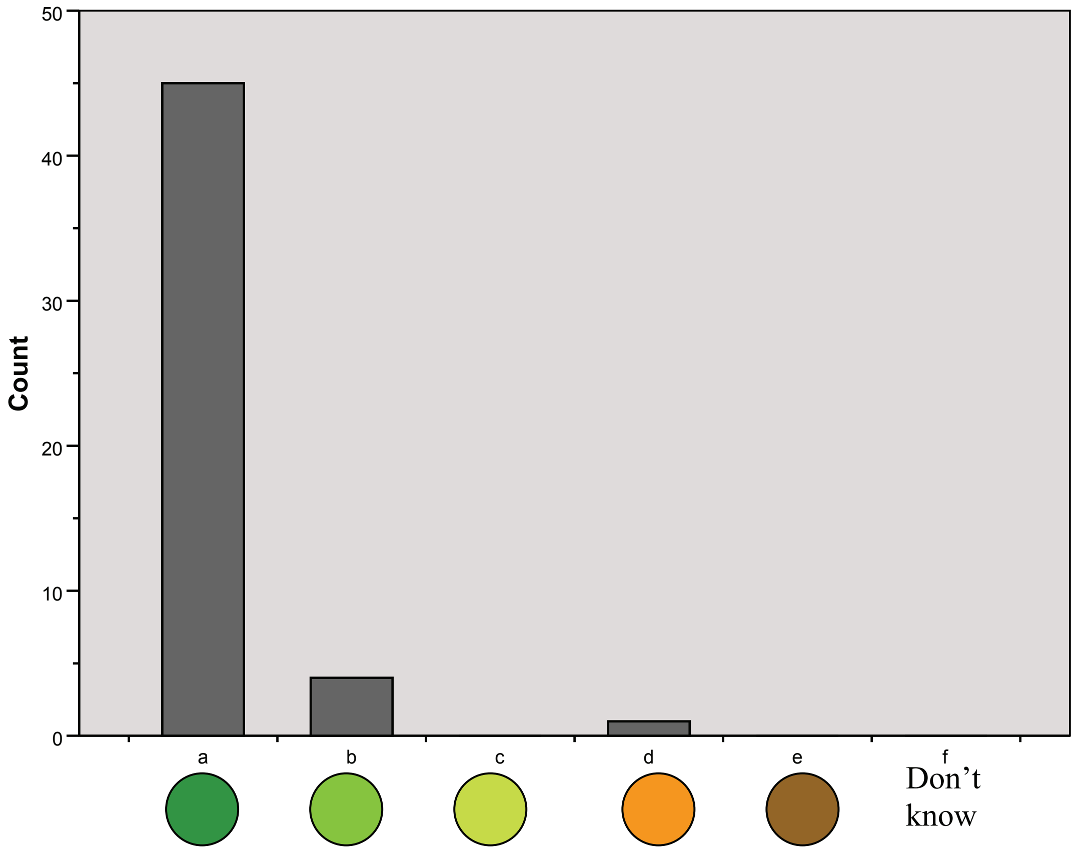
The same descriptive analyses were done for colours as for symbols. The following graphs indicate the colours respondents found most appropriate for selected features. The y-axis indicates the number of participants who chose each of the alternatives, while the x-axis shows each of the alternatives denoted as a, b, c, … The colours are given as dots under, to get an intuitive understanding of the results.



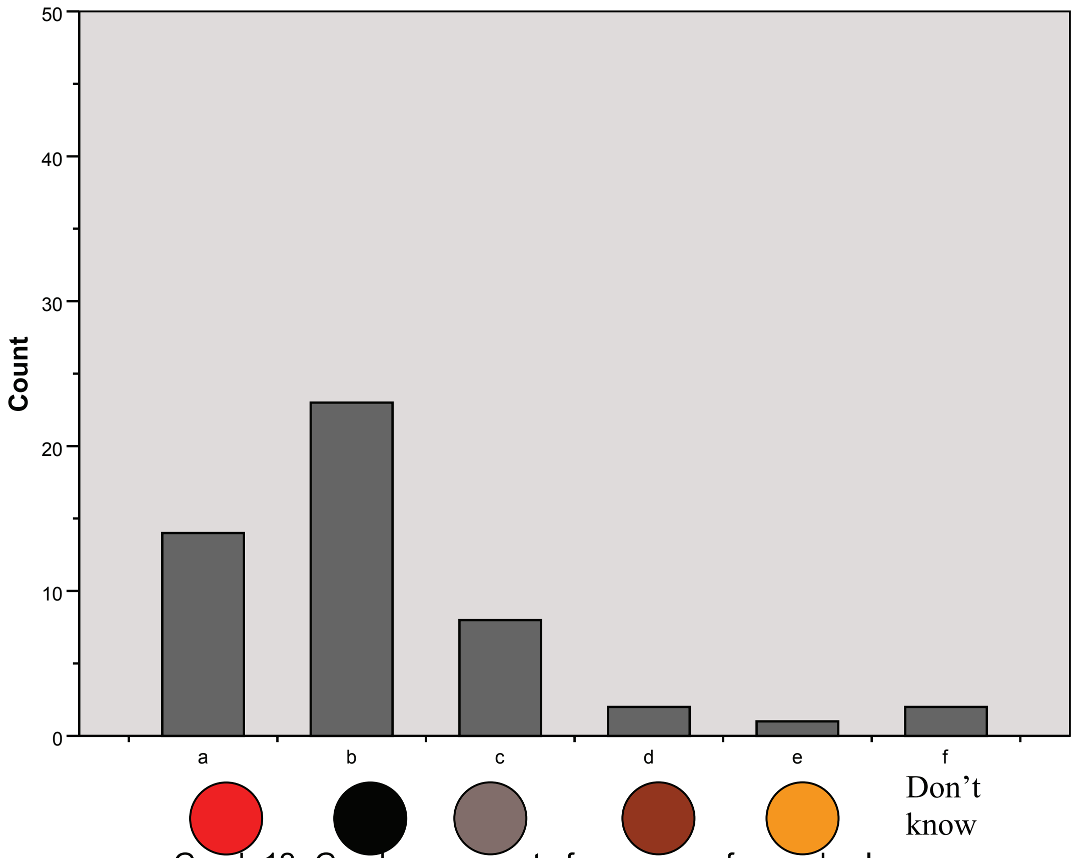
Graph 9 Graph over count of responses for river colour



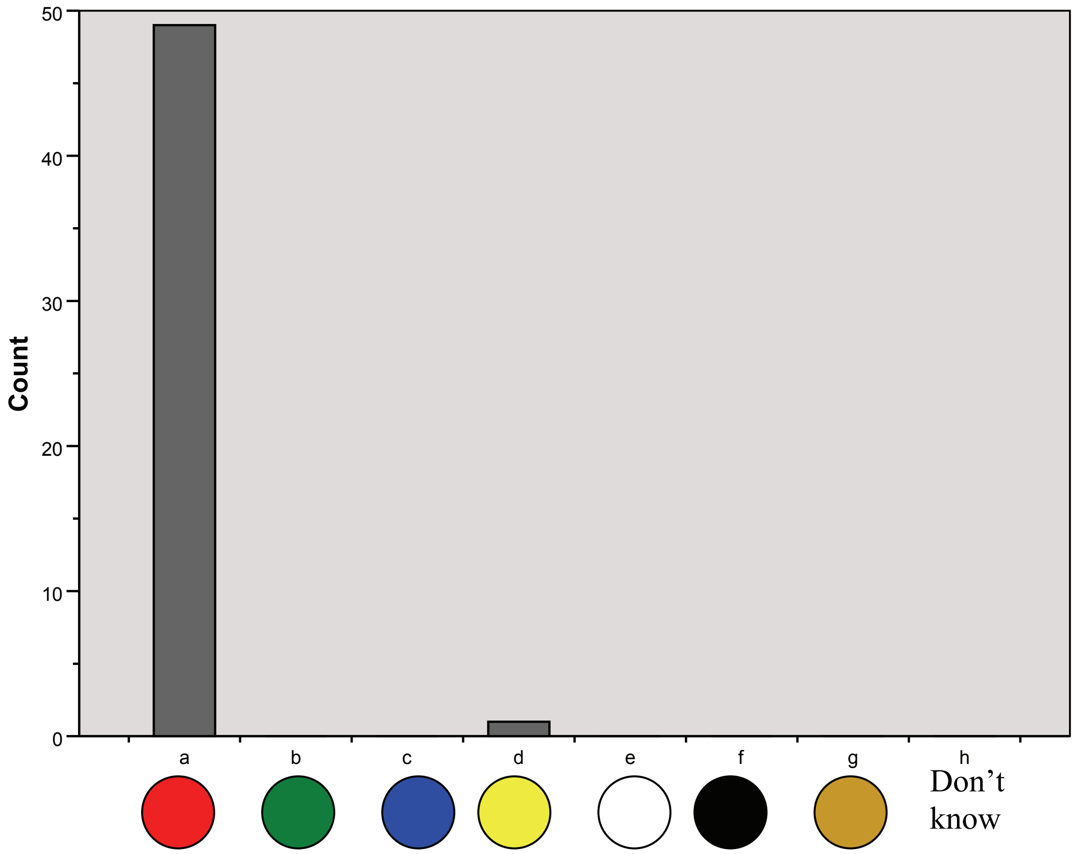
Graph 10 Graph over count of responses for water colour



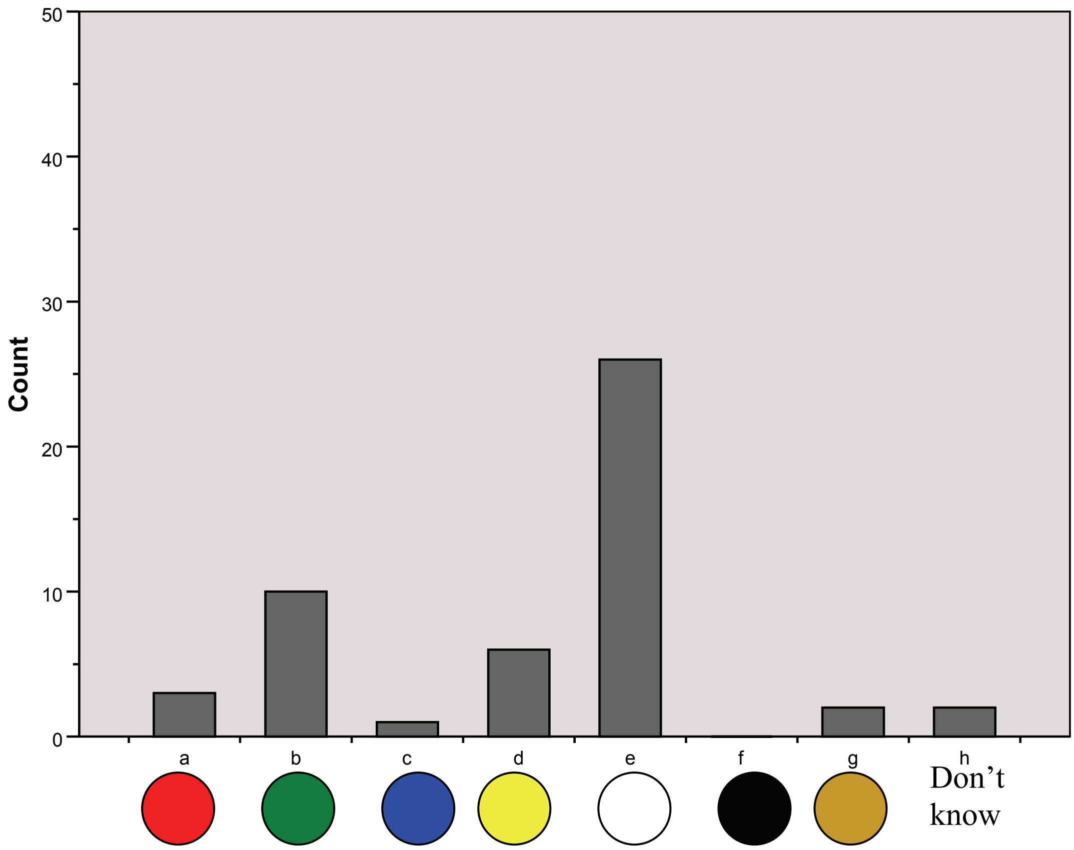
Graph 11 Graph over count of responses for crops colour



Graph 12 Graph over count of responses for road colour



Graph 13 Graph over count of responses for danger colour



Graph 14 Graph over count of responses for safe colour

5.3 GIS FOR ADDITIONAL MAPPING OF CONTAMINATION IN ZIMBABWE

To extend the geographic information system to cover the whole of Zimbabwe, a map basis must be obtained. The easiest solution would be to get hold of shape files that covers the whole country. When a map basis is in place, water samples and analysis must be taken and embedded into a database. It may be more appropriate to find a better suitable database system than Access for such a big project.

In this project a proposal to a map basis was made in ArcMap, based on the layers created in MicroStation. The following layers were added into a basis.mix file in ArcMap for further development and work:

Table 11 Data basis in ArcMap for further work and analysis

Map basis made in MicroStation:	Water samples from Access:
Cliff Fence House IDP_Building Playground Pounds River Road	Boreholes Water samples pH values
Road_small	Sulphate events

The basis.mix file with the content summarized in Table 11 is attached as an electronic appendix. The pH values listed under Water samples from Access has the same appearance as in Figure 19 were pH is depicted on a map. Sulphate events are those depicted in Figure 16. One does not have to us the same appearance and classification as on those two maps.
The intended users for further work are not familiar with ArcMap. An instruction manual is made for basic functions and operations in ArcMap. The manual is attached as Appendix 6 .

The work done in MicroStation V8 is done once for all, and it is not necessary to repeat. All layers are imported into ArcMap for further work.

5.4 PROPOSAL OF POSSIBLE MAP TO LOCALS AROUND IDP

One map based on the results from the questionnaire and the water samples were made that illustrated the drinking water quality to the inhabitants around Yellow Jacket River. The resulting map is given in Figure 20. The map is produced in ArcMap from the map basis made in MicroStation.

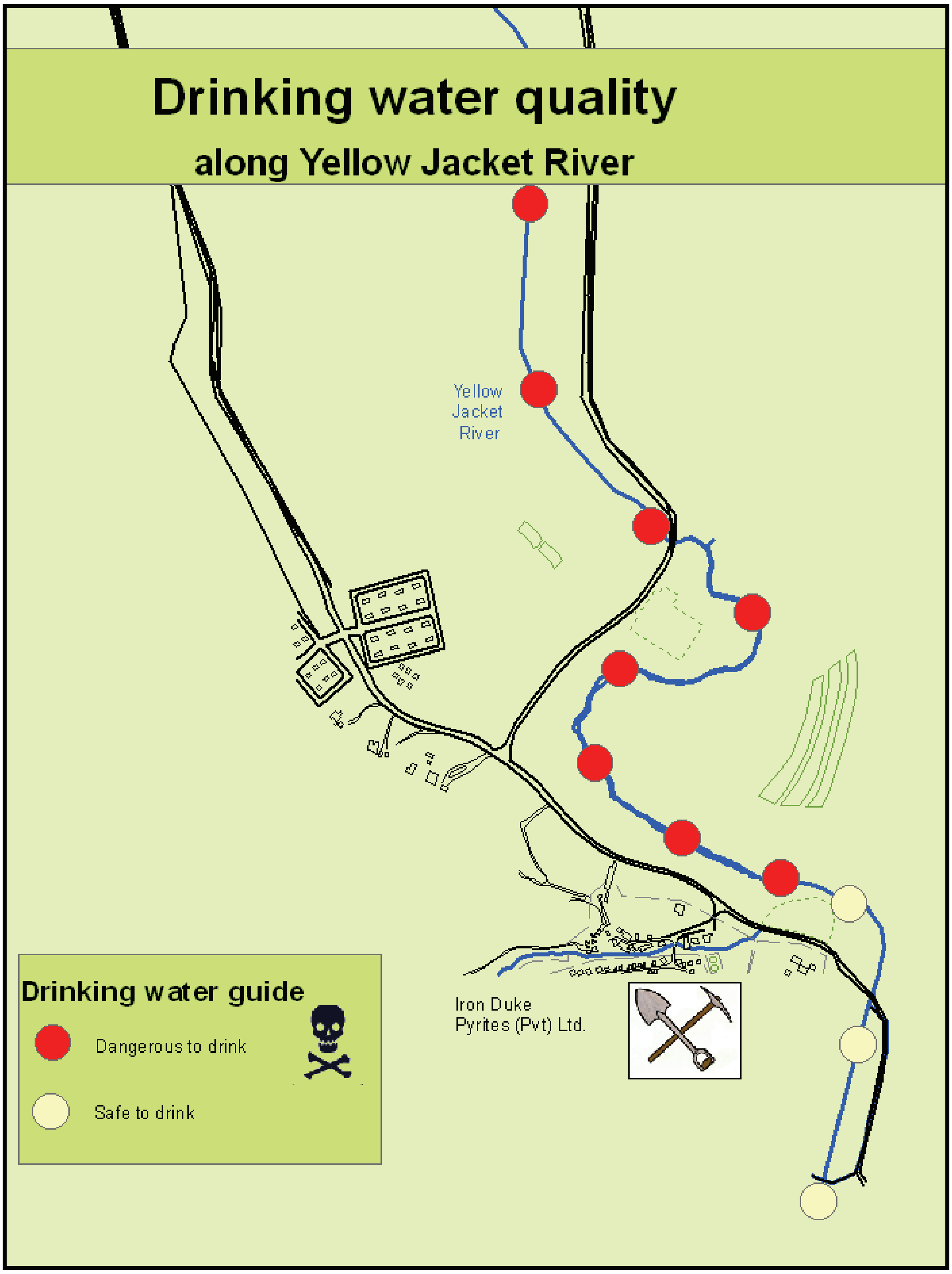


Figure 20 Resulting map illustrating drinking water quality to inhabitants around Yellow Jacket River

The original plan was to make two maps to the inhabitants around YJR. One map that was based on the worst case scenario of contamination during dry season and one map based on worst case scenario during rain season. Each map with identification to the season they represent. The dry season would have a golden yellow/orange background and the wet season a green background with an enlarged river.

After discussing the contamination differences with the other master degree student doing a project at IDP, Bård Tobiassen, and the conclusion was that the contamination is too heavily and one can not recommend someone to drink the contaminated water in Yellow Jacket River no matter which season. One did not have to create two maps, and the locals did not have to be confused of different information to different times.

CHAPTER 6 DISCUSSION

6.1 DRINKING WATER QUALITY AT IDP

The maps and diagrams given in *5.1 Results from The water quality samples* , shows clear evidence that the Yellow Jacket River and the ground water around IDP is heavily polluted from the mine facility. With such values of pollution, it is essential that living creatures do not drink the polluted water. The contamination seems to be worst just before the rainy season starts in January/February. Later in the rainy season, water from the dam above IDP flows over and dilutes the polluted water. Although some of the results indicated that the situation is not as bad all year around, one chose to base the map illustrating contamination from the worst case scenario. The consequence of wrong information can be deadly among the inhabitants, so a worst case scenario seemed most reasonable.

The results from Table 10 gives values from YJR just before it runs into Mazowe River and Mazowe River upstream and downstream from that point. The values are not too bad at Glendale Waterworks where the pollution from YJR is diluted into the river. It seems that Mazowe buffer the pollution well. These results are not enough to conclude that the drinking water satisfies the standards given by ZIMBA (Appendix 2). More measurements and analysis is necessary before a conclusion can be taken.

There is reason to believe that a thorough analysis of the Glendale Waterworks should be conducted. It supplies water to a large population, and one can not ignore that YJR runs into Mazowe and therefore contribute to contaminated water. Although Mazowe is much larger and can buffer contamination, it may not buffer all evidence of contamination.

6.2 SURVEY

All though the survey was as simple and straight forward as possible, some misleading information may have appeared in the result. When the questionnaire was made, some thoughts and prevision were made, that might have influenced the content. All thou a pilot survey were run and some of those subjective components were detected, it is not a guarantee that everything was detected. Also the translator could have some presumption and thoughts of what would or should come out from the survey. The respondents will not understand the questions better that the translator, if the translator got some of the questions wrong, then the respondents will most probably get it wrong as well.

It is difficult for the researcher to find out or decide if the local language, shona, has a good word for “map”. It may be they don’t have a good word describing map the way “we” understand the word “map”.

Together with the resulting diagram from the questionnaire, came some contradictory information. Some of the participants commented that some inhabitants along the river got drinking water from a local well or the river during the rain season. This did not get revealed in the questionnaire. Several respondents told that all inhabitants around IDP are dependent on the mine to get their drinking water. It is IDP that facilitates tapped water to local inhabitants, those working at the mine and others. Some participants also revealed that IDP threatened to close the tapped water to locals in some situations. The validity of those comments will not be discussed here but it is a serious comment that should be taken serious and further.

6.2.1 Motivation for an efficient information source

The first half of the questionnaire gave a realization of how well a map would work as an information source, and how important it is with information to all local inhabitants around the mine. Do they need information about the water quality.

Question 4 had unique answers, all 50 respondents said that they fetch drinking water, and that the water was from a tap. When the survey was carried out, some of the study participants commented that they knew of some inhabitants that did not fetch water from the tap during rain season. When it was much water in the river the inhabitants got their drinking water from the same place as the baboons, and that was along Yellow Jacket River. It was inhabitants that lived far from a tap and downstream along YJR. That is very serious, and it is important to get through to those inhabitants with information of the condition of the river. It is a well known fact among the inhabitants that the river is polluted, and they are told to get drinking water from the tap. The problem with such pollution is that they can not taste that the water is bad, and they do not necessary get immediate syndromes. It may be they think that the water is not dangerous when it is diluted with rain water. It could also be a result from risk behaviour. Regardless of reason for such behaviour, information to all inhabitants is essential. Can map be a solution?

More information came on the agenda when the questionnaire was carried out. Some study participants mentioned that the mine (IDP) had in some situations threatened the inhabitants living in the area to shot down or close the tap. Everyone that lives around IDP and YJR is utterly dependent on the water from the taps. The tapped water is the only water they have access to that is not heavily polluted. If the mine closes the tap, their basis of existence vanishes. That is a terrible and serious threat. It is not verified or investigated further. It is just a comment from some of the participants. One will not conclude anything from that comment here, but it amplifies the need to flare information about water quality around the area to everyone. A benefit with a map as information source is that a map can easily illustrate the degree of pollution and the location of the pollution in the one and same display.

It would be very interesting to see the damage polluted ground water may have on crops. 96% of the respondent had crops they need to sprinkle. The ground water may have an impact on the crops, and what happened when people or animals eat crops that have been postponed to pollution. It is known that polluted water is a problem for animals and heavy metals increases the ratio of concentration upwards in the food chain. That means that the impact will increase to humans when humans eat meat from animals that has been postponed to heavy metals. 20% of the respondent had farming animals when the survey was carried out, it is not known how many actually eat farming animals from the area around YJR. Is it possible to make the animals drink water from other sources than polluted water? Can a map help the farmers to find better water?

6.2.2 The respondents comprehension of maps

Part two of the survey exposed the respondents to four different maps. 90 % said that they had seen a map before, and relative many said that they knew where the map was from. The second map was the map most respondents found easiest to interpret, almost 80 % knew that the map was from the area of IDP, but only 46 % of the respondents could point out the main gate to IDP. That indicates that their understanding was not very good despite their answer that they recognized the area. The same tendency was reflected in the third and fourth map as well. 62 % could say that the third map was from IDP, while only 8 % could point out the gate on the topographic map. It could be a lot of reasons for those results. It could be that the respondents lied and just said "*Yes, I know where this is!*" because it was a question of pride. A reasonable guess from the respondents could be the reason why so many said IDP. And also, if the respondents looked closely at the third and forth map, he or she could see that it was written Iron Duke Mine in the lower right corner of the map. One should maybe expect that all respondents said IDP because they could see it on the map, but not many seemed to notice the text in the corner.

Many of the respondents did not have a clue of where the gate could be, some pointed places along the river, and some meant that it was outside the map and so on. That indicated that they had no comprehension of maps. To comprehend maps is like comprehending language, it must be learned trough practise and exposure. Map no four was better than map no three, which was the same map, only some features emphasised. It seemed that map no three had to much information, and that they did not manage to select those features interesting. Contours and topographic features that interfered with more relevant topographic features disturbed the map and made it difficult for the respondents to interpret. It is not surprising that the first map was difficult to interpret; it did not have any information that indicated that it was taken from the area, only the shape of the river and roads. It can be difficult to picture to oneself the shape of a river from above, when one has never seen the river from above. Question 16 showed that most of the participants found map no 2 easiest to interpret. Map no 2 was also that map most people could point out the gate from, 23 participants pointed the right place. All that together summon that an easy sketch-like map with the most important features like roads, buildings and rivers together with explanatory text is the best alternative for those inexperienced users in the area of IDP.

6.2.3 The respondents comprehension of symbols for specific features on maps

Most of the study participants agreed upon the symbol for drinking water. 88 % found the water-tap with a glass under was most appropriate for symbolizing drinking water. That makes sense since all inhabitants must get their drinking water from such a tap. But if the question had been the other way, and asked like "*Do you know what this symbolize?*" and showing the same symbol, it is not for sure that people would answer "*drinking water*". That is an interesting problem to be addressed for later work. The symbol most popular for drinking water is the same symbol the Norwegian Map Authority uses as standard symbol for drinking water. With such a clear majority, no other analyses or statistics was necessary.

For house symbol, most study participants found symbol A and symbol B most appropriate as can be seen from Graph 3 . The majority found the "*traditional African house*" most suitable, but also the standard from the Norwegian Mapping Authority was popular. The symbol taken from the Norwegian standard was for tourist hut, and not a house, as it was asked for in the survey. It was important to try different alternatives without suspended to former standards. The symbol A could also be interpreted as a round house, but not as clearly as symbol B. To find out if the round traditional African house had a significant margin to the other house, statistical test had to be executed, but in this stage of the research, it was not important to know if it was a significant margin between those two alternatives. What is interesting in this stage was that it is proven that one can not take for granted that traditional western symbols should be used – it may be necessary to try out other symbols that could be better suited. Graph 3 also shows that the participants found the symbols drawn in perspective easier to interpret than symbols seen from above. A simple circle or square did not get any responses. If it is possible to chose, drawings showing houses from the same perspective as one sees every day is better that perspectives showing houses from the air. Many of the participants in the survey had houses with flat roof, but only 3 participants found that house most appropriate, symbol C.

Graph 4 gave a clear trend that the mine symbol for Iron Duke Pyrites was the most popular alternative. It indicated that most respondents recognized and preferred familiar symbols. Surprisingly many found symbol D suitable as well, that may be because people recognize their working situation. It is a symbol describing how they work at the mine, and that's maybe what made them chose that symbol.

Graph 5 gives the responses from well symbols. Many respondents used long time on this question, and did not find a good alternative. It was difficult to find good answer alternatives that gave a good and wide basis. Although many did not know, and used long time, they did not have any suggestions for better alternatives. It may be because no one had ever tried to picture a well or borehole before. It is difficult to get a picture or good association to something one really don't see, that is under the ground. One alternative emerged form the researcher during the execution of the survey, a drawing or symbol where one sees the well in perspective from one side. Illustrated under:

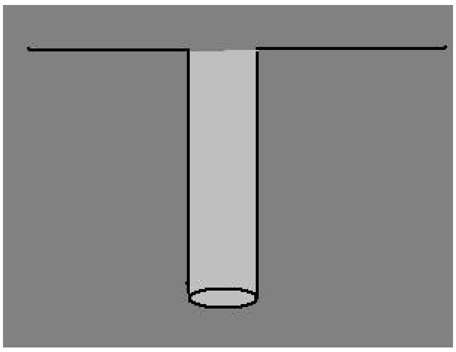


Figure 21 Alternative drawing of a well

It was not a part of this survey, but could been a good alternative for further research. Most respondents found the symbol of a glass most appropriate, that is not a surprise since the only joining the respondent has to a well is drinking water. Many found symbol D as a good alternative as well. Symbol D showed how a well was from the top. To summarize the alternatives for a well, one can say that no one of the alternatives were very good, many did not know (alternative E) and others answered as well as they could among the alternatives given.

To find good symbols for dam was a challenge, The Norwegian symbol that are used in different kinds of map are well known among Norwegians, but it is not for sure that those symbols are intuitive and easy to interpret for not experienced users. The symbol proposed by the Norwegian Map Authority for dam, was actually the alternative the majority of the participants selected. The other three drawings was an attempt to illustrate a dam as it is illustrated on a usual topographic map. It was a clear trend among those alternatives, that the drawing with saturation on water was the best alternative. Graph 6 showed that 6 respondents did not know, that indicated an element of uncertainty, and that no alternative was very suited for dam symbol. No one came with better alternatives.

The last question about symbols was symbol for danger. Graph 7 gave that almost everyone found the deaths' head most appropriate to indicate danger, 47 out of 50 respondents. The last three respondents found one of the alternative with a triangle most appropriate. The deaths' head were used around the mining area to indicate danger zones, and most people had seen such a sign before. That may be one reason why most respondents chose that symbol.

6.2.4 The respondents comprehension of colours on specific features on maps

This part of the survey was important, and gives many results that can be basis for later work and that set out some question on former theories and presumptions. Ideas that make basis for western approach to interpretation of colours, may not apply to everyone around the world. This survey gives an earnest of what can be expected.

Graph 9 and Graph 10 gave the result from answers of most appropriate colour for river and water. The majority chose blue as the most appropriate colour; light blue was more popular than dark blue. Dark and light blue got just over 50 % of the votes against the rest of the alternatives for both river and water colour. With the same question in Norway, almost 100 % would have answered one of the blue colours. The river-like colour (orange-reddish) got 16 % of the respondents vote for best appropriate colour, quite many. Almost 50 % of the respondents chose other colours than blue for water, and that is a dramatic amount. It is difficult to try to understand the reason for such a result, the causes can be many. One situation that did not get revealed was if the respondents were colour-blind. As discussed in previous section, one did not want to ask such a question, and the results may be influenced by that decision. It may have been coherence by those who have seen and understood a map before, and those who has not. It may be likely that those who has seen and understood a map before, had learned something, they may have learned that water is illustrated with blue. Attention should be given to the other alternatives (not blue) and more research carried out.

The crops colour results, given in Graph 11 showed that most respondents found green as best alternative. That may be because the survey was executed during the end of the rain season and all crops was green at that time. Other possibilities may be that the other alternatives were not good. Or it can simply be that most participants thought that green was the best colour to depict crops.

The last topographic feature the respondents had to find appropriate colour for were, road. Black and red was the colours most participants chose. 46 % had the opinion that black was the best alternative while 28 % had the opinion that red was the best alternative. The road-like colour given as alterative C was chosen by 16 % of the respondents. Just a few participants chose alternative D or E which was different brown and orange-brown colours. Most respondents answered that question, only 4 % did not know. This result showed that most respondents liked clear colours better that mixed colours, black and red was the two best alternatives.

The two last questions were to choose appropriate colours for danger and safe. The best colour to illustrate danger was rather unambiguous, 49 out of 50 respondents chose red, while one respondent chose yellow. The colour for safe was more doubtful. White was the colour with most votes, 26 out of 50. Green and yellow was the other alternatives respondents chose. 2 respondents did not know. Graph 14 tells that all colours were elected except black. This result is in contrast with what is assumed here in Norway. Most Norwegians would probably say that red is colour for danger and green is colour for safe. This is based on learning and what Norwegians is used to see. Walking or driving around, all robots shows red for stop and green for OK. This may be one of the causes why colours have the transferred meaning as it has. Based on the survey, danger should be depicted with red and safe with white.

6.3 GIS AS A TOOL FOR MAPPING AND ANALYSING CONTAMINATION

6.3.1 The choice of GIS software

MicroStation V8 was an advanced drawing software program. It had lots of functions and possibilities including the possibility to make maps and use geo-references. That was very valuable in this project. It was not adapted for a geographic information system or for presentation of maps. One had to use much time to learn how to use MicroStation V8, and half a year was to short time for such an advanced program. In co-operation with master degree student Bård Tobiassen, the most basic and necessary tasks were preformed. Layers with geo-references were made and exported as .dng-files.

ArcMap accept drawing files and all .dng-files were imported into ArcMap. ArcMap was more user-friendly and better suited for presentation. ArcMap could be used as a geographic information system in this project because it supported the functions and tasks necessary to conduct the work in the connection of mapping contamination around IDP. Those that will precede the mapping and analysis of contamination have access to ArcMap though NTNU.

Access were used for storage of water samples data because it is easy to use and a part of the Microsoft Access package. Easy-to-use and access to the software was the main factor why Microsoft Access was chosen. Microsoft Access was not good software if one wanted to analyse the data and make graphs and illustrations of contamination over time. It gave limited possibilities for statistical analysis and creation of diagrams. It was possible to open Microsoft Access database or table in Microsoft Excel for that purpose.

More work on improvement of a GIS could have been made if shape-files had been available, and one could use more time on that particular task and analysis. Since the shape files gathered from Zimbabwe were useless, the priority was to create a map basis that could be used in later work. Some analyses were run of the measurements and water samples, to be able to draw the final maps. One did not have the opportunity to see if the contamination was correlated to external factors such as rainfall or activity level at the mine. It is an interesting task for further work and analysis.

6.3.2 Further work based on the existing GIS

The choices made in this project may not be the best choices for a big geographic information system. A more advanced database should be created and developed together with a special developed GIS for this problem. Before one starts such a project, it is important that the intended users see the possibilities and usefulness of a GIS in the process of mapping and analysing contamination.

Since the intended users were not familiar with GIS-software, one tried to arrange the data basis in a logical and clear way. User manuals were constructed that will help the users with basic functions and creation of maps for presentation. If this work satisfies the users, one can expand this system or create a new system that is more adapted to what they need.

6.4 CREATION OF A MAP TO THE LOCAL INHABITANTS

6.4.1 Map as a rational information source?

It is difficult to tell if a map is a good information-source to inhabitants around Iron Duke Pyrites and along Yellow Jacket River. Conclusions form the survey can not be drawn to a bigger population or to other villages in Zimbabwe or Africa, but it does give a good basis for further research. The survey will only be valid in the same area as from which it was executed; the results can be used in a map for the inhabitants around Yellow Jacket River. That is; if one finds that a map will work as a good information-source.

It is not clearly that a map is the best information-source to inhabitants. The survey showed that they had little comprehension of maps and orientation in maps. It was not many that could point out the feature one asked for in the survey, but quite many new that the maps was from their area. A profit from execution of the survey was that many learned something about maps and how to orientate in a map during the survey. The participants were exposed to four different maps over their own home-area, and they may have learned something from the survey. After the survey, the translator used much time to explain the map and show them features of interest. If the same maps were shown to the participants now, maybe many could have answered the questions from the questionnaire.

The translator got very involved and motivated from the survey. He wanted to use the maps later for teaching inhabitants how to interpret maps. The school would also use the maps more actively to teach children how to read maps. When there has not existed a map for inhabitants, the motivation and possibilities to learn how to read and interpret maps has not been present. It the inhabitants can get access to maps or be postponed to maps, the motivation will arise, and learning by seeing will be possible.

A map is an excellent tool for illustration of spatial information. When the primary factor is location and position in relation to other features, map is unique. It is effective, and can give lots of information easy and well arranged. Once one has learned how to read and interpret maps, it is easy to read different types of maps that illustrate different things. The alternative for inhabitants around Yellow Jacket River is that someone tells everyone about the situation, that is time-consuming, and has the limitation that every time the situation changes, someone has to contact and tell all inhabitants again. One could send a note or a letter to inform people, but not everyone can read.

The advantage with a map as an information-source is that posters or small hand outs are all that is needed. If the mine invests in a big signboard of a map over the area, that map can be basis for whatever one wants to tell the inhabitants. It can be placed a place where many people pass or stay, like outside the local grocery or at the buss-stop. If the basis map of topologic features is correct, most inhabitants will learn to read the map after some exposure. Then it will be easy for people to read the information one wants to give. It is of primary concern to keep the map as simple and intuitive as possible. What may be a hard part independent of the map or another information-source is to motivate and make the inhabitants understand why they should avoid polluted water. That is beyond this thesis, but vital for making the inhabitants understand and follow the guidelines given.

6.4.2 The proposal of a map to locals around IDP

The most important factor for making a map to the locals was to make it as plainly and easy to read as possible. The most important features had to be included, like roads, houses and rivers. One wanted to emphasise the message about water quality, one did not want to emphasis other things, and the topographic features were made as simple as possible. Most features had narrow lines and same colour so that it did not steal much attention. Water quality was based on observations of all measurements and of all figures and tables listed under the chapter of results. A clear trend emerged about where the ground water and therefore the river were polluted. The water quality were displayed in to categories, *safe to drink* and *dangerous to drink.* That was because the results showed such a clear trend where the pollution into Yellow Jacket River started, to add categories like *possible to drink* or *OK to drink* could be just a confusing as explanatory. One does not want to make things more unclear then they are, and the simple is often the best.

Figure 20 illustrates the resulting map. The map showed that some of the results form the questionnaire was implemented into the map. Colour for safe and danger were used to illustrate the water quality. The background of the map was given a light green colour. A colour that did not attract attention and that gave some contrast to white and red were chosen. Green was a good alternative, since most of the area around IDP is green and vigorous.

The symbol of danger was added to the explanation of water quality identification. Those who do not read may be able to understand the meaning of the symbol beside the text. One did not add a legend to the topographic features on the map; it would give to much superfluous information. Most topographic features had the same appearance, and one concluded that the shape gave better indications that a legend for most of the features.

The symbol of IDP mine and a text label were added to the area of mine administration and the area of extraction of pyrites. That made it possible to read the map for known and unknown people in the area. Local will immediate recognize the sign while other people will be more familiar with the text.

CHAPTER 7 CONCLUSIONS

7.1 WATER QUALITY SITUATION

The problem of contamination from the mine facilities is considerable. Yellow Jacket River is heavily polluted from where contaminated groundwater flows into the river. More thorough analysis must be conducted before one can say something about the compound situation.

The water has too bad quality and should not be used as drinking water in any situation. The results from Mazowe River did not have bad values, but more samples needs to be taken before conclusion about the drinking water quality in Mazowe River and Glendale Waterworks can be drawn.

7.2 IMPORTANT RESULTS FROM THE QUESTIONNAIRE

The work with preparing and carrying out a questionnaire was very informative. One had to build up much information about the area of interest, knowledge of maps and map symbolization. There was much to learn about how research should be conducted, how to ensure valid and informative results, how to behave when conducting the questions and so on.

Quite a few conclusions could be drawn from the results from map symbols, but also there is some uncertainty factors that must be investigated further before conclusion can be drawn.

Some interesting results were revealed from the descriptive statistics run in SPSS. The participants understanding and interpretation of maps was not much present. They were very eager to learn, and wanted to say that they did understand everything. The respondents understanding of symbols were not influenced by earlier acquired information about map symbols. A clear trend was that they choose symbols that were familiar for them. If they had seen some of the symbols before, on a sign or in other context, they tend to choose what they had seen before. They found it difficult to choose symbols among features they had not seen before and did not have a clear idea about what to visualize, like a well. All respondents knew what a well was, but they found it difficult to choose a symbol for it. It is not something one sees in the local environment.

What was most surprising was their chose of colours to different features. Just above 50 % chose blue as most appropriate colour for water, green was a popular alternative among others. After closer reflection, it is not strange that one got those results. It was probably not may that had seen blue water in the area of IDP. The river is more orange then blue.

Part three of the questionnaire gave a good impression of the respondents interpretation of symbols, but lost of question are still unanswered. Symbols about features they have never seen pictured or symbolized before was most difficult to choose, and the alternatives may have been to narrow for those features. Symbols that were familiar and drawings they had seen before was most popular, like the deaths' head for danger and the IDP brand image for mine symbol.

It gives a very good starting point for further analysis about Africans interpretation. One can not generalize anything from this questionnaire, but there was many interesting result for further research and analysis.

7.3 A GIS AS A TOOL FOR MAPPING OF CONTAMINATION

The focus on creating a geographic information system changed when all shape files received from the University of Zimbabwe was incomplete. It was not possible to use those shape files, and one had to use other methods to make a map basis. MicroStation V8 was appropriate drawing software with good accuracy and functionality. Some unconventional methods were used to create layers one could import into ArcMap. A picture of a topographic map was used as background, GPS points as reference to coordinate system and to adjust the background to correct position. Layers of road, house, river, fence and so on were made in the same coordinate system as the known GPS points on basis of the picture as a background and available track logs from the GPS.

The layers made in MicroStation V8 gave a good basis for ArcMap, but one did not get the opportunity to create map and layers of features of a larger area.

All water quality data were stored in Access, and imported into ArcMap. When correct format were selected in Access, it was easy to import those data and present the results on the map. Access was not well adapted to make diagrams and graphs of trends among the water samples, but the data files made in Access was easy to export into other software that was more adapted for presentation of descriptive statistics

A geographic information system makes many new alternatives for presentation and analysis possible. It is essential for such a mapping project to have the opportunity to import the result into a GIS. This project gives just some samples of all possibilities that can be implemented into a GIS. If one wants to expand the area of mapping, new data layers must be found. Then it will be time consuming to create everything in MicroStation V8. Different sources has mentioned during this project that there exist shape files over Zimbabwe, and those files would be more appropriate for a larger project.

7.4 THE PROPOSAL OF A MAP FOR LOCALS

A map was created based on the results from the water quality samples and from the results of the questionnaire. The map was made as easy to read as possible with only the most important features. The topographic features were drawn with narrow lines and without colours to make sure it did not attract attention from the information one wanted to illustrate.

The water quality was divided into two categories, dangerous and safe. More categorisation could act against the aim of the map and confuse the reader. Symbols and colours that were used were chosen based on the results from the questionnaire. The map will be distributed to the mine in both electronic version and paper version. One will ask the mine administration to hang the map in convenient locations so that the locals will be exposed to the map. One hope and believe that those inhabitants that have no comprehension of a map, will learn to understand the map if they are exposed to it at different occasions.

7.5 PROPOSITION FOR FURTHER WORK

This project has been in the initial phase of creating a GIS. Much work and improvement can be made to this proposal of a GIS. Zimbabwe has no overview over pollution from mines and contamination in ground water. Much job has been done at the University of Zimbabwe, but it has never been gathered into one large system. A GIS of contamination of groundwater for the whole country would be to much help for the country. Such a GIS would give valuable information about the ground water situation and would be unique for presentation.

A geographic information system for mapping of contamination in ground water in Zimbabwe would need well adapted database management. A database is the great part of the work, and will be the basis for further analysis and presentation. One will need map basis over all parts of Zimbabwe. Shape files are available somewhere, somehow.

A professor at the University of Zimbabwe is very involved in the work of organizing and generating data about ground water quality in Zimbabwe. He really believes in the usage of a GIS in that connection. Maybe this thesis can help him to implement his project.

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Questionnaire about maps and map symbolization

Trying to find the best symbolization and map presentation for inhabitants around Yellow Jacket River and Mazowe River. So a map can be generated that gives indications where it is safe and where it is not safe to fetch drinking water.

Master thesis of Merete Sørjoten

Background information

Analysis from water samples show that much of the water in Yellow Jacket River is heavily polluted and dangerous to drink for people and animals. It is important that everyone that lives near the river knows where the water is polluted and where it is safe to get water.

I will make a map that is easy to interpret, that indicate where you can and where you should not get drinking water. To make a map you understand, you need to be involved in the process, and that's why I would like to ask you some questions.

Cooperation between:

The Norwegian University of Science and Technology

University of Zimbabwe

Iron Duke Pyrites Ltd

Part 1

Please, answer the following questions.

1 Your age?

Under 10 years	10-25 years	25-40 years	40-55 years	Over 55 years
A	B	C	D	E

2 Sex?

Male	Female
A	B

3 Occupation? ____________________

4 Do you get drinking water?

Yes	No
A	B

4 i) If Yes, where_____________________

5 Do you have farming animals?

Yes	No
A	B

6 Do you have crops?

Yes	No
A	B

7 Have you seen a map before?

Yes	No
A	B

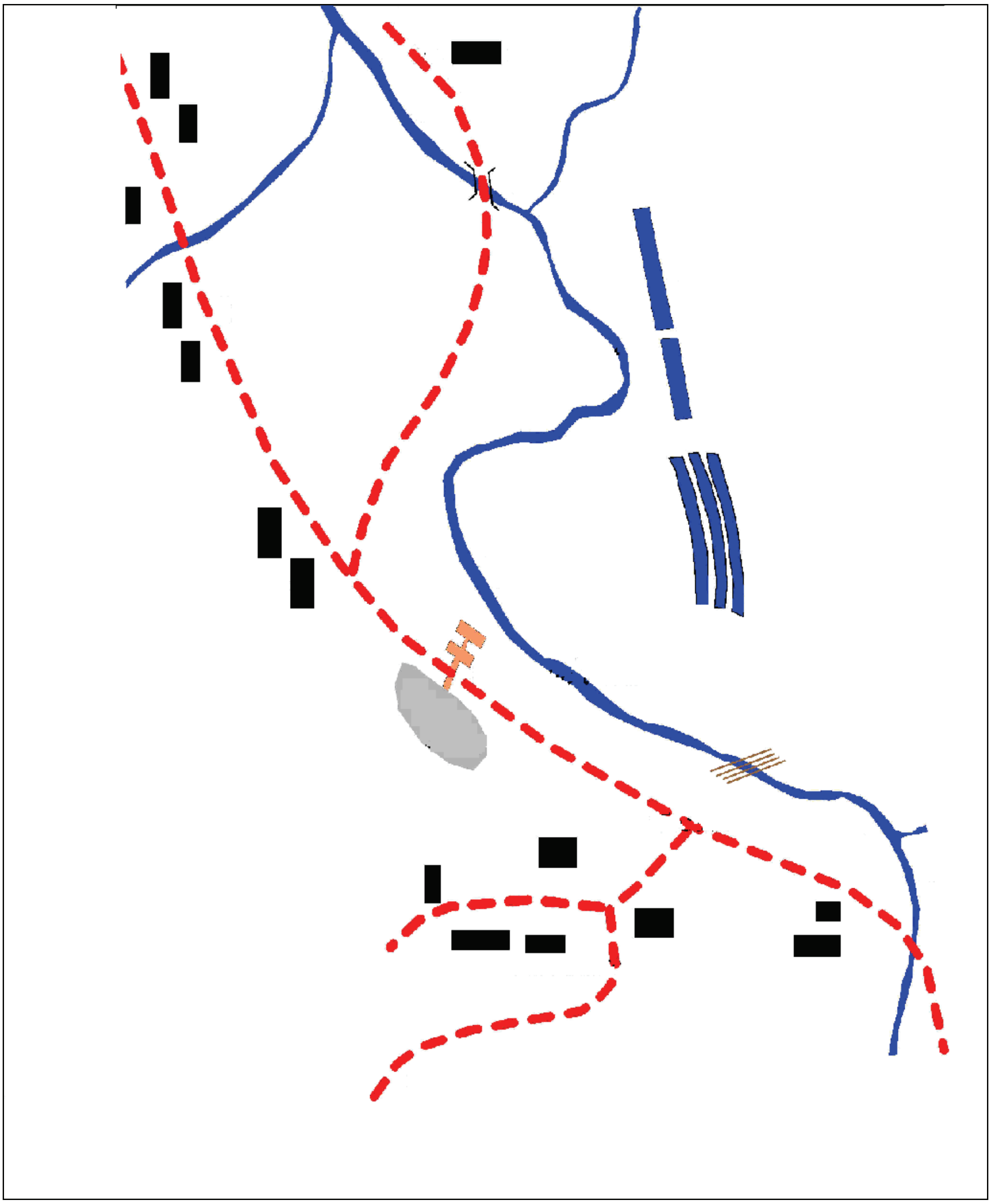
8 How do you recognize where you are, and orientate in the terrain?

River , trees, buildings, roads etc	Sun, stars, moon	Mountains, fields, valleys	Don’t orientate	Others?
A	B	C	D	E

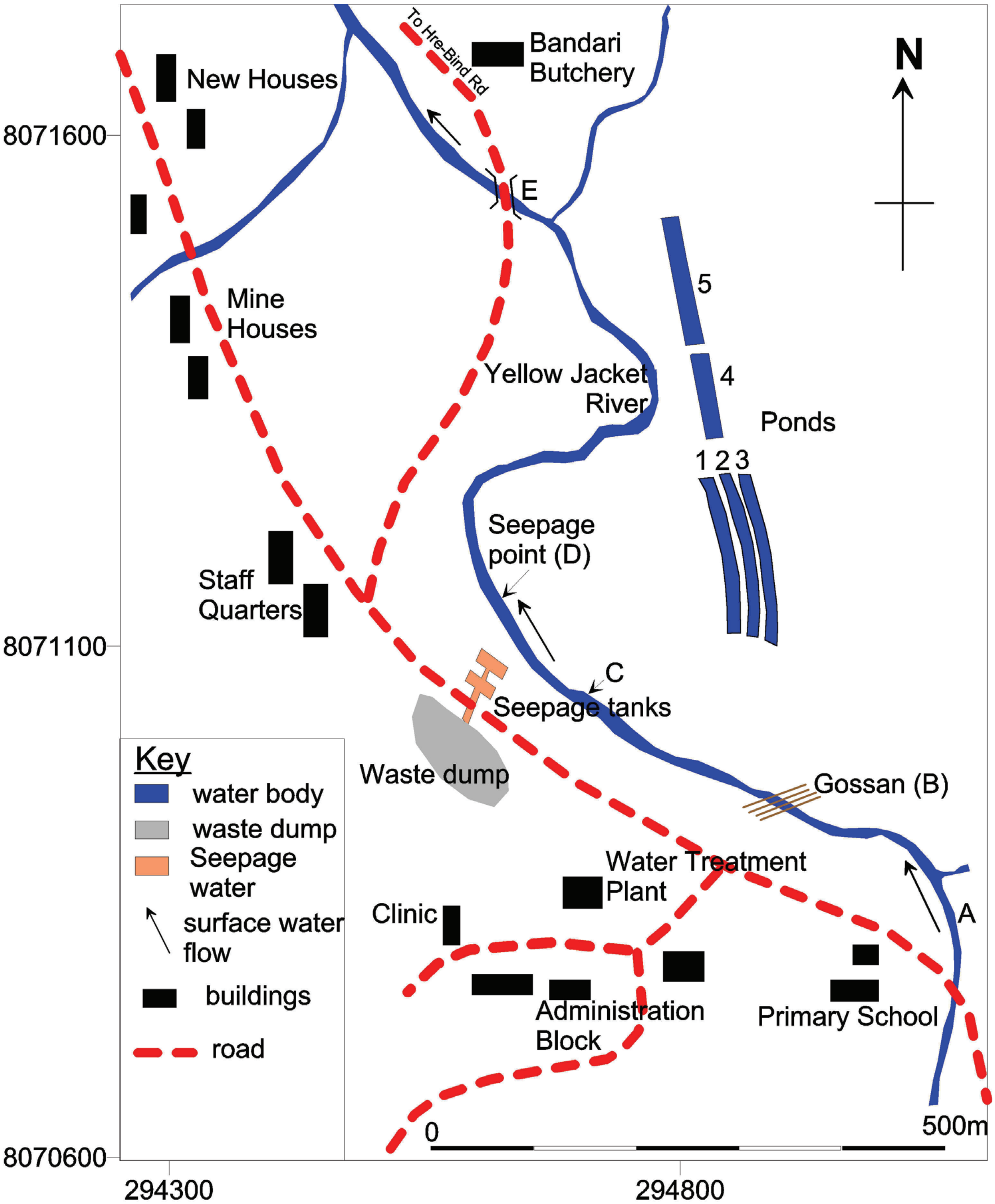
Part 2

Do your best, and try to interpret the next pictures…

9 Do you know where this is?

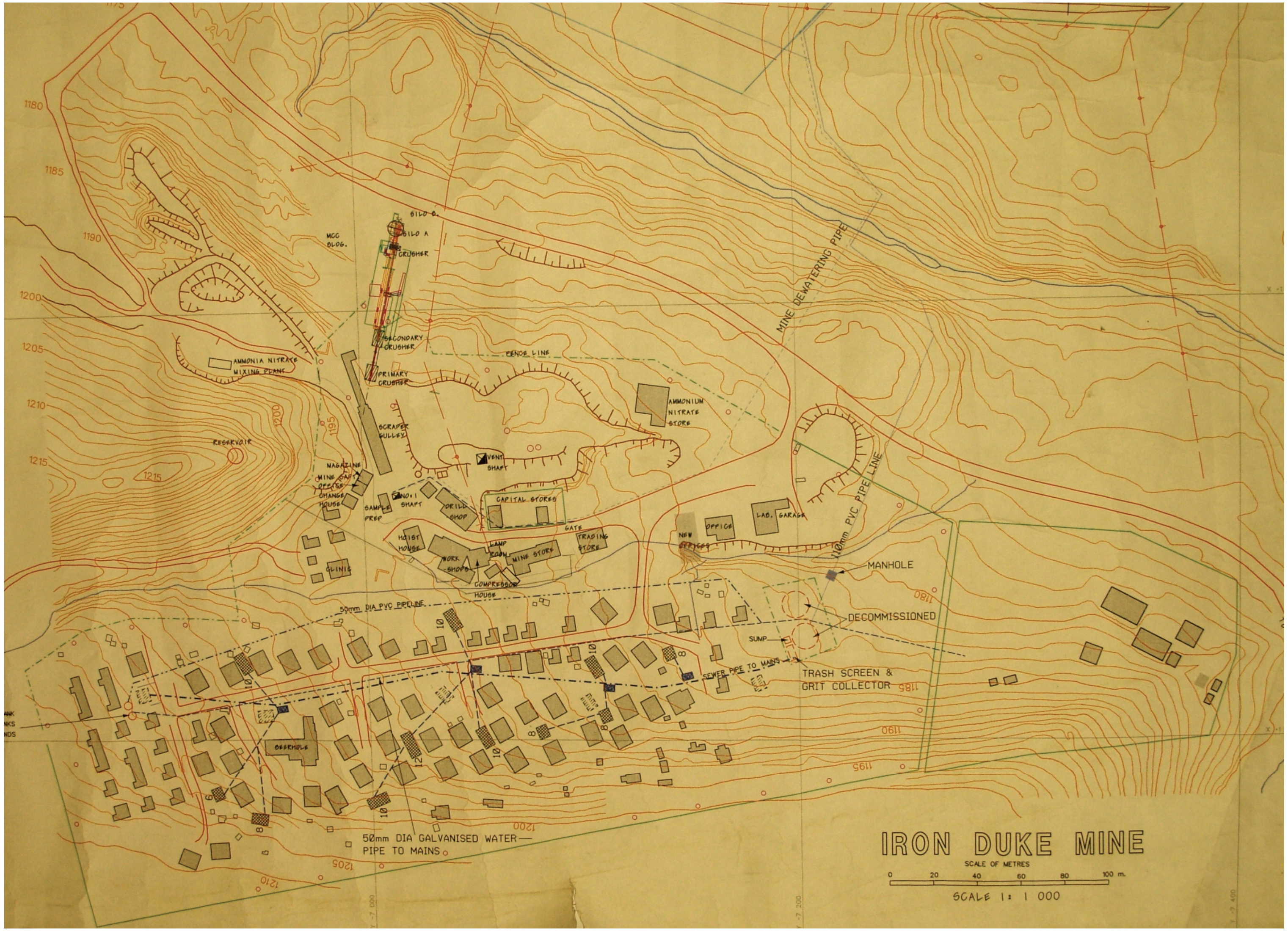


10 Do you know where this is?



11 Can you find the gate to Iron Duke Pyrites?

12 Do you know where this is?



13 Can you find the gate to Iron Duke Pyrites?

14 Do you know where this is?

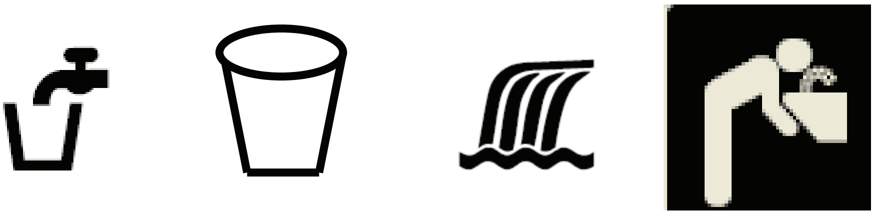
15 Can you find the gate to Iron Duke Pyrites?

16 What map was easiest to interpret?

Part 3

Which of the following symbol alternatives do you find most appropriate and least appropriate for describing the following terms?

17 Drinking water?



Don't Know

A B C D E

18 House?

Don't Know

A B C D E F

19 Mine?

Don't Know

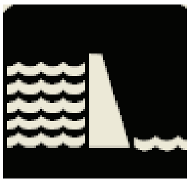
A B C D E

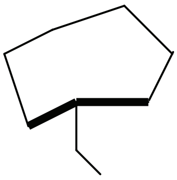
20 Well (bore hole)?

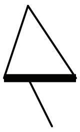
Don't Know

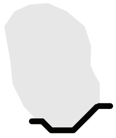
A B C D E

21 Dam?


A


B

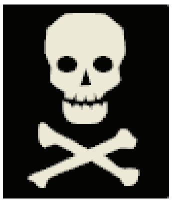

C


D

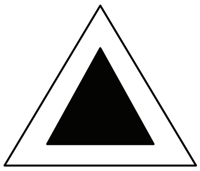
Don't Know
E

22 Danger?


A

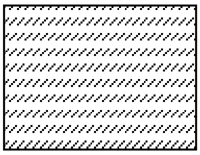

B

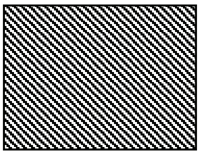

C

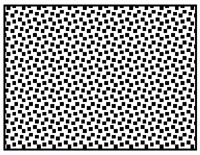

D

Don't Know
E

23 Crops?


A


B


C


D

Don't Know
E

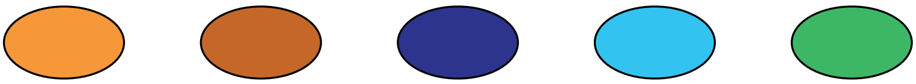
Part 4

Which of the following color alternatives do you find most appropriate and least appropriate for describing the following terms?

24 River?

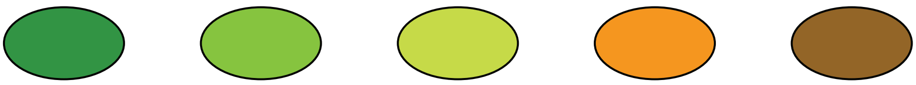
A B C D E Don't Know F

25 Water?



A B C D E Don't Know F

26 Crops?

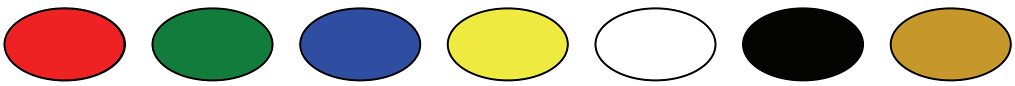


A B C D E Don't Know F

27 Road?

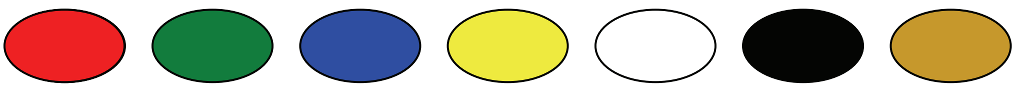
A B C D E Don't Know F

28 Danger?



A B C D E F G Don't Know H

29 Safe?



A B C D E F G Don't Know H

Zimbabwe Standards SAZS 560:1997

Drinking water

Parameters:	Units:	Recommended limit	Maximum allowable limit
Alkalinity	mg/l HCO_3	*	*
Cadmium	mg/l Cd	0,01	0,02
Calcium	mg/l Ca	*	*
Biological Oxygen Demand	mg/l	0,01	0,02
Chemical Oxygen Demand	mg/l	*	*
Chloride	mg/l Cl	200	300
Cobalt	mg/l Co	*	*
Conductivity	uS/cm	700	3000
Copper	mg/l Cu	0,1	2
Dissolved Oxygen	saturation %	*	*
Iron	mg/l Fe	0,3	1
Magnesium	mg/l Mg	*	*
Maganese	mg/l Mn	0,1	1
Nickel	mg/l Ni	*	*
Nitrates	mg/l NO_3	10	50
Nitrite	mg/l NO_2	0,001	3
Oxygen Absorbed (PV)	mg/l	*	*
pH		6.5 - 8.5	6.0 - 9.0
Phosphates	mg/l P	*	*
Potassium	mg/l K	*	*
Sodium	mg/l Na	100	200
Sulphate	mg/l SO_4	200	500
Total dissolved solids	mg/l	*	*
Total Hardness	mg/l TH	20 - 300	500
Total Suspended solids	mg/l	*	*
Turbidity	NTU	1	5
Zinc	mg/l Zn	1	3

Answers from Questionnaire carried out at IDP 25th, 26th and the 28th of April

Q.no	Hint	Respondents no 1	2	3	4	5	6	7
1	Age	D	C	B	D	C	C	C
2	Sex	A	A	B	A	B	A	A
3	Occupation	mine	mine	student	mine	housew	mine	mine
4	Get water?	A	A	A	A	A	A	A
4i	Where?	tapped	tapped	tapped	tapped	tapped	tapped	tapped
5	Animals	B	B	B	A	B	B	B
6	Crops	A	A	A	A	B	A	A
7	Map?	B	A	A	A	A	A	A
8	Orientate	C	A	C	C	B	C	A
9	Where?	NJA	NO	NO	NO	NO	NO	NO
10	Where?	NJA	YES	NJA	NO	NO	YES	YES
11	Gate to IDP?	NO	YES	NJA	-	-	NJA	YES
12	Where?	NO	NO	YES	NO	NO	YES	NO
13	Gate to IDP?	NO	NO	NO	-	-	NO	-
14	Where?	YES	NO	YES	NO	NJA	YES	NO
15	Gate to IDP?	YES	-	YES	NJA	YES	NO	-
16	Easiest?	NO 4	NO 3	NO 2	NO 4	NO 4	NO 2	NO 2
17	Drinking water	A	A	A	A	D	D	A
18	House	C	A	A	B	A	B	A
19	Mine	B	B	B	D	A	B	B
20	Well	C	D	C	A	E	D	E
21	Dam	D	A	A	D	A	D	A
22	Danger	B	B	B	B	B	B	B
23	Crops	A	A	A	A	A	C	E
24	River	A	A	F	C	A	C	C
25	Water	E	F	D	C	A	C	C
26	Crops	A	A	A	A	A	B	A
27	Road	A	B	C	E	A	B	B
28	Danger	A	A	A	A	A	A	A
29	Safe	E	B	E	E	A	B	B
Comments		no English		some English	no English	no English		

Q.no	Hint	Respondents no 8	9	10	11	12	13	14
1	Age	C	C	B	B	B	C	C
2	Sex	A	B	B	B	B	B	B
3	Occupation	mine	housew	housew	housew	housew	housew	housew
4	Get water?	A	A	A	A	A	A	A
4i	Where?	tapped	tapped	tapped	tapped	tapped	tapped	tapped
5	Animals	A	A	A	B	B	A	B
6	Crops	A	A	A	A	A	A	A
7	Map?	B	A	A	A	A	A	A
8	Orientate	A	A	A	C	C	A	C
9	Where?	NO	YES	NJA	YES	NO	NO	NJA
10	Where?	NO	YES	NO	NO	NO	YES	YES
11	Gate to IDP?	-	NJA	-	-	-	YES	NJA
12	Where?	NO	NO	NO	NO	NO	NO	NO
13	Gate to IDP?	-	-	-	-	-	-	-
14	Where?	NO	NO	NO	NO	NO	NO	YES
15	Gate to IDP?	-	-	-	-	-	-	YES
16	Easiest?	NO 4	NO 4	NO 2	NO 2	NO 2	NO 2	NO 4
17	Drinking water	A	A	A	A	A	A	A
18	House	B	B	B	B	B	A	B
19	Mine	D	A	B	B	B	B	D
20	Well	C	C	E	C	E	C	D
21	Dam	A	A	D	A	A	A	A
22	Danger	B	B	B	B	B	B	B
23	Crops	A	A	C	A	E	C	A
24	River	F	F	D	C	F	D	D
25	Water	A	F	A	F	F	D	D
26	Crops	A	A	A	A	A	A	A
27	Road	A	A	B	B	A	C	C
28	Danger	A	A	A	A	A	A	A
29	Safe	E	A	C	E	E	D	E
Comments		no English					map 3 and 4 to small	

		Respondents no						
Q.no	Hint	15	16	17	18	19	20	21
1	Age	B	E	B	C	B	B	B
2	Sex	A	B	B	A	A	A	B
3	Occupation	student	teacher	nothing	mine	student	student	student
4	Get water?	A	A	A	A	A	A	A
4i	Where?	tapped	tapped	tapped	tapped	tapped	tapped	tapped
5	Animals	A	A	B	A	B	B	B
6	Crops	A	A	A	A	A	A	A
7	Map?	A	A	A	A	A	A	A
8	Orientate	C	C	D	A	C	A	A
9	Where?	YES	YES	NO	NO	YES	NO	NO
10	Where?	YES	YES	NO	YES	YES	YES	YES
11	Gate to IDP?	YES	YES	-	YES	NO	YES	NO
12	Where?	NO	NO	NO	YES	YES	YES	YES
13	Gate to IDP?	-	-	-	NO	NO	NO	NO
14	Where?	NO	YES	NO	YES	YES	YES	YES
15	Gate to IDP?	-	YES	-	NO	NO	YES	NJA
16	Easiest?	NO 2	NO 4	NO 2	NO 2	NO 2	NO 4	NO 2
17	Drinking water	A	A	A	B	A	A	A
18	House	C	B	B	A	C	A	B
19	Mine	B	B	B	B	B	B	B
20	Well	E	C	D	C	D	C	C
21	Dam	A	A	A	A	A	A	E
22	Danger	B	B	D	B	B	B	B
23	Crops	C	C	E	E	C	B	C
24	River	C	C	F	B	A	D	C
25	Water	C	C	F	E	A	C	D
26	Crops	A	A	A	A	A	A	B
27	Road	B	B	B	B	B	A	B
28	Danger	A	A	A	A	A	A	A
29	Safe	E	E	E	E	E	E	G
Comments								

		Respondents no						
Q.no	Hint	22	23	24	25	26	27	28
1	Age	C	E	B	C	C	B	B
2	Sex	B	A	B	A	B	B	B
3	Occupation	housew	mine adm	student	teacher	bookkeper	student	housew
4	Get water?	A	A	A	A	A	A	A
4i	Where?	tapped	tapped	tapped	tapped	tapped	tapped	tapped
5	Animals	B	B	B	B	B	B	B
6	Crops	A	A	A	A	A	A	A
7	Map?	A	A	A	A	A	A	A
8	Orientate	A	C	C	C	A	A	A
9	Where?	NO	YES	NO	YES	NO	NO	NO
10	Where?	YES	YES	YES	YES	YES	YES	YES
11	Gate to IDP?	NJA	YES	YES	YES	YES	NO	YES
12	Where?	YES	YES	YES	YES	YES	NO	YES
13	Gate to IDP?	NO	NO	NO	NJA	YES	-	NO
14	Where?	YES	YES	NO	YES	YES	NO	YES
15	Gate to IDP?	NO	NO	-	NO	YES	-	NO
16	Easiest?	NO 2	NO 2	NO 2	NO 2	NO 2	NO 2	NO 2
17	Drinking water	A	A	A	A	A	C	A
18	House	B	C	B	A	A	A	B
19	Mine	D	B	B	B	B	B	B
20	Well	A	A	E	C	D	D	E
21	Dam	A	A	D	D	A	D	A
22	Danger	B	B	B	B	B	B	B
23	Crops	A	A	A	E	A	B	C
24	River	D	D	D	D	D	D	D
25	Water	D	D	D	D	D	D	D
26	Crops	A	A	A	A	A	A	B
27	Road	D	B	B	A	B	A	F
28	Danger	A	A	A	A	A	A	A
29	Safe	E	E	E	D	B	H	G
Comments								

		Respondents no						
Q.no	Hint	29	30	31	32	33	34	35
1	Age	B	C	D	B	D	B	B
2	Sex	B	A	B	B	A	A	A
3	Occupation	housew	teacher	housew	student	mine	student	mine
4	Get water?	A	A	A	A	A	A	A
4i	Where?	tapped	tapped	tapped	tapped	tapped	tapped	tapped
5	Animals	B	B	B	B	B	B	B
6	Crops	A	A	A	A	A	B	A
7	Map?	A	A	B	A	A	A	A
8	Orientate	A	A	A	A	A	C	A
9	Where?	NO	NO	NO	NO	YES	NO	YES
10	Where?	YES	YES	NO	YES	YES	YES	YES
11	Gate to IDP?	NO	YES	-	YES	NO	NO	YES
12	Where?	NO	YES	YES	YES	YES	YES	YES
13	Gate to IDP?	-	NO	NO	NO	NO	NO	NO
14	Where?	NO	YES	YES	YES	YES	YES	YES
15	Gate to IDP?	-	NO	NO	NO	NO	NO	NO
16	Easiest?	NO 2	NO 2	NO 2	NO 2	NO 2	NO 2	NO 2
17	Drinking water	A	A	A	A	A	A	A
18	House	B	A	B	B	A	B	A
19	Mine	B	D	D	D	B	D	B
20	Well	E	D	E	C	E	C	C
21	Dam	E	E	A	D	B	D	A
22	Danger	B	B	A	B	B	B	B
23	Crops	E	A	A	B	A	E	A
24	River	C	D	A	D	B	C	C
25	Water	C	D	A	D	C	D	C
26	Crops	A	A	A	A	A	A	B
27	Road	C	A	A	B	B	B	B
28	Danger	A	A	A	A	A	A	A
29	Safe	H	E	A	E	D	E	E
Comments								

Q.no	Hint	Respondents no 36	37	38	39	40	41	42
1	Age	C	B	C	D	C	C	B
2	Sex	B	B	B	B	B	A	B
3	Occupation	housew	student	housew	housew	housew	mine	student
4	Get water?	A	A	A	A	A	A	A
4i	Where?	tapped	tapped	tapped	tapped	tapped	tapped	tapped
5	Animals	A	B	B	A	B	B	B
6	Crops	A	A	A	A	A	A	A
7	Map?	B	A	A	A	A	A	A
8	Orientate	A	A	C	A	A	A	C
9	Where?	NO	YES	NO	NO	NO	YES	NO
10	Where?	YES	YES	YES	YES	YES	YES	YES
11	Gate to IDP?	NO	NO	NJA	YES	NJA	YES	NO
12	Where?	YES	YES	NO	YES	YES	YES	YES
13	Gate to IDP?	NO	NO	-	NO	NO	YES	NO
14	Where?	YES	YES	NO	YES	NO	YES	YES
15	Gate to IDP?	NO	YES	-	NO	-	YES	NO
16	Easiest?	NO 2	NO 4	NO 2	NO 2	NO 2	NO 4	NO 2
17	Drinking water	D	A	A	A	A	A	A
18	House	B	B	B	A	C	A	A
19	Mine	B	B	B	B	B	B	B
20	Well	C	D	C	D	D	D	D
21	Dam	D	D	D	E	D	A	D
22	Danger	B	B	B	B	B	B	B
23	Crops	A	A	D	A	C	A	A
24	River	D	C	B	B	F	B	B
25	Water	C	C	C	E	D	C	D
26	Crops	A	A	A	A	A	A	A
27	Road	C	B	C	C	A	B	B
28	Danger	A	A	A	A	A	A	A
29	Safe	E	B	E	E	E	B	E
Comments				no English	no English	no English		English

Q.no	Hint	Respondents no 43	44	45	46	47	48	49
1	Age	B	B	C	C	C	D	C
2	Sex	A	A	A	B	B	A	A
3	Occupation	mine	student	mine	housew	housew	mine	mine
4	Get water?	A	A	A	A	A	A	A
4i	Where?	tapped	tapped	tapped	tapped	tapped	tapped	tapped
5	Animals	B	B	B	B	B	B	B
6	Crops	A	A	A	A	A	A	A
7	Map?	A	A	A	A	B	A	A
8	Orientate	A	D	A	A	A	C	A
9	Where?	YES	YES	NO	NO	YES	YES	YES
10	Where?	YES	YES	YES	YES	NO	YES	YES
11	Gate to IDP?	YES	NO	YES	NO	YES	YES	YES
12	Where?	YES	YES	YES	YES	NO	YES	YES
13	Gate to IDP?	NO	NO	NO	NO	-	YES	YES
14	Where?	YES	YES	YES	YES	NO	YES	YES
15	Gate to IDP?	YES	NO	NO	NO	-	YES	YES
16	Easiest?	NO 4	NO 2	NO 4	NO 2	NO 1	NO 2	NO 2
17	Drinking water	A	A	A	A	A	B	A
18	House	B	A	A	C	A	A	A
19	Mine	B	D	B	D	B	D	A
20	Well	E	C	A	E	C	C	A
21	Dam	A	A	A	E	E	A	A
22	Danger	B	A	B	B	B	B	B
23	Crops	A	A	A	C	E	A	A
24	River	A	B	D	D	B	D	A
25	Water	A	A	E	D	B	E	A
26	Crops	A	A	A	A	A	A	D
27	Road	B	A	D	F	C	B	A
28	Danger	A	A	A	A	A	D	A
29	Safe	E	B	B	E	B	E	B
Comments							English	

Q.no	Hint	Respondents no 50
1	Age	D
2	Sex	A
3	Occupation	mine
4	Get water?	A
4i	Where?	tapped
5	Animals	B
6	Crops	A
7	Map?	A
8	Orientate	A
9	Where?	NO
10	Where?	YES
11	Gate to IDP?	YES
12	Where?	YES
13	Gate to IDP?	NO
14	Where?	YES
15	Gate to IDP?	YES
16	Easiest?	NO 2
17	Drinking water	A
18	House	B
19	Mine	B
20	Well	B
21	Dam	D
22	Danger	B
23	Crops	A
24	River	A
25	Water	E
26	Crops	A
27	Road	A
28	Danger	A
29	Safe	D
Comments		

Frequency Table form answer alternatives generated from SPSS

1 Age

		Frequency	Percent	Valid Percent
Valid	10-25 years	18	36,0	36,0
	25-40 years	22	44,0	44,0
	40-55 years	8	16,0	16,0
	over 55 years	2	4,0	4,0
	Total	50	100,0	100,0

2 Sex

		Frequency	Percent	Valid Percent
Valid	male	23	46,0	46,0
	female	27	54,0	54,0
	Total	50	100,0	100,0

3 Occupation

		Frequency	Percent	Valid Percent
Valid	bookkeep	1	2,0	2,0
	housew	17	34,0	34,0
	mine	15	30,0	30,0
	mine adm	1	2,0	2,0
	nothing	1	2,0	2,0
	student	12	24,0	24,0
	teacher	3	6,0	6,0
	Total	50	100,0	100,0

4 Drinking water

		Frequency	Percent	Valid Percent
Valid	yes	50	100,0	100,0

5 Farming Animals

		Frequency	Percent	Valid Percent
Valid	yes	10	20,0	20,0
	no	40	80,0	80,0
	Total	50	100,0	100,0

6 Crops

		Frequency	Percent	Valid Percent
Valid	yes	48	96,0	96,0
	no	2	4,0	4,0
	Total	50	100,0	100,0

7 Seen a map before

		Frequency	Percent	Valid Percent
Valid	yes	45	90,0	90,0
	no	5	10,0	10,0
	Total	50	100,0	100,0

8 Orientate and recognize in the terrain

		Frequency	Percent	Valid Percent
Valid	River , trees, buildings, roads etc	30	60,0	60,0
	Sun, stars, moon	1	2,0	2,0
	Mountains, fields, valleys	17	34,0	34,0
	Don't orientate	2	4,0	4,0
	Total	50	100,0	100,0

9 Where? Simple map without labels

		Frequency	Percent	Valid Percent
Valid	yes	16	32,0	32,0
	nja	3	6,0	6,0
	no	31	62,0	62,0
	Total	50	100,0	100,0

10 Where? Simple map with labels

		Frequency	Percent	Valid Percent
Valid	yes	39	78,0	78,0
	nja	2	4,0	4,0
	no	9	18,0	18,0
	Total	50	100,0	100,0

11 Find gate to IDP on map?

		Frequency	Percent	Valid Percent
Valid	yes	23	46,0	54,8
	nja	7	14,0	16,7
	no	12	24,0	28,6
	Total	42	84,0	100,0
Missing	9	8	16,0	
Total		50	100,0	

12 Where? Topographic map

		Frequency	Percent	Valid Percent
Valid	yes	31	62,0	62,0
	no	19	38,0	38,0
	Total	50	100,0	100,0

13 Find gate to IDP on map?

		Frequency	Percent	Valid Percent
Valid	yes	4	8,0	12,1
	nja	1	2,0	3,0
	no	28	56,0	84,8
	Total	33	66,0	100,0
Missing	9	17	34,0	
Total		50	100,0	

14 Where? Topographic map with emphasize

		Frequency	Percent	Valid Percent
Valid	yes	32	64,0	64,0
	nja	1	2,0	2,0
	no	17	34,0	34,0
	Total	50	100,0	100,0

15 Find gate to IDP on map?

		Frequency	Percent	Valid Percent
Valid	yes	13	26,0	38,2
	nja	2	4,0	5,9
	no	19	38,0	55,9
	Total	34	68,0	100,0
Missing	9	16	32,0	
Total		50	100,0	

16 Easiest to interpret

		Frequency	Percent	Valid Percent
Valid	map no 1	1	2,0	2,0
	map no 2	36	72,0	72,0
	map no 3	1	2,0	2,0
	map no 4	12	24,0	24,0
	Total	50	100,0	100,0

17 Drinking water symbol

		Frequency	Percent	Valid Percent
Valid	a	44	88,0	88,0
	b	2	4,0	4,0
	c	1	2,0	2,0
	d	3	6,0	6,0
	Total	50	100,0	100,0

18 House symbol

		Frequency	Percent	Valid Percent
Valid	a	21	42,0	42,0
	b	23	46,0	46,0
	c	6	12,0	12,0
	Total	50	100,0	100,0

19 Mine symbol

		Frequency	Percent	Valid Percent
Valid	a	3	6,0	6,0
	b	36	72,0	72,0
	d	11	22,0	22,0
	Total	50	100,0	100,0

20 Well symbol

		Frequency	Percent	Valid Percent
Valid	a	5	10,0	10,0
	b	1	2,0	2,0
	c	19	38,0	38,0
	d	13	26,0	26,0
	e	12	24,0	24,0
	Total	50	100,0	100,0

21 Dam symbol

		Frequency	Percent	Valid Percent
Valid	a	28	56,0	56,0
	b	1	2,0	2,0
	d	15	30,0	30,0
	e	6	12,0	12,0
	Total	50	100,0	100,0

22 Danger symbol

		Frequency	Percent	Valid Percent
Valid	a	2	4,0	4,0
	b	47	94,0	94,0
	d	1	2,0	2,0
	Total	50	100,0	100,0

23 Crops symbol

		Frequency	Percent	Valid Percent
Valid	a	28	56,0	56,0
	b	3	6,0	6,0
	c	10	20,0	20,0
	d	1	2,0	2,0
	e	8	16,0	16,0
	Total	50	100,0	100,0

24 River color

		Frequency	Percent	Valid Percent
Valid	a	8	16,0	16,0
	b	8	16,0	16,0
	c	11	22,0	22,0
	d	17	34,0	34,0
	f	6	12,0	12,0
	Total	50	100,0	100,0

25 Water color

		Frequency	Percent	Valid Percent
Valid	a	8	16,0	16,0
	b	1	2,0	2,0
	c	13	26,0	26,0
	d	17	34,0	34,0
	e	6	12,0	12,0
	f	5	10,0	10,0
	Total	50	100,0	100,0

26 Crops color

		Frequency	Percent	Valid Percent
Valid	a	45	90,0	90,0
	b	4	8,0	8,0
	d	1	2,0	2,0
	Total	50	100,0	100,0

27 Road color

		Frequency	Percent	Valid Percent
Valid	a	14	28,0	28,0
	b	23	46,0	46,0
	c	8	16,0	16,0
	d	2	4,0	4,0
	e	1	2,0	2,0
	f	2	4,0	4,0
	Total	50	100,0	100,0

28 Danger color

		Frequency	Percent	Valid Percent
Valid	a	49	98,0	98,0
	d	1	2,0	2,0
	Total	50	100,0	100,0

29 Safe color

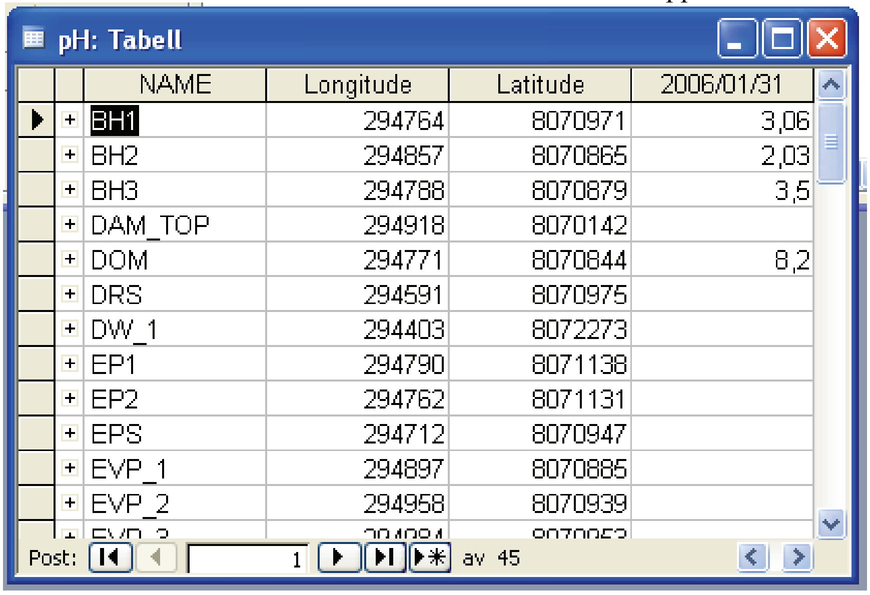
		Frequency	Percent	Valid Percent
Valid	a	3	6,0	6,0
	b	10	20,0	20,0
	c	1	2,0	2,0
	d	6	12,0	12,0
	e	26	52,0	52,0
	g	2	4,0	4,0
	h	2	4,0	4,0
	Total	50	100,0	100,0

How to use Microsoft Office Access
-for storage of pH, temperature, conductivity etc. values-

1 Open Microsoft Office Access
Start → All Programs → Microsoft Office → Microsoft Office Access 2003

2 Open the database and files
File → Open. Find the local place where the files are stored. Double-click on IDP

3 Find the correct table
Double-click on the icon for wanted table. A table will appear like this:


pH: Tabell

NAME	Longitude	Latitude	2006/01/31
BH1	294764	8070971	3,06
BH2	294857	8070865	2,03
BH3	294788	8070879	3,5
DAM_TOP	294918	8070142	
DOM	294771	8070844	8,2
DRS	294591	8070975	
DW_1	294403	8072273	
EP1	294790	8071138	
EP2	294762	8071131	
EPS	294712	8070947	
EVP_1	294897	8070885	
EVP_2	294958	8070939	

Post: 1 av 45

4 Add a new column for new measurement values
View → Design View. In the end of the list, add Field Name, Data Type and Description (Optional).

Field Name is the date the measurement is taken written in different forms depending on values.
Values from measurements at one particular day are given as:
YYYY/MM/DD
Ex: 2006/03/21
Values of average calculation form one month is given as:
MonthYear
Ex: February2006

DataType is Number

Description is optional, comments and special conditions can be added there.

5 Add measurement data
View → Datasheet View. Find the new column. Add the new data in correct row according to sample point name.

6 Save data
When finished, all data must be saved.
File → Save.

Do not change any data in the columns of Longitude or Latitude. If one wants to add a new name for a new sample point, go to the bottom of the list, and add the new name in the column of NAME.

Made by Merete Sørjoten

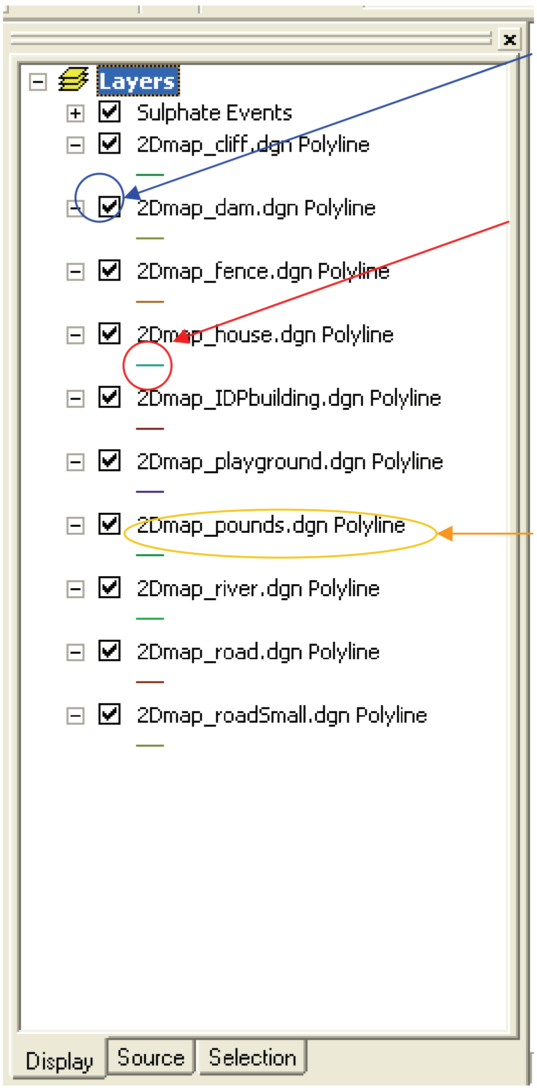
How to use ArcMap for adjustments of maps.

With available map basis stored in a mixed file for ArcMap

1 Open a mixed file that is used as a basis where all data are imported and stored
When ArcMap – ArcView is opened, a window appears. Chose to open *an existing map*. Browse for the mix-file if it is not listed in the white frame.

2 Choosing layers and appearance of the map
All layers available is listed in the left side. One can choose to show the list of layers as *Display*, *Source* of *Selections*. It is optional what view to choose, but *Display* indicates how each layer is displayed. The right side shows the map.

Before one starts to manipulate the map, it may be a good idea to save the result with a different name, so that one does not destroy or removes something from the basis file. File → Save As. Choose an appropriate name for the resulting map.



Choosing layers to be displayed
Press the v on or off for each layer, you will se the layer disappears or appears on the map.

Change the appearance of a layer
Double click on the figure that indicates the layer. A new window will pop up.
One can choose from a predefined list displayed on the right in the window, or modify the existing one with different colours and weight.
Clicking *Properties* gives more alternatives.

Changing names of a layer
Click on the name you want to change. Click one more time, and you can change the name to a more intuitive name.

Remove a layer from the list
Click on the name of the layer you want to remove. Right click on your mouse. Chose *Remove*.

3 Add a layer to the map

File → Add data. Browse to the .dng file or shape file you want to add, and press *Add.* For .dng-files, you must choose the file with a light blue icon. Many new layers will appear in the layer display. You can remove all layers that are not used in the map for the feature.

One has to assign a coordinate system to the new layer.
Tools → ArcCatalog. Find the new layer, right click with your mouse and choose *Properties*. *Projection* will be *undefined.* Choose *Edit*. For the window of *Coordinate System*, choose *Select.* Browse to find wanted coordinate system:
Projected Coordinate System → Utm → Wgs 1984 → WGS 1984 UTM Zone 36S.prj. Click *Add.* Check that it is chosen and click *OK* in the *Properties of Spatial References* window. And *OK* in the *CAD features Dataset Properties* window.
Close ArcCatalog.

4 Add data from the database (Microsoft Office Access) to the map

Tools → Add XY Data. Browse to the wanted database and table. The X and Y fields must be specified, *X Field* should be LONGITUDE and *Y Field* should be LATITUDE. The coordinate system must be defined. Choose *Edit*. For the window of *Coordinate System*, choose *Select.* Browse to find wanted coordinate system:
Projected Coordinate System → Utm → Wgs 1984 → WGS 1984 UTM Zone 36S.prj. Click *OK*. And *OK* in the *Add XY Data* window.

A new layer will appear. One can choose to display quantitative data or other and give different appearance to different values. Right click on the name of the layer, choose *Properties*. Choose the tabulator *Symbology*. You can choose different value field from the table and many possibilities for display are available.

If you have come this fare, you are an advanced user of ArcMap. I suggest you to try different opportunities and explore the possibilities. It is difficult to give a recipe because of the diversity, but most answers can be fond in *Help* or on the Internet ☺

5 Export the map and add features like Legend and Title

View → Layout View. The layout of your map will be displayed on the left. From *Insert,* you can choose to add *Legend, Title, Scale Bar etc.*

Made by Merete Sørjoten