Ground Movement as a Result of Dewatering in the Far West Rand Area of Johannesburg Resulting in the Formation of Sinkholes and Dolines

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Abstract—The discovery of gold at Langlaagte led to the development of gold mining in the Far West Rand in 1934. When the mines cease operating, re-watering of the dolomitic compartments will occur as a natural consequence. When water comes to within six metres of the roof of the aquifer, ground instability which will result in the formation of dolines and sinkholes will occur. This will threaten the rail link between Pretoria and Cape Town, as well as the N12 between Johannesburg and Potchefstroom, and also the R28 to the Vaal Industrial area. Dewatering caused the soil which formed the roof of the aquifers to dry. Re-watering will cause this dry, stable roof to become wet and unstable as it already happened in the past when mines were not coping with water abstraction during rainy seasons. If re-watering is not carefully managed the rising water table will undoubtedly trigger sinkholes, with catastrophic consequences.

Keywords—Far West Rand, Gold Mining, Levelling Sinkholes.

I. INTRODUCTION

Gold was discovered in the Witwatersrand in 1886 which resulted in considerable interest in the area and its surroundings. The Pullinger brothers carried out prospecting on the farms Gemsbokfontein, Libanon and Venterspost, and the results let to the sinking a shaft on Gemsbokfontein. At a depth of approximately 29 metres, dolomite was intercepted and the shaft was abandoned due to the large volumes of water encountered. (Enslin, 1956). Mines had to develop a strategy of getting rid of the water in order to mine safely but this came with its own challenges.

The mines had government support because they provided government with much needed revenue to support their infrastructure developments. Dealing with underground water for the mines was like dealing with waste which was to be disposed off in whichever convenient way they saw fit. The abstraction of water created the development of dolines and sinkholes with negative effects to infrastructure and properties in the Westonaria and Merafong municipalities.

II. AREA COVERED

The dolomitic area of the FWR extends from the Zuurbekom compartment in the east, to Welverdiend in the west, approximately fifty-five kilometers from Potchefstroom in the west along the Wonderfonteinspruit. (Figure 1). This figure also shows important infrastructure, such as the Railway line which connects Pretoria and Cape Town, the N12 from Witbank through to Cape Town, the R28 from Pretoria through to the Vaal Triangle and the 1 metre pipe line which is used to carry the Wonderfontein Spruit water over the Venterspost, Bank and Oberholzer compartments to Turffontein compartment in order to avoid recirculation of the water. The municipalities of Merafong and Westonaria are also located within this area.

The area is divided into a number of ground water compartments by watertight syenite dykes, which intruded the sediments along tension faults, generally striking in a north-south direction. The large quantities of water were stored in these aquifers, which have been found to extend to depths of 200 metres below the dolomite. The ground water compartments vary in area/size from a few square kilometers to more than 400 kilometers. (Enslin, 1951).
III. WESTONARIA MUNICIPALITY AND THE INFRASTRUCTURE IN THE AREA

The potential hazard of ground instability which could take place when re-watering takes place on the dolomitic compartments of the Far West Rand has always been a subject of debate. To support what could happen, reference is made to events that took place between 1975 and 1978. Far West Rand which had an above average rainfall during summer months with up to 3 500 MI/day some days caused Donaldson Dam to overflow. (Swart, et al., 2002). When this happened, the overflowing water got into the Wonderfontein Spruit and eventually into the dewatered Venterspost compartment through sinkholes. As a result, the water level of the Venterspost Compartment rose rapidly leading to the re-activation of old sinkholes and the formation of new ones in the area known as the “sinkhole farm”. Not much alarm was raised as this area was owned by the Venterspost Gold Mine.

According to some reports, before this occurrence this part of the Venterspost compartment had been stable for a period of 30 years (Swart, et al., 2002). Surveyors were brought in to monitor the surface in the Westonaria town and they found that there was an increase of 20% in the occurrence of subsidences and sinkholes. Experts who worked on this area at the time warned that development should not be allowed to take place on this area even after the area has stabilized. In order to avoid loss of life and property, the FWRDWA negotiated with the private land owners and purchased a number of properties in this compartment, in extent 5 349, 2657 hectares.

Rainfall weakens the already poor rock strata of the caverns, increasing the rate of sinkhole formation. The link between rainfall and the formation of sinkholes has been established beyond doubt. Thus, if rainfall during a certain period is heavier than normal, the likelihood of more sinkholes and dolines forming is increased. Five sinkholes which appeared during the 1966 and 1967 heavy rainfall in the Venterspost area were all attributed to this phenomenon. Municipalities generate their own cash-flow through rates and taxes. However, the town of Westonaria could not increase its taxes. However, the town of Westonaria could not increase its tax base because growth restrictions were placed on the municipality by the unsafe conditions on the surface. This became evident in 1970, when a group of investors who bought land from the council for the development of an airport was made expensive by the SCTC, when the committee placed a number of conditions for the safe development of this project. The project failed as a result. People were nervous to reside and invest in Westonaria. Due to the danger posed by sinkholes, the town could only expand in an easterly direction.

IV. MERAFOG MUNICIPALITY AND THE INFRASTRUCTURE IN THE AREA

In the mid-1950s, the Carletonville/ Blyvooruitzicht area experienced a series of sinkholes. Gravity and geophysical surveys were preferred because it was faster and the results could quickly be confirmed by borehole drilling on a suspect area. Gravity survey stations were laid out over an area extending approximately 150m South and 250m North of the P111 road, from Carletonville to Potchefstroom over a distance of 4km. About 2 500 magnetometer readings were taken and the profile of the vertical magnetic force in gammas was used to produce the plotting which gave an indication of which areas were more dangerous than others.

The P111/1 is the road that joins the towns of Westonaria, Carletonville and Potchefstroom. Unfortunately the Driefontein, Blyvooruitzicht and Doornfontein mines constructed their slimes dams along this road. (See figure 2). From the early days of mining and the construction of slimes dams along this road, signs of cracks, subsidences and sinkholes where noticed on and also along the sides of the road close to the Blyvooruitzicht slimes dams from as early as 1964. (Fison, 1965). The road was repaired and re-opened after levelling.

Movement on this road was again noticed on the side of Blyvooruitzicht mine in the form of cracks in May of 1980. The possible cause of the movement was slime rushing into a sinkhole close to both the road and the slimes dam. Monitoring in the form of levelling was carried out regularly in the area and within the first fourteen days a downward movement of 15mm was observed. In order to determine the geological formation underneath the road, a number of boreholes were drilled on both sides of the road. Eight of the ten boreholes drilled intersected cavities and in order to make the road stable a decision was taken to pump slime into the cavities. (See the accompanying figures 3 and 4 for the positions of levelling stations and borehole positions.) (Swart, 1980). In order to make sure that the mixture of cement and slime deposited through boreholes into cavities intersected would not be washed away after rainy seasons of the following years, more boreholes were drilled to establish if cavities were intersected and they were completely filled with the slime and cement mixture.

Gravity surveys later suggested that certain areas would be free from the possible occurrence of sinkholes. This area is defined by the relatively low gravity values, due to the combined total gravity effect of a thick cover of chert, rubble and soil. This area is marked on the plan as “safe”. The second area on the plan is marked as dangerous and should be regarded as an area where sinkholes may possibly occur. All the steep gravity gradients fall in this area, as well as areas of relatively high gravity values. The third area is marked as doubtful. In this area, the thickness of overburden on dolomite is unknown and may be anything from 6m to 20m. Wherever the suggested deviations traverse this area or the dangerous area, boreholes were to be drilled to confirm the underground conditions.

The levelling by FWRDWA on critical areas such as the P111, continued even after the bulk of dewatering was completed. At that stage nobody knew what would happen when the water was removed. For that reason monitoring through leveling continued so that any future movement could be noticed. Leveling in the Far West Rand is still carried out
today. Leveling results on the loops surveyed, (Loop 1A, 1B and 1C) show very slight movements on Loop 1A. Twenty five pegs have been established on this section of the road and levelling observations are carried out quarterly to see how this differs from the previous quarter. Different Loops leveled are shown on the plan below. (Fig 5) The road is fairly stable with the biggest progressive elevation difference obtained being nine millimeters. (Oosthuizen, 2012).

Figure 5 below show parts of the P111 road which is being monitored because of its previous history of continued subsidence and sinkholes. The continued instability along this road is brought about by slimes dams built in close proximity to the road. Large amounts of slime have been deposited in sinkholes which developed in the slimes dam areas until no more could be absorbed. The water table has dropped, possibly the slime has solidified, hence the stability that is observed along the road surveyed. (Erasmus, 2012).

The risk of sinkholes is also increased by urban development which can interrupt the natural surface drainage by preventing storm water from flowing naturally and accumulating in unwanted ponds, as well as leakage from water bearing utilities which results in concentrated ingress of water into the ground. Carletonville was initially managed by the operating mines in the area because their employees stayed
in this town. For this reason and for the safety of the occupants of the town, the mines maintained the infrastructure in the town. This helped to minimize the formation of sinkholes. Proper drainage facilities and proper road infrastructure were provided and maintained by the mines. A further assistance to the town of Carletonville keeping it free of sinkholes is the fact that the town has been built on a chert poor zone, which is not sinkhole friendly. (Erasmus, 2012)

4. South African Railway Line on the Bank Compartment

An intensive study was carried out in the Bank Compartment particularly the area around the Bank Station and the Bank Village. Gravimetric surveying was done first because it was cheaper. The gravimetric survey done incorporated 847 gravimeter readings along the Randfontein line and 1 255 readings along the Westonaria line. The gravity maps compiled from those readings assisted in selecting sites for drilling purposes.

Further precautions were taken by carrying out levelling surveying along the railway lines as well as the areas occupied by the Bank Station and Bank Village. The results were plotted to show contours of movement over six monthly periods. In addition graphs were maintained, which illustrated the rate of movement per unit of time over unstable areas. In this way 1 041 control points were regularly measured as follows:-

Bank Station and Bank Village = 756 points
Randfontein line = 109 points
Westonaria line = 176 points
Total = 1 041 points

Surface monitoring by levelling established that a serious surface subsidence of up to 3m had occurred near the Bank Station. This justified the decision by the SCTC to vacate most of the people residing on the Bank Compartment. At the same time, precise levelling was carried out and the graphical records of settlement, or movement versus time of selected points along the railway lines and the Bank Station area were plotted and monitored for movement. (Cable, 1978)

As a result of the intensive investigations the vulnerable stretch of the railway line and the parallel P89/1 road from the Bank Station to the Oberholzer Station in Carletonville was identified. The road together with the railway line has been reinforced several times by grouting in the past. The assumption made is that since this grout mixture is not the same composition as the rock formations in the area, it could dissolve due to the rising water levels resulting in the reactivation of sinkholes old and new

V. Conclusions and Recommendations

The Far West Rand Dolomitic Water Association and the State Coordinating Technical Committee, two committees which were formed by agreement between the state and the mining industry, should be given the responsibility to collate information on sinkholes and subsidence, together with water quality and or recharge of the dolomitic compartments. A data base of this information should be established and dedicated people should be appointed to manage the system. Most of this information is there already, the problem is it is not readily available.

It is suggested that one of the first issues that need to be addressed is the formulation of a uniform “re-watering” policy that will apply to all mines on the Far West Rand. Presently, the wealth of data and information, much of it unique and irreplaceable, lies sterile in the files of the SCTC archive. Most of the questions being posed at present have cropped up and may have been fully addressed. Researching the history of the SCTC would prevent duplication.

Given the situation that the consequences of re-watering may only occur when the water tables reach their original levels, some 30 to 50 years after the last mine stop operating, the members of the FWRDWA will no longer be in existence, despite the rules that may apply. It would be prudent to plan for this eventuality via the establishment of a Trust Fund recommended by the Jordaan Committee in 1960, to cover the anticipated eventualities.

The unique advantage of the SCTC lies in the scientific archive and documented history of dewatering. A thorough understanding of the dolomite dewatering process will be invaluable in anticipating and solving future problems. It is considered important that the areas sensitive to ground movement should be identified and demarcated. Continue vigilance in this respect will save many lives in the future.

In order to minimize or take away the dependence of farmers from the mines during the dewatering phase, also to reduce the thread of loosing life due to the formation of sinkholes, mines bought all land which was considered unsafe. Tax concessions were made between the mining industry and government then. Possibly this land should not be sold by the mines, it should be given back to government to distribute to municipalities.

The closure and subsequent flooding of mines will necessitate the investigation into the rate at which the mines would flood if pumping ceases. The groundwater table recovery within the dolomite aquifer is equally important as it is believed to govern ground stability and may introduce a spate of sinkhole occurrence. What will happen when the groundwater table recovers is still matter of debate as there has never been a conclusive agreement as to how the influence will be once it happens. It is therefore important to establish a monitoring programme during the recovery period.

It is considered that levelling is a FWRDWA obligation and that the FWRDWA must produce regular reports to the SCTC and to the standard required by the SCTC. In this connection an audit is required of the historic areas of ground movement and what the present status of the area is. It would appear that no levelling of the railway lines takes place. Given the fact that according to the Chairman of the FWRDWA, ingress into two unsealed boreholes were responsible for the near catastrophic disaster involving passenger train No. 9146 on the evening of the 9th April 1975 between the Oberholzer and Bank Stations, it would amount to gross negligence if this present situation was allowed to persist. The enormity of the problem should not be underestimated as, depending on which source of information one accepts, there are between 12 000
and 20 000 boreholes in the area and any one, or two of them if unsealed, may be contributing to the formation of a sinkhole.

The effect damages the confidence in these towns which in turn has a negative influence in the development of the towns. It is government responsibility to ensure that the land on which the public lives is safe and they can live without fear of injury or loss of life. To this end government must make sure that a piece of land sold or rented out is free of cave-ins or any other problem that can be ascribed to geological composition of the land. To safeguard themselves against claims by the public, these towns instituted a variety of precautionary measures which are not business friendly because it take a long time to approve the sale of a piece of ground to investors.

REFERENCES