IMPLEMENTING AN EFFICIENT MINE WATER MONITORING AND MANAGEMENT PROGRAM: KEY CONSIDERATIONS

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ABSTRACT

South Africa is not only exposed to water shortages in many parts of the country, but, of more significance, is the increase in water pollution (acidic and saline), from diffuse and point sources, rendering this valuable resource even scarcer. The mining and industrial sectors require a vast amount of water for their operations. Water utilised in the mining sector subsequently gets stored in impoundments in the form of raw water, process water, tailings, slimes, pollution control dams and other process related facilities. Some of the water may also be recycled so as to minimise the consumption of water. In some cases there is discharge of process or excess plant water via pipes or canals to nearby water bodies, by mining companies. The mining footprints undoubtedly impact on water sources whether it is surface or groundwater. Surface water, groundwater and discharged water, in close and immediate vicinity of mines, need to be monitored in order to quantify and characterise the impact the mining activity has on the immediate and greater catchment environment and the subsequent ecosystem. These monitoring programs are of vital importance as they not only provide baseline information on the state of the environment before, during and after the operation of mines, but the information can also be used as a modelling tool. These modelling tools allow the detection and prediction of potential pollution plumes and enable the monitoring of rehabilitation activities, the efficiency of implemented integrated water and waste management plans, and the quantification and identification of point and diffuse pollutant sources. This approach creates a solid foundation for implementing the principles of environmental management concerning integrated water pollution management. This manuscript focuses on the integrated development of surface water monitoring and management programs together with the incorporation of the applicable best practice guidelines for mining activities (as published by the Department of Water Affairs and Forestry (2006)), illustrating the key aspects in formulating an efficient integrated surface water monitoring program pertaining to the importance, role and implementation of such programs in mine water quality management.

KEYWORDS

Water shortages, pollution, mining, industrial, impoundments, discharge, surface water, groundwater, impact, ecosystem, monitoring programs, management.

1. INTRODUCTION

Aquatic systems are currently threatened on a global scale by a variety of contaminants, a multitude of water management practices and destructive land uses. It has also been shown that water with a high quality (drinking water quality), are a critical component for sustainable socio-economic development (Bartram and Balance, 1996). In South Africa, with a pending water crisis on our doorstep, ensuring good water quality is vital in terms of sustainable development.

The behaviour of contaminants in an aquatic ecosystem is complex and can involve precipitation, solubilisation, biological uptake, adsorption-desorption, excretion and sedimentation and then re suspension (Bartram and Balance, 1996). Apart from the natural processes that impact on water quality, there are also a multitude of anthropogenic impacts, such as man induced point and diffuse sources, xenobiotics, alteration of water quality due to water use and river engineering projects (Chapman, 1996) and also various land uses that detrimentally impact on water quality at a micro and macro level in the catchment. A catchment, however, refers to the area from which rainfall will drain into a watercourse or watercourses or part of a watercourse through surface flow to a common point or points (DWAF, 2006).

The degradation of water sources have increased the need to determine the baseline quality status of water sources, so that an indication of changes can be provided which will subsequently indicate induced anthropogenic activities. Water quality monitoring thus refers to the acquisition of representative and quantitative information on the chemical, physical and biological characteristics of a water body in time and space (Sanders et al 1983). In order to understand the process dynamics of a catchment area, a well designed water quality monitoring program needs to be implemented. The program should be able to identify water quality problems, along with the points of origin of pollution, whilst establishing baseline values for short and long term trend analysis (Strobl & Robillard, 2008).

When considering the establishment of a water monitoring program, an integrated approach is necessary and the following must be considered: the nature of the catchment area, the nature of the mining operations (for which a monitoring system may need to be devised) and the objectives and functions of the system. The design for the water monitoring program then needs then to be drawn up and the applicable quality assurances incorporated. Once implemented, the program needs to be audited on an on-going basis and any changes implemented (pertaining to changes taking place in the catchment or mining operations functions). The monitoring program design should take into account the best practice guideline: G3 (Water Monitoring Systems) of DWAF (2006), and incorporates the design aspects into the integrated water monitoring design approach.

This paper mainly focuses on water quality program design applicable for surface water, however, the suggested monitoring program design key considerations can be extrapolated for groundwater monitoring programmes.

2. INTEGRATED WATER MONITORING SYSTEM AND PROGRAM DESIGN APPROACH: KEY CONSIDERATIONS

Best Practice Guidelines: Management Actions

Accurate and reliable data forms an integral component of many environmental management actions (DWAF, 2006) and is also applicable to water monitoring programs. If monitoring is not performed correctly or errors are contained within the monitoring program, sample analysis will not be representative of the actual situation and will result in an indiscriminate wastage of finances, manpower and time. An efficient water monitoring program, yielding reliable and representative results, not only assist mines in their operational planning, in monitoring the impact of mining operations and activities on surface water, in establishing origins of pollution sources, and in monitoring rehabilitation activities, amongst others, but also forms part of the legal requirements for integrated water use licenses and environmental management plans and allows conformance with other regulations and subsequent environmental best practice.

As per DWAF (2006), the most common environmental management actions require data and thus the objectives of water monitoring include:

1. Development of environmental and water management plans based on incident and impact monitoring which facilitates decision making, and serves as an early warning system to allow remedial measures and subsequent actions to be taken for the mine and region.
2. Generation of baseline / background data before the project implementation phase.
3. Identifying the sources of pollution and the extent thereof, which constitutes legal implications or liabilities associated with risks of contamination, moving off site from the current mining operations or activities.
4. Monitoring of water usage (including downstream and upstream) by various users. This also implies costs in usage of water and water reuse activities and potentials.
5. Verification and calibration of various prediction and assessment models. This includes planning for decommissioning and closure pertaining to financial provisions and required actions.
6. Design and identification and also the monitoring of appropriate water treatment technology.
7. Control of unit processes such as process plants and water treatment plants.
8. Auditing and evaluation of the success of implemented management actions such as ISO 14001 and compliance monitoring.
9. Assessment of compliance with set standards and legislation such as Integrated Water Use licenses, Environmental Management Plans, etc.
10. Assessment of the impacts of the mining operation and activities on the receiving water environment.

The water quality monitoring system should therefore be designed so as to allow for remedial action and for sustainable water management. It generally involves a vast number of key activities.

The Integrated Water Monitoring System and Program Design Approach

An integrated water monitoring program should include firstly an overview of the general catchment area and the mining operations; the design of the monitoring system (calibrated for specific site conditions); the procedures for the sampling protocol, sample preservation and handling; as well as the analytical methods used (including field instrument testing procedures), including quality control measures. Quality assurance ensures that the final product meets the needs of its users and guarantees the compatibility of results from different sampling sites as well as the reproducibility of data collected by different observers (Cline & Burkman, 1989).

Figure 1 illustrates the key considerations for purposes of formulating and implementing an integrated surface water monitoring program. Appendix A - D illustrate the key considerations of each section of the integrated surface water monitoring program (Figure 1).

Before designing a monitoring program the nature of the catchment area, in which the mining operation is situated in, needs to be taken into account. This not only impacts on the baseline water quality of surface water networks but also impacts on the design and applicability of the monitoring program (Appendix A).

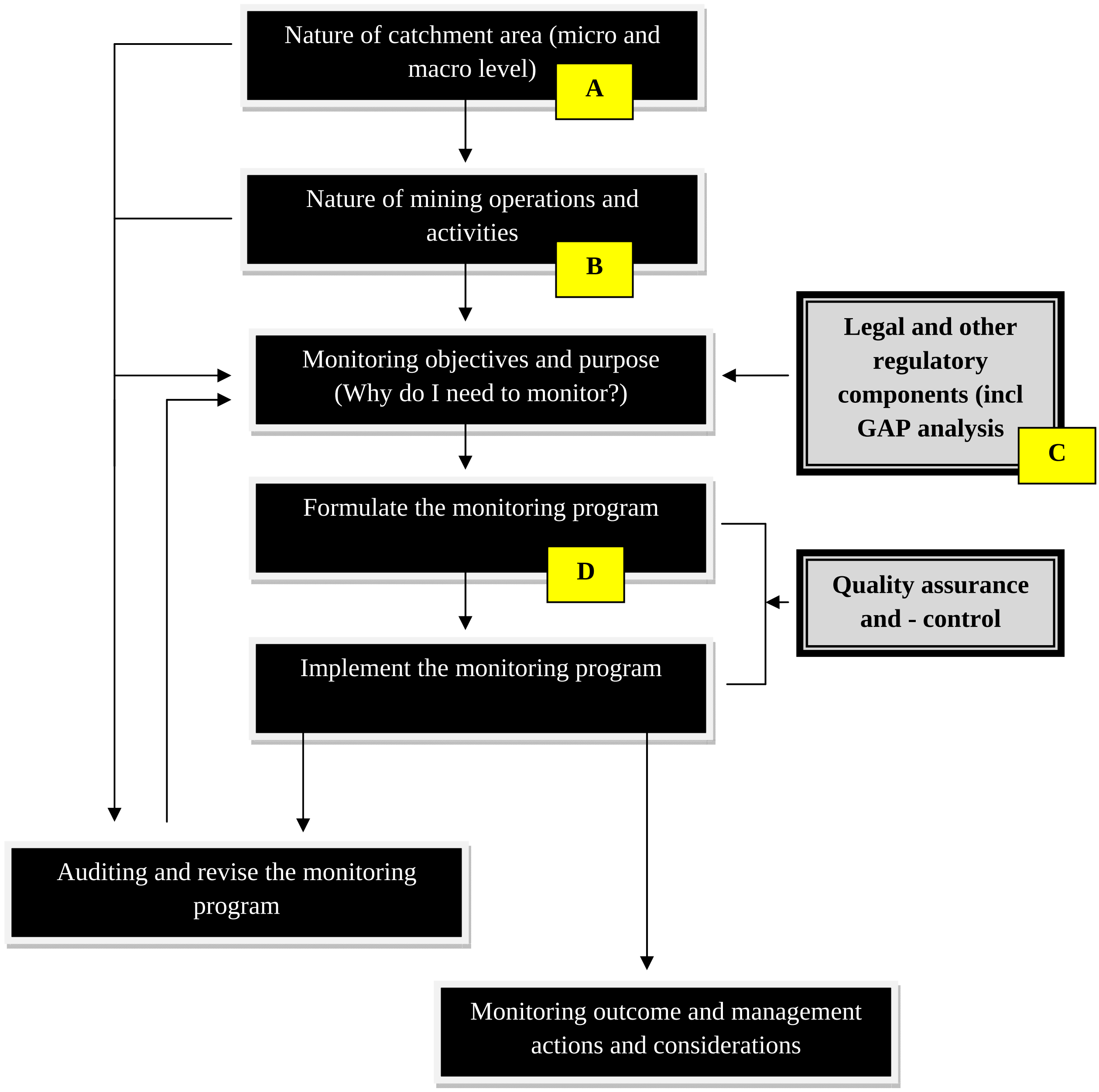

Figure 1: Key steps in formulating and integrated water monitoring program

(See Appendix A-D)

The nature of the mining operations / activities need to be identified so as to understand the various points of potential diffuse and point pollution sources that may arise (Appendix B). The identification of the nature of the mining operation / activities - together with the nature of the catchment area in which the mine is situated in - assists in developing the monitoring program e.g. where to site monitoring points.

The regulatory requirements (amongst other) and applicable codes of practice pertaining to water contamination and pollution prevention for a mining operation also impacts on the objectives of a water quality monitoring program and cannot be excluded (Appendix C). A GAP analysis should be conducted initially to identify as to what is in place, pertaining to applicable legal and other requirements (Appendix C), and what needs to be put into place. Due consideration should also be given, amongst other, to the catchment visionary, reserve requirements and SANS standards applicable to the design of monitoring programs.

Appendix D illustrates key considerations (as adapted from DWAF 2006 and Sanders *et al* 1983) in designing a water quality monitoring program. The design program should be able to provide answers as to “what, when, where and how” to monitor (Strobl & Robillard, 2008). Quality assurance and control aspects need to be incorporated into the design and should include chain of custody forms, sample preservation techniques, sampling procedures, field and trip blanks, etc. Analyses from water samples should be checked and quality control measures applied immediately upon receiving the data so as to detect discrepancies in analysis data or errors in reporting.

The reporting requirements in the form of formal reports, feedback as part of a Public Participation Process (where required, in example for the water use license process), executive feedback and monthly data collation and modelling also needs to be confirmed at the monitoring program design stage. It is advisable that reporting to senior management or to internal divisions on water quality, takes strong cognisance of the objectives of the water monitoring program.

It is also advisable to audit and revise the water monitoring program on an annual basis (which forms part of the management of the program in total) or at a feasible frequency. This applies to the usage of new technology in sample analysis, changes to mining operations and other activities taking place (upstream or downstream) in the catchment i.e. new industrial, residential developments.

3. CONCLUSION

The optimal design of an integrated water monitoring program is vital to the success of water monitoring activities and to achieving the necessary objectives. An integrated approach is necessary where the nature of the catchment and mining operations / activities are taken into consideration together with the applicable regulatory aspects and guidelines applicable to water monitoring system design. The incorporation of quality assurance and control measures are important to ensure that representative samples are taken of a surface water network to yield reliable results and to portray the actual / present water quality situation of a particular surface water network, where point and diffuse pollution sources will be clearly identified. The revision and auditing of such a water monitoring program, forming part of the management of the monitoring program, assist further in identifying sources of error to exclude, and also to incorporate changes from mining operations / activities and changes in the micro and macro catchment.

An efficient integrated water monitoring program should not only be able to successfully track certain specific substances, but also be effective in assisting in understanding as to how various ecosystem components interact and change over the long term and subsequently to also interpret the impact of the mining activities on the relevant ecosystem.

Furthermore, the water monitoring program should account for both effects-based monitoring, which measures the present condition of the water environment, as well as stressor-oriented monitoring, which focuses on measuring parameters that are suspected or known to be associated with a negative impact on water environmental health / quality (Strobl & Robillard, 2008). These substances should then be linked to the subsequent origin of diffuse or point pollution sources.

In conclusion, an integrated water monitoring program is of vital importance as it not only provides baseline information on the state of the environment before, during and after the operation of mines but can also be utilised as a modelling tool in order to detect and predict potential pollution plumes, monitoring rehabilitation activities and the efficiency of implemented integrated water and waste management plans, quantifying and identifying the origin of point and diffuse pollutant sources and subsequently also contributing in conforming to applicable legal and other requirements.

4. REFERENCES CITED

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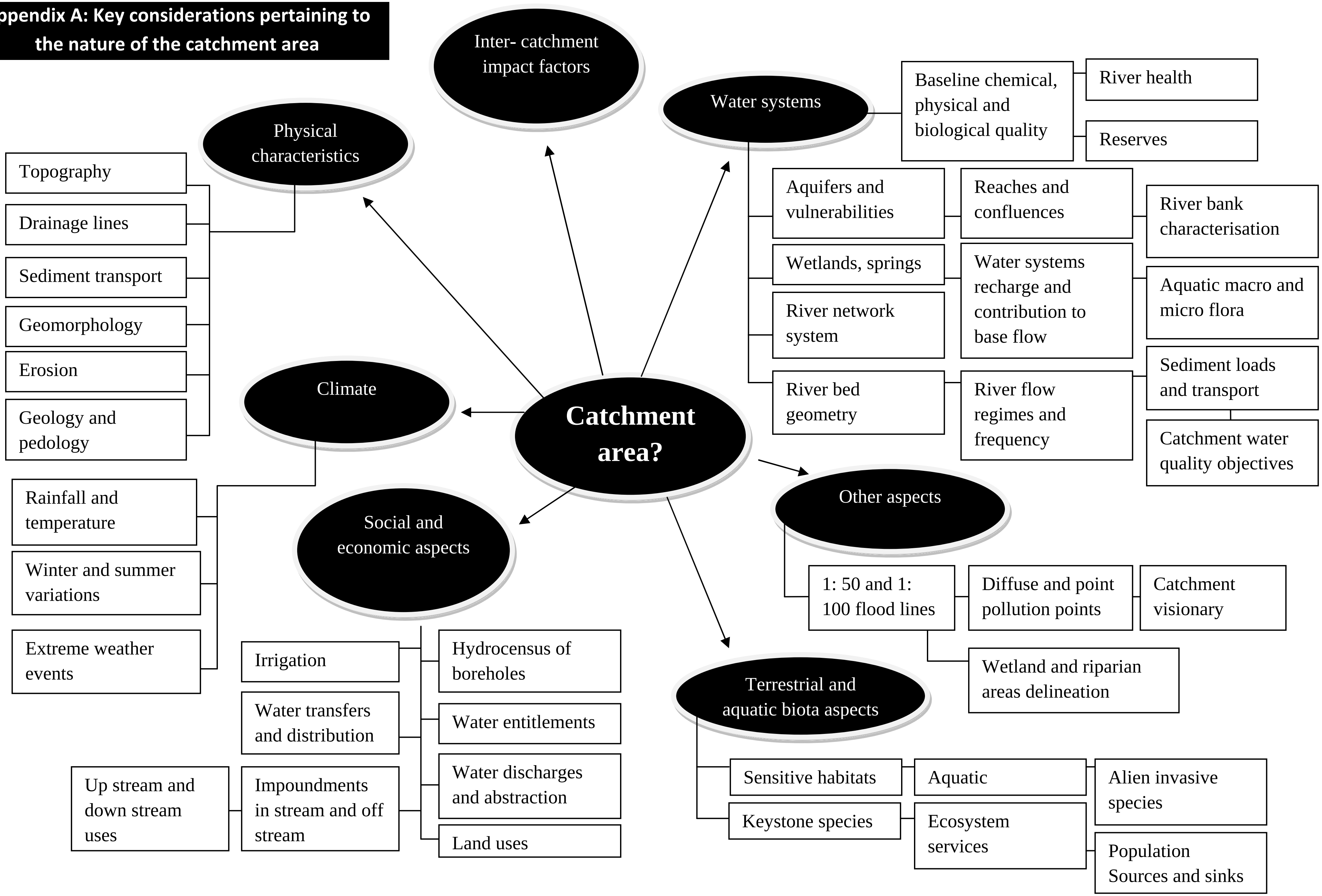
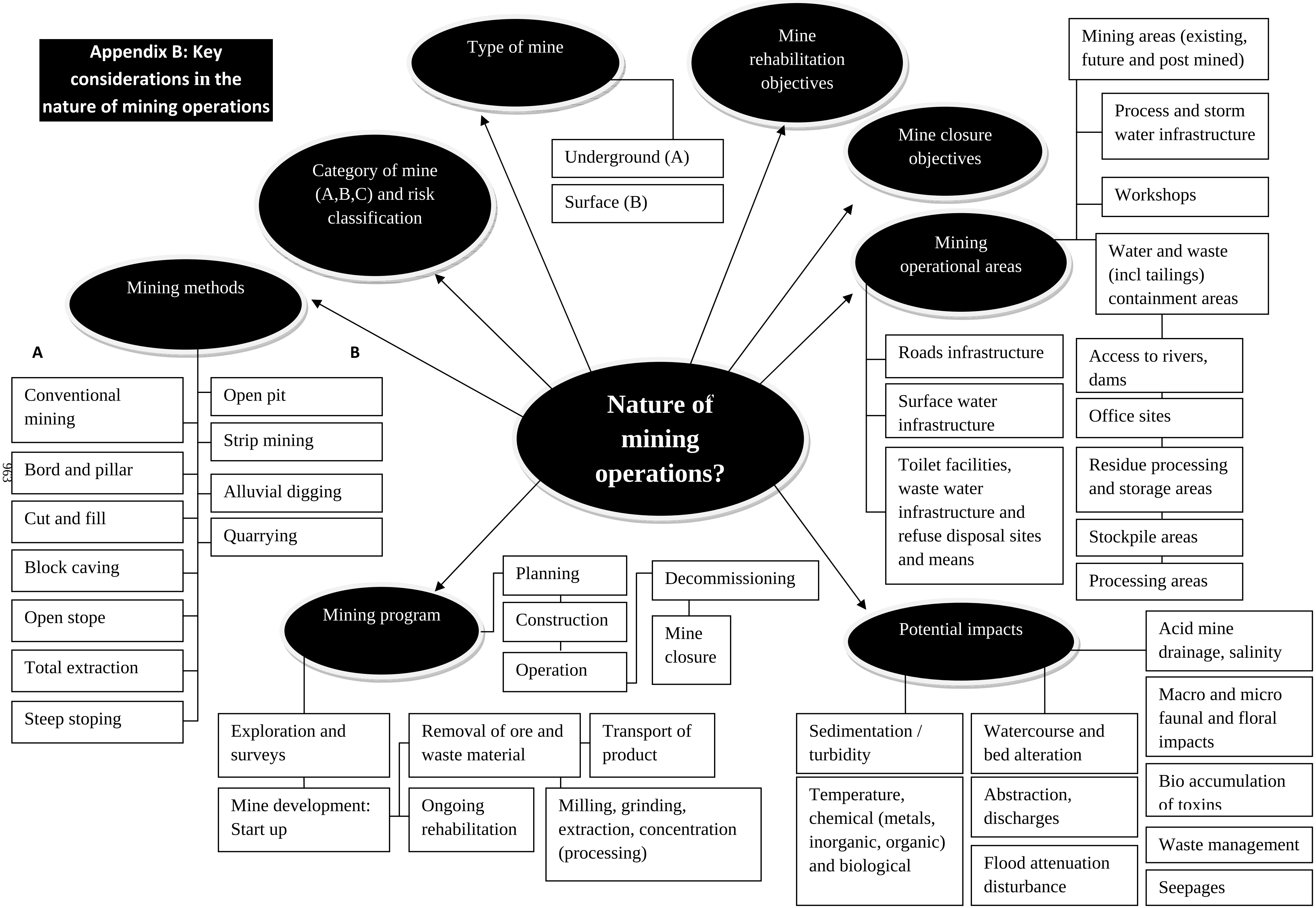
Appendix A: Key considerations pertaining to the nature of the catchment area



Appendix B: Key considerations in the nature of mining operations



Appendix C: Key considerations pertaining to applicable Regulatory aspects the nature of mining operations pertaining to water impacts

Regulatory requirements

Do GAP analysis: what is in place at the mine and what is required?

National Environmental Management Act (NEMA) (Act no 107 of 1998)

- Environmental Management Plans and Environmental Impact Assessment Regulations as per GN 385 , 386 and 387 of 2006
- Section 2: Principles of NEMA
- Section 28: Duty of care NEMA

National Water Act (NWA) (Act no 36 of 1998)

- Water use registrations (GN 1352 1999; GN 519 of 2009)
- GN 704 of 1999
- Water Use Licenses: Section 40-41 of the NWA, together with (Integrated) Water and Waste Management Plans
- General Authorisations (GN 1191 of 1999 and 398 of 2004); Section 39 of NWA
- Dam safety regulations and Chapter 12 of the NWA
- Section 19: Pollution Prevention (NWA)

Mineral and Petroleum Resources Development Act (Act no 28 of 2002)

- Mining permits, - rights, prospecting rights and Environmental Management Plans
- Mineral and Petroleum Resources Development Act: Regulations (Government Gazette No 26275, 23 April 2004)

Constitution of the Republic of South Africa Act (Act 108 of 1996)

- Sections 24, 33 and 38

Department of Water and Environmental Affairs requirements

- Catchment management strategies
- National Water Resource Strategy
- Catchment management, objectives and reserve requirements
- Water Resource Availability and Utilization
- Waste discharge charge system
- Water Conservation and Water Demand Management
- Water Classification System and the National Groundwater Strategy

Other

- Conservation of Agricultural Resources Act (Act no 43 of 1983)
- SANS 0286 of 1998: Code of practice for mine residues
- Water services act (Act no 108 of 1997)
- Best Practice Guidelines (DWAF series)
- DWA(F) water quality guidelines
- SANS 241:2005; 5667:1980; 5667-2:1991; 5667-3:2006; 5667-4:1987; 5667-5:2006; 5667-11:1993; 5667-6:2006; 5667-10:2007; 5667-13:2007; 5667-14:2007

Appendix D: Considerations pertaining to the development of a monitoring program (adapted from DWAF 2006 and Sanders *et al* 1983)