Figure 28: Structures identified where ground vibration mitigation will be required – York Pit

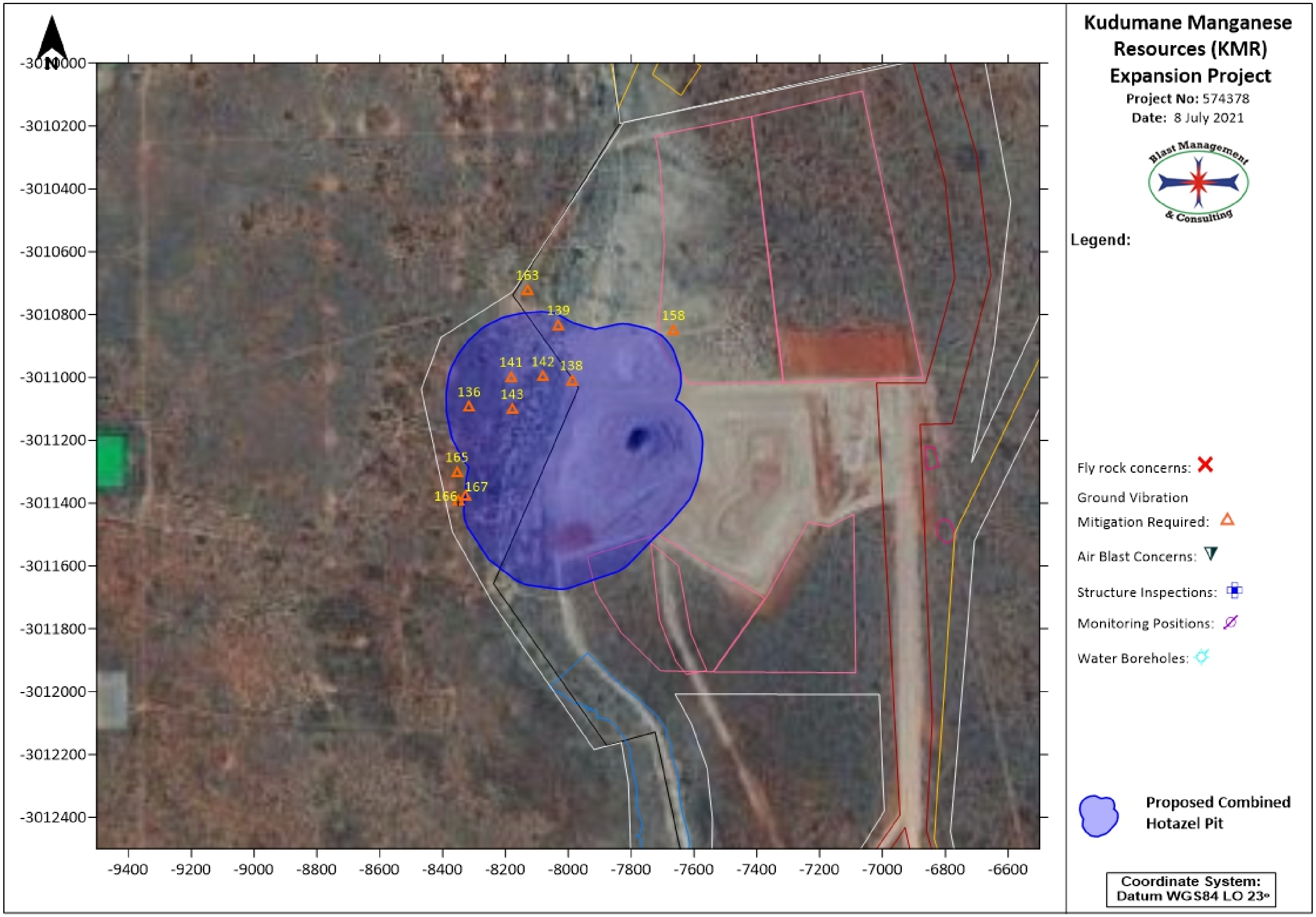

Figure 29: Structures identified where ground vibration mitigation will be required – Hotazel Pit

Figure 30: Structures identified where ground vibration mitigation will be required – Kipling Pit

Mitigation of ground vibration for this can be done applying the following methods:

- Do blast design that considers the actual blasting and distance of blast from POI, and the ground vibration levels to be adhered too.
- Only apply electronic initiation systems to facilitate single hole firing.
- Do design for smaller diameter blast holes that will use fewer explosives per blast hole.
- Relocate the POI / acquire the POI of concern – mined owned. Specific attention should also be given to heritage sites. Heritage specialist to provide best action to preserve where necessary. In cases where structures are not required to be protected rather destroy completely to prevent unintentional use.

The identified POI's of concern are found in close proximity of the planned operations. In order to give indication of the possibilities of mitigation to consider two basic indicators are presented. Firstly, the maximum charge per delay that can be allowed for the shortest distance between blast and POI. Secondly the minimum distance between blast and POI to maintain ground vibration limits for minimum and maximum charge per delay as applied in this report.

Table 31 do show mitigation in the form of maximum charge mass that will be allowed to maintain safe levels of ground vibration. Table 32 shows minimum distance between blast and POI to maintain ground vibration limits for the minimum and maximum charge per delay applied in this report.

Table 31: Mitigation measures: Maximum charge per delay for distance to POI

Tag	Description	Y	X	Specific Limit (mm/s)	Distance (m)	Total Mass/Delay (kg)	Predicted PPV (mm/s)	Structure Response @ 10Hz
York Pit								
80	Return Water Dam	7000.03	3015510.87	25	273	723	25	Acceptable
147	Hydrocensus Borehole (T1)	7599.61	3015804.93	50	142	454	50	Acceptable
148	Hydrocensus Borehole (T2)	7396.59	3015802.59	50	206	952	50	Acceptable
151	Hydrocensus Borehole (windmill 4)	7291.18	3014027.95	50	186	776	50	Acceptable
157	Hydrocensus Borehole (Ykdw4)	7290.29	3014022.51	50	191	821	50	Acceptable
Hotazel Pit								
158	Heritage (KMR 001 - Historical Site - Abandoned Cottage) See Note1	7664.18	3010852.50	6	37	2	6	Acceptable
163	Heritage (KMR 007 - Burial Ground)	8128.79	3010725.86	50	68	105	50	Acceptable
Kipling Pit								
8	Railway Line	7491.02	3008861.93	150	117	1176	150	Acceptable
127	Diversion R380 Road (Planned)	7553.33	3008875.04	150	54	247	150	Acceptable
150	Hydrocensus Borehole (wh02)	8016.87	3009442.75	50	223	1123	50	Acceptable

Note1: If structure is going to be demolished then not applicable.

Based on evaluation done for the planned charge masses mitigation will be required for the dirt road and powerline pylons. These POI's vary in distance and it will be required that each be evaluated in relation to a blast to be done. The distance should be checked, the charge mass allowed be calculated and then a design of charging or timing applied to ensure that the limits are not exceed. In most cases basic planned design does not need to change but timing can be adjusted as well electronic timing can used to reduce the charge mass per delay. This must be confirmed with monitoring of ground vibration at the POI.

Table 32: Mitigation measures: Minimum distances required per ground vibration limit

Tag	Example POI	Specific Limit (mm/s)	Distance (m)	Total Mass/Delay (kg)
Minimum Charge mass per delay				
158	Heritage (KMR 001 - Historical Site - Abandoned Cottage)	6	473	386
80	Return Water Dam	25	199	386
147	Hydrocensus Borehole (T1)	50	131	386
127	Diversion R380 Road (Planned)	150	67	386
Maximum Charge mass per delay				
Tag	Example POI	Specific Limit (mm/s)	Distance (m)	Total Mass/Delay (kg)
158	Heritage (KMR 001 - Historical Site - Abandoned Cottage)See note1	6	863	1285
80	Return Water Dam	25	364	1285
147	Hydrocensus Borehole (T1)	50	239	1285
127	Diversion R380 Road (Planned)	150	239	1285

Note1: If structure is going to be demolished then not applicable.

Data provided in tables above clearly indicate that distance between blast and POI will have influence on the allowed charge mass per delay with regards to the different ground vibration limits.

Further it must be confirmed with the respective authorities for infrastructure not owned by the mine what the minimum distance between the various pit areas and these infrastructure must be. The current distance between the R380 diversion road is small, and it is certain that minimum requirements from the authorities will indicate distances further than current.

18.3.1 Air Blast and Fly rock

Though more concentration is placed on ground vibration air blast and fly rock are as important. In many cases air blast is the largest contributor to complaints. Air blast and fly rock can be controlled using proper charging methodology irrespective of the blast hole diameter and patterns used.
The current design applied in the report utilises a stemming factor of 25 times the blasthole diameter. This factor is a good factor. However by increasing the stemming length to 30 time the blasthole diameter will contribute to lesser air blast and better fly rock control.

19 Closure Phase: Impact Assessment and Mitigation Measures

During the closure phase no mining, drilling and blasting operations are expected. It is uncertain if any blasting will be done for demolition. If any demolition blasting will be required it will be reviewed as civil blasting and addressed accordingly.

20 Alternatives (Comparison and Recommendation)

No specific alternative mining methods are currently under discussion or considered for drilling and blasting.

21 Monitoring

A monitoring programme for recording blasting operations is recommended. The following elements should be part of such a monitoring program:

- Ground vibration and air blast results;
- Blast Information summary;
- Meteorological information at time of the blast;
- Video Recording of the blast;
- Fly rock observations.

Most of the above aspects do not require specific locations of monitoring. Ground vibration and air blast monitoring requires identified locations for monitoring. Monitoring of ground vibration and air blast is done to ensure that the generated levels of ground vibration and air blast comply with recommendations. Proposed positions were selected to indicate the nearest points of interest at which levels of ground vibration and air blast should be within the accepted norms and standards as proposed in this report. The monitoring of ground vibration will also qualify the expected ground vibration and air blast levels and assist in mitigating these aspects properly. This will also contribute to proper relationships with the neighbours.

Eleven monitoring positions were identified as possible locations that will need to be considered. Not all points will be required at once but active monitoring and observation of where blasting is done will dictate the requirements for the areas around the pit. Some of these points may be applicable to more than one location to be monitored. Monitoring positions are indicated in Figure 31 to Figure 33 and list of the coordinates provided in Table 33. These points will need to be re-defined with an availability of a detailed mining plan and after the first blasts done.

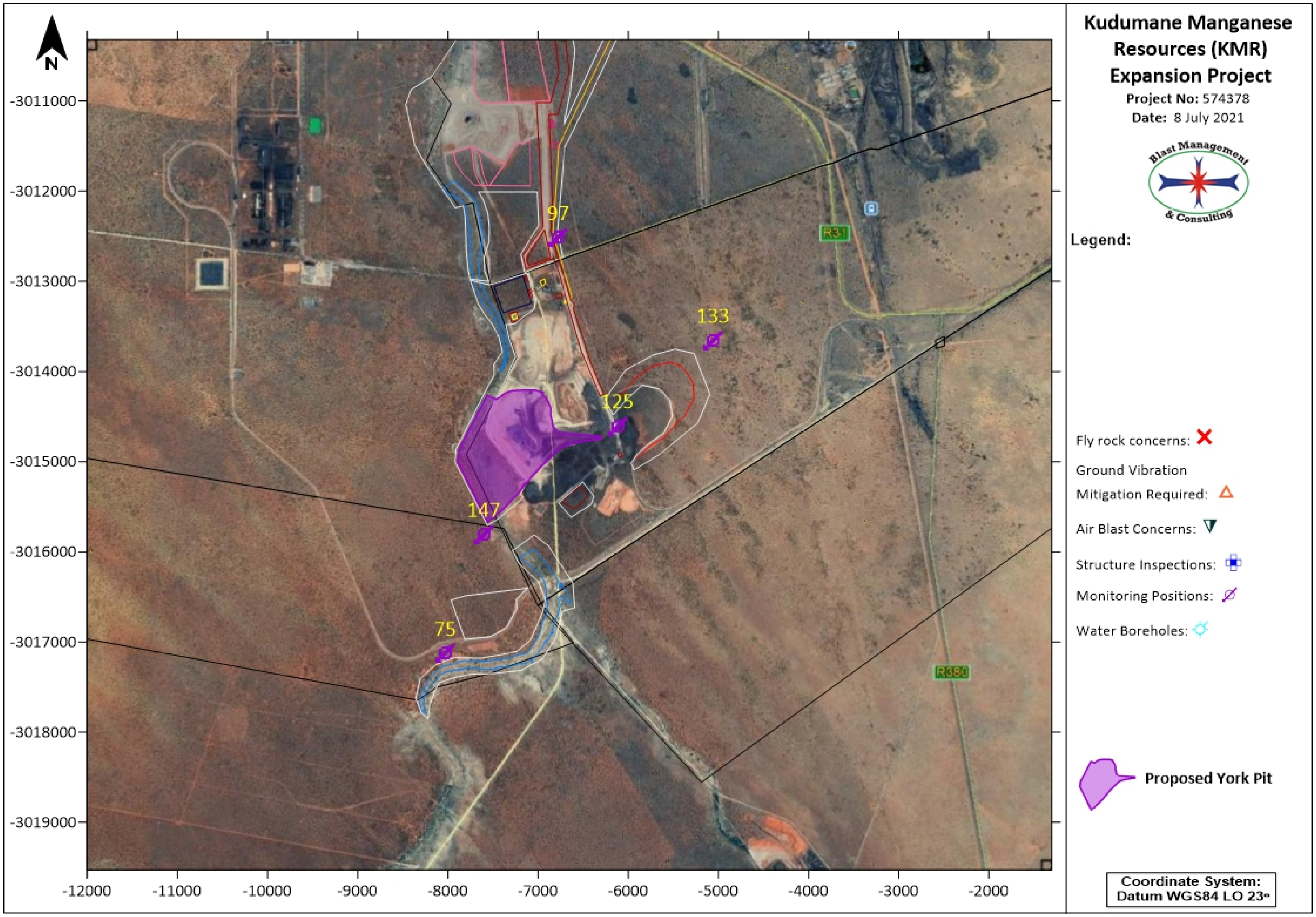

Figure 31: Suggested monitoring positions for York Pit

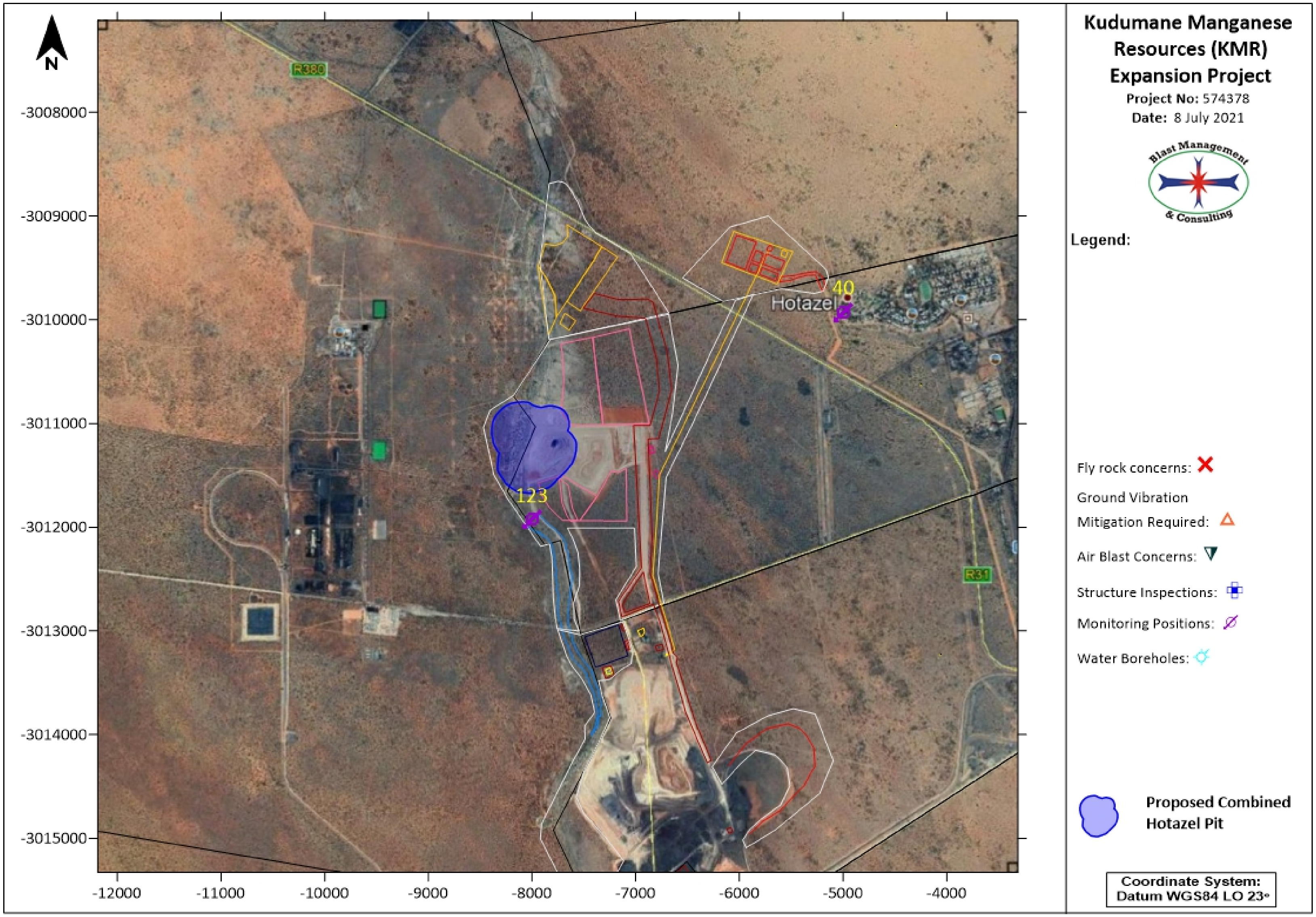

Figure 32: Suggested monitoring positions for Hotazel Pit

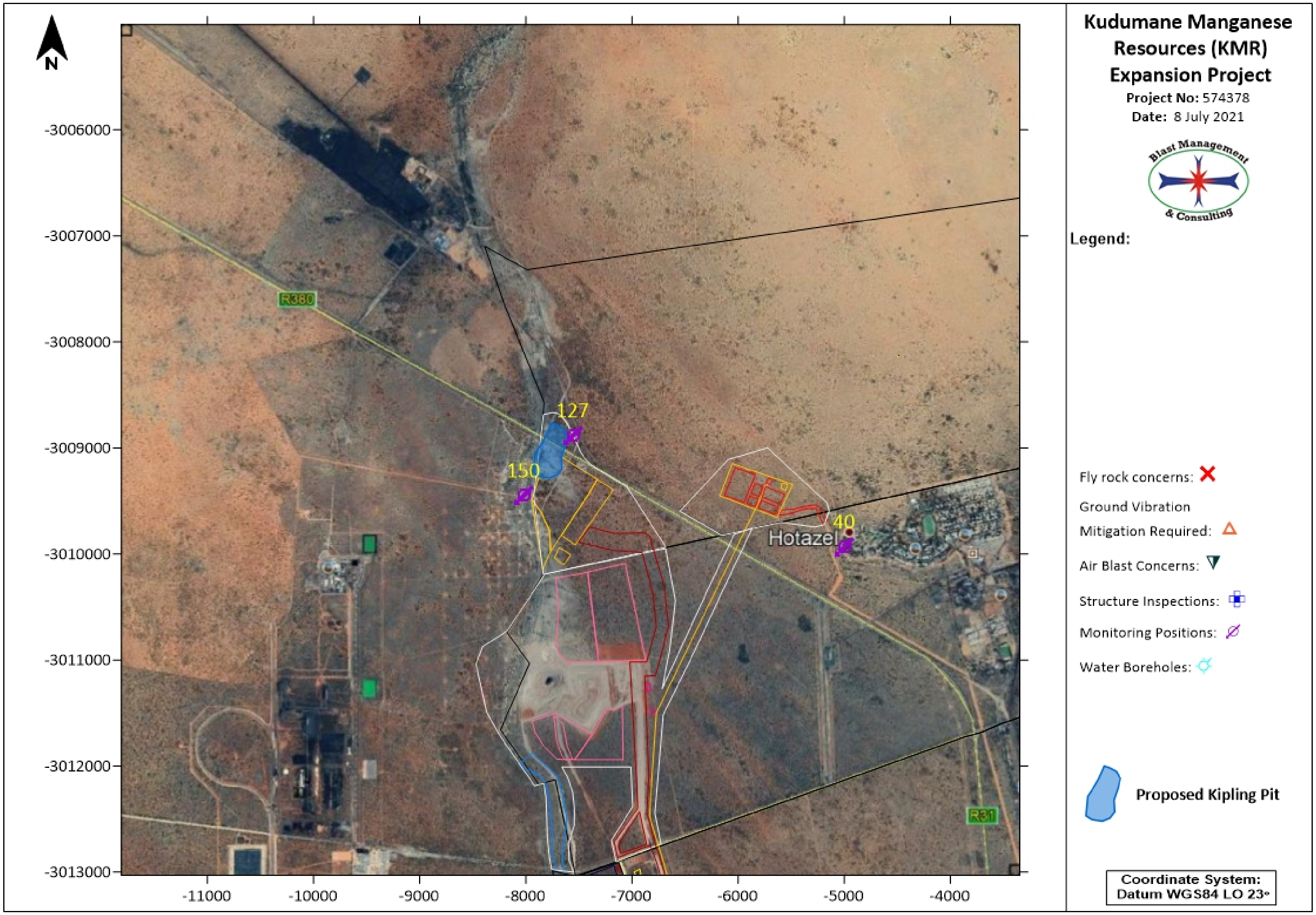

Figure 33: Suggested monitoring positions for Kipling Pit

Table 33: List of possible monitoring positions

Tag	Description	Y	X
	York Pit		
40	Houses	4995.56	3009926.74
97	Power Line/Pylon	6773.52	3012513.37
133	Lodge	5057.78	3013654.63
125	Railway Line	6118.59	3014603.12
147	Hydrocensus Borehole (T1)	7599.61	3015804.93
75	Farm Buildings/Structures	8024.94	3017127.66
	Hotazel Pit		
40	Houses	4995.56	3009926.74
123	Attenuation Dam (Planned)	8000.15	3011927.89
	Kipling Pit		
40	Houses	4995.56	3009926.74
127	Diversion R380 Road (Planned)	7553.33	3008875.04
150	Hydrocensus Borehole (wh02)	8016.87	3009442.75

22 Recommendations

The following recommendations are proposed.

22.1 Regulatory requirements – MHSA Reg. 4.16(2)

Regulatory requirements indicate specific requirements for all non-mining structures and installations within 500 m from the mining operation. Three POI's are observed within 500 m from the mining area. The mine will have to apply for the necessary authorisations as prescribed in the various acts, and specifically Mine Health and Safety Act Reg 4.16 as well as recommendations regarding infrastructure within the pit area. Table 34 shows list of these installations. Figure 34 to Figure 36 below shows the 500 m boundary around the opencast pit areas. The location of non-mining installations is clearly observed.

Table 34: List of possible installations within the regulatory 500 m

Tag	Description	Y	X
	York Pit		
71	Mine Activity	6985.66	3013795.81
73	Gravel Road	6797.41	3015614.46
74	Old Farmstead (Inside York Pit Area)	7859.09	3014890.11
77	Rail Loading Bay	6080.60	3014728.56
78	Railway Line	5884.20	3014897.10
79	Mine Buildings	6284.84	3015147.38
80	Return Water Dam	7000.03	3015510.87
124	Attenuation Dam (Planned)	7426.22	3014004.99
125	Railway Line	6118.59	3014603.12
147	Hydrocensus Borehole (T1)	7599.61	3015804.93
148	Hydrocensus Borehole (T2)	7396.59	3015802.59
151	Hydrocensus Borehole (windmill 4)	7291.18	3014027.95
153	Hydrocensus Borehole (YGW01)	5983.75	3015118.14

Tag	Description	Y	X
154	Hydrocensus Borehole ((YGW03)	6557.81	3013921.71
155	Hydrocensus Borehole (YGW04)	7280.83	3013937.64
157	Hydrocensus Borehole (Ykdw4)	7290.29	3014022.51
	Hotazel Pit		
123	Attenuation Dam (Planned)	8000.15	3011927.89
136	H4 - Potential grave (Inside Hotazel Pit Area)	8314.60	3011097.13
138	Hydrocensus Borehole (HTDW 002) - Inside Hotazel Pit Area	7988.81	3011012.76
139	Hydrocensus Borehole (HTWM 004) - Inside Hotazel Pit Area	8030.24	3010837.38
140	Hydrocensus Borehole (Htwm005)	7117.45	3011109.07
141	Hydrocensus Borehole (KSX23) - - Inside Hotazel Pit Area	8180.82	3011002.25
142	Hydrocensus Borehole (KU20-09) - Inside Hotazel Pit Area	8078.87	3011000.63
143	Hydrocensus Borehole (KU20-12) - Inside Hotazel Pit Area	8177.08	3011104.19
144	Hydrocensus Borehole (KU20-13) -- Inside Hotazel Pit Area	8077.92	3011102.91
158	Heritage (KMR 001 - Historical Site - Abandoned Cottage)	7664.18	3010852.50
159	Heritage (KMR 002 - Single fragment of a broken lithic blade)	7755.22	3010477.04
162	Heritage (KMR 005 - Scatter of stone tools)	7581.11	3011683.50
163	Heritage (KMR 007 - Burial Ground)	8128.79	3010725.86
165	Heritage (KAL02 - Scatter of Stone Age artefacts)	8352.30	3011304.42
166	Heritage (KAL03 - Artefacts)	8351.25	3011395.28
167	Heritage (KAL04 -Scatter of Stone Age Artefacts) - Inside Hotazel Pit Area)	8328.47	3011379.75
	Kipling Pit		
7	Railway Line	7628.32	3008478.02
8	Railway Line	7491.02	3008861.93
35	Gravel Road	7617.81	3008754.82
37	Gravel Road	7887.18	3008928.19
127	Diversion R380 Road (Planned)	7553.33	3008875.04
150	Hydrocensus Borehole (wh02)	8016.87	3009442.75

Figure 34: Regulatory 500 m range for the York Pit area

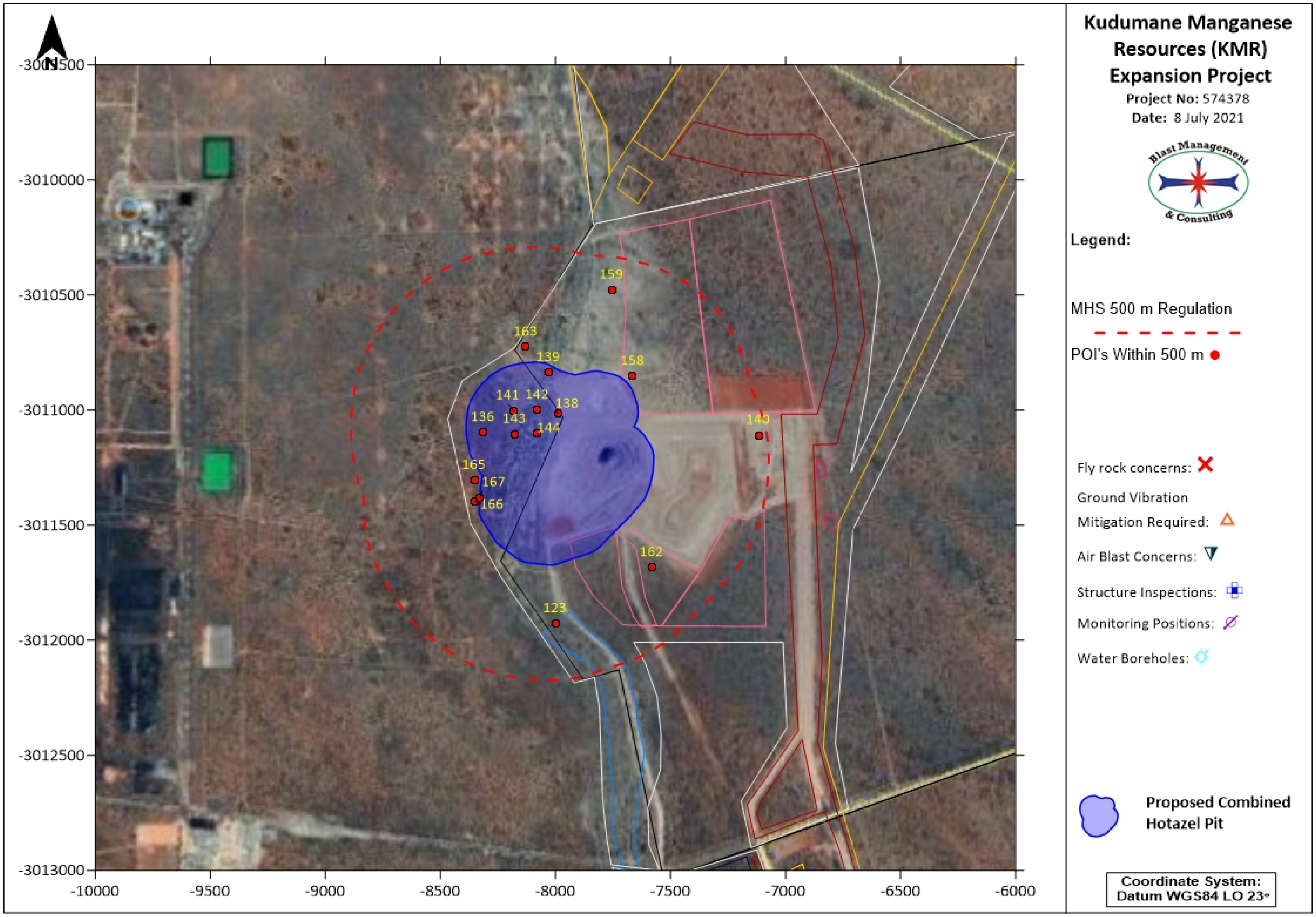

Figure 35: Regulatory 500 m range for the Hotazel Pit area

Figure 36: Regulatory 500 m range for the Kipling Pit area

22.1 Regulatory requirements – MHSA Reg. 17.6(a)

On review of the pit area's location, it is such that Mine Health and Safety act regulation 17.6(a) will be applicable and will need to be considered. The location of the opencast Pit boundary is not closer than 100 m from private installations and no necessary legal requirements will need to be addressed. Figure 37 to Figure 39 shows the Pit areas with 100 m boundary that indicate no infrastructure are within the 100 m.

Figure 37: Regulatory 100 m range for York Pit area

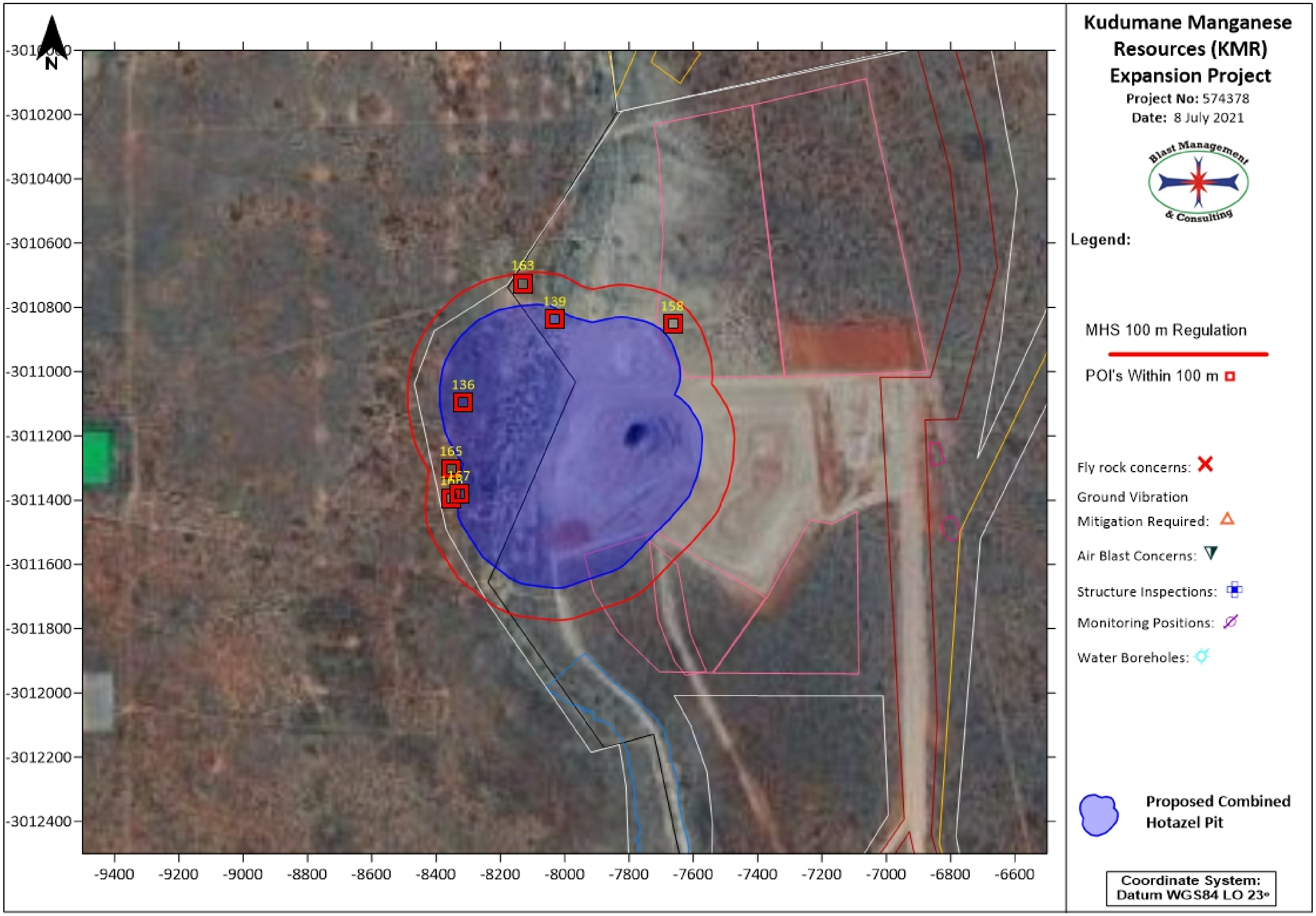

Figure 38: Regulatory 100 m range for Hotazel Pit area

Figure 39: Regulatory 100 m range for Kipling Pit area

22.2 Blast Designs

Blast designs can be reviewed prior to first blast planned and done. Specific attention can be given to the possible use of electronic initiation rather than conventional timing systems. This will allow for single blast hole firing instead of multiple blast holes where necessary if ground vibration is of concern for the specific blast. Single blast hole firing will provide single hole firing – thus less charge mass per delay and less influence.

22.3 Test Blasting

It is always good to conduct a first test blast to confirm levels and ground vibration and air blast. It is recommended that such a blast be done, and detail monitoring done and used to help define blasting operations going forward. This test blast can be based on the existing design and only after this blast it may be necessary to define if changes are required or not.

22.4 Stemming length

The current proposed stemming lengths used provides for some control on fly rock. Consideration can be given to increase this length for better control. Specific designs where distances between blast and point of concern are known should be considered. Recommended stemming length should range between 20 and 30 times the blast hole diameter. In cases for better fly control this should range between 30 and 34 times the blast holes diameter. Increased stemming lengths will also contribute to more acceptable air blast levels.

22.5 Safe blasting distance and evacuation

Calculated minimum safe distance is 278 m. The final blast designs that may be used will determine the final decision on safe distance to evacuate people and animals. This distance may be greater pending the final code of practice of the mine and responsible blaster's decision on safe distance. The blaster has a legal obligation concerning the safe distance and he needs to determine this distance.

22.6 Road management

The planned R380 diversion road is at an approximate distance of 54 m from the Kipling Pit area and will require specific consideration regarding effects from blasting operations. There are other Roads and Gravel roads in the vicinity of the Project area but are all expected to be within the recommended limits. There may however be people and animals on these routes and will require careful planning to maintain safe blasting radius. It will be required that clearance distances are set, and road travel managed during blasting operations.

22.7 Photographic Inspections

The option of photographic survey of all structures up to 1500 m from the pit areas is recommended. The mine will be operating for a significant number of years. This will give advantage on any negotiations with regards to complaints from neighbours on structural issues due to blasting. This process can however only succeed if done in conjunction with a proper monitoring program. It is expected that ground vibration levels will be significantly less than proposed limits at 1500 m, but this process will ensure record of the pre-blasting status of the nearest structures to the pit area. At 1500 m the expected level of ground vibration will be perceptible.

The York pit has two POI's of concern to be considered for inspection. There are no houses within 1500 m from the Hotazel or Kipling pit areas that requires inspection. Figure 40 shows extent of the range of 1500 m around the York pit area with POI's identified. One POI is the Heritage site (KMR 004 - Historical Site - Abandoned Farm House) and if needed to be preserved it should be inspected.

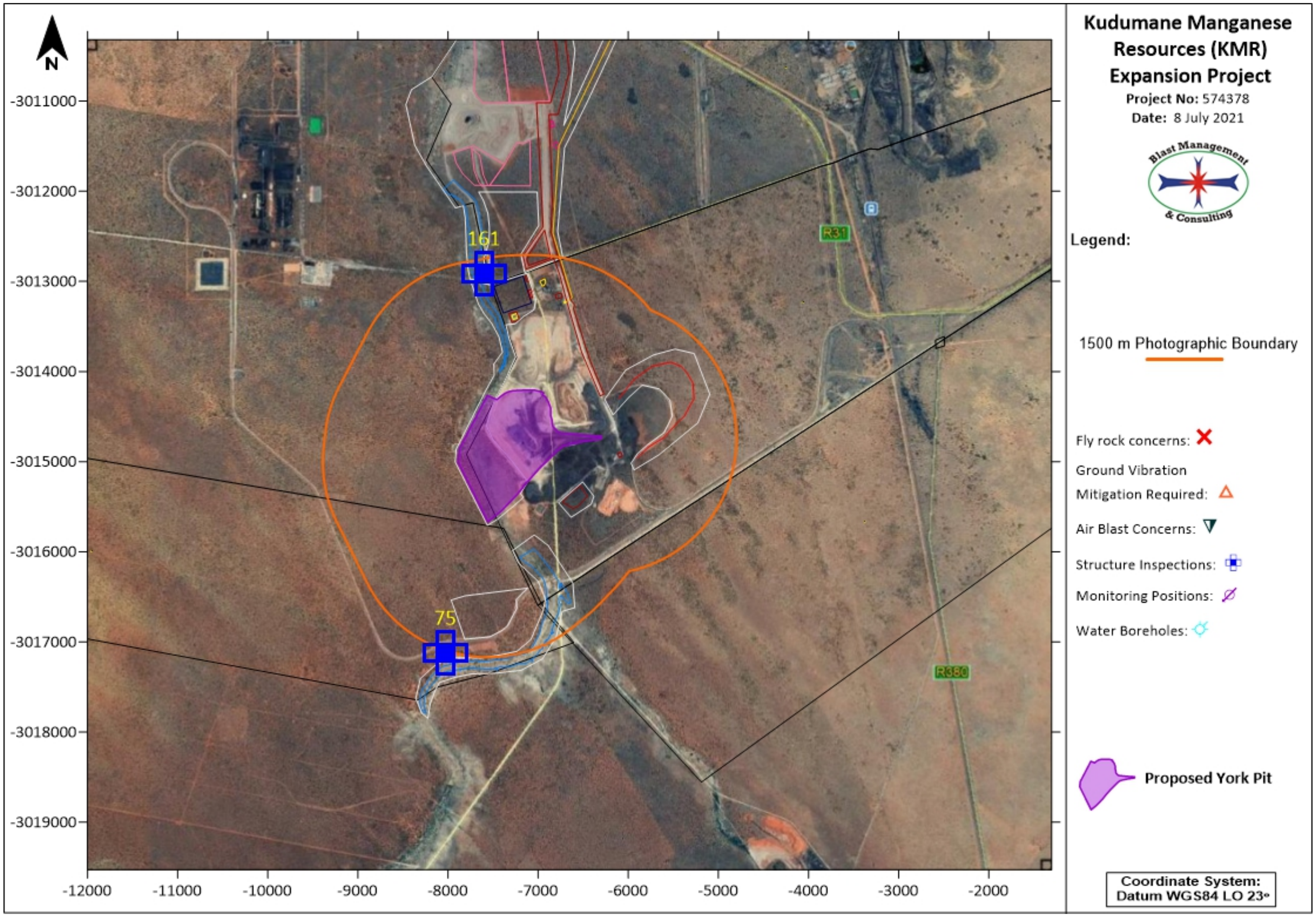

Figure 40: 1500 m area around York Pit area identified for structure inspections.

Table 35: List of structures identified for inspections

Tag	Description	Y	X
	York Pit		
75	Farm Buildings/Structures	8024.94	3017127.66
161	Heritage (KMR 004 - Historical Site - Abandoned Farm House)	7599.62	3012917.78

22.8 Recommended ground vibration and air blast levels

The ground vibration and air blast levels limits recommended for blasting operations in this area are provided in Table 36.

Table 36: Recommended ground vibration air blast limits

Structure Description	Ground Vibration Limit (mm/s)	Air Blast Limit (dBL)
National Roads/Tar Roads:	150	N/A
Electrical Lines:	75	N/A
Railway:	150	N/A
Transformers	25	N/A
Water Wells	50	N/A
Telecoms Tower	50	134
General Houses of proper construction	USBM Criteria or 25 mm/s	Shall not exceed 134dB at point of concern but 120 dB preferred
Houses of lesser proper construction (preferred)	12.5	
Rural building – Mud houses	6	

22.9 Blasting times

A further consideration of blasting times is when weather conditions could influence the effects yielded by blasting operations. It is recommended not to blast too early in the morning when it is still cool or when there is a possibility of atmospheric inversion or too late in the afternoon in winter. Do not blast in fog. Do not blast in the dark. Refrain from blasting when wind is blowing strongly in the direction of an outside receptor. Do not blast with low overcast clouds. These 'do nots' stem from the influence that weather has on air blast. The energy of air blast cannot be increased but it is distributed differently and therefore is difficult to mitigate.

It is recommended that a standard blasting time is fixed and blasting notice boards setup at various routes around the project area that will inform the community of blasting dates and times.

22.10 Third party monitoring

Third party consultation and monitoring should be considered for all ground vibration and air blast monitoring work. This will bring about unbiased evaluation of levels and influence from an independent group. Monitoring could be done using permanent installed stations. Audit functions may also be conducted to assist the mine in maintaining a high level of performance with regards to blast results and the effects related to blasting operations.

22.11 Video monitoring of each blast

Video of each blast will help to define if fly rock occurred and from origin. Immediate mitigation measure can then be applied if necessary. The video will also be a record of blast conditions.

23 Knowledge Gaps

The data provided from client and information gathered was sufficient to conduct this study. Surface surroundings change continuously, and this should be considered prior to initial blasting operations considered. This report may need to be reviewed and updated if necessary. This report is based on data provided and internationally accepted methods and methodology used for calculations and predictions.

24 Project Result

In view of the data evaluated it is the opinion of the author that the project can be executed successfully with proper management and control on the aspects of ground vibration, air blast and fly rock. Specific problems were identified, and recommendations made.

25 Conclusion

Ground vibration, air blast, fly rock and fumes are some of the aspects as a result from blasting operations. The report evaluates the effects of ground vibration, air blast and fly rock and intends to provide information, calculations, predictions, possible influences and mitigations of blasting operations for this project.

The evaluation of effects yielded by blasting operations was evaluated over an area as wide as 3500 m from the mining area considered. The range of structures observed is typical roads (tar and gravel), low cost houses, corrugated iron structures, brick and mortar houses, power lines/pylons, Hydrocencus boreholes and graves.

The location of structures around the Pit areas is such that the charge evaluated showed possible influences due to ground vibration. The closest structures observed are the Hydrocencus Boreholes, Railway Line, planned Attenuation Dam, Mine Buildings, Heritage Sites, Gravel Road and planned diversion R380 Road. Ground vibrations predicted for the pit area ranged between low and very high. The expected levels of ground vibration for some of these structures are high and will require specific mitigations in the way of adjusting charge mass per delay to reduce the levels of ground vibration. Ground vibration at structures and installations other than the identified problematic structures is well below any specific concern for inducing damage.

Air blast predicted showed the same concerns for opencast blasting. High levels may contribute to effects such as rattling of roofs or door or windows with limited points that are expected to be damaging and others could lead to complaints. The current accepted limit on air blast is 134 dBL. Damages are only expected to occur at levels greater than 134dB. It is maintained that if stemming control is not exercised this effect could be greater with greater range of complaints or damage. The pits are located such that "free blasting" – meaning no controls on blast preparation – will not be possible.

On charges considered it is expected that air blast will be greater than 134 dB at a distance of 458 m and closer to pit boundary. The structures inside the Pit area are expected to be relocated and will then not be of concern as it is currently inside the pit area. Infrastructure at the pit area such as roads, heritage sites and Power lines/Pylons are present, but air blast does not have any influence on these installations.

Fly rock remains a concern for blasting operations. Based on the drilling and blasting parameters values for a possible fly rock range with a safety factor of 2 was calculated to be 278 m. The absolute minimum unsafe zone is then the 278 m. This calculation is a guideline and any distance cleared should not be less. The occurrence of fly rock can however never be 100% excluded. Best practices should be implemented at all times. The occurrence of fly rock can be mitigated but the possibility of the occurrence thereof can never be eliminated.

Specific actions will be required for the pit area such as Mine Health and Safety Act requirements when blasting is done within 500 m from structures and mining with 100 m for structures. The Burial Ground, Abandoned Cottage and planned R380 diversion road falls within the 500 m range from the pit area.

The pit areas are located such that specific concerns were identified and addressed in the report.

This concludes this investigation for the proposed Kudumane Manganese Resources Project. There is no reason to believe that this operation cannot continue if attention is given to the recommendations made.

26 Curriculum Vitae of Author

J D Zeeman was a member of the Permanent Force - SA Ammunition Core for period January 1983 to January 1990. During this period, work involved testing at SANDF Ammunition Depots and Proofing ranges. Work entailed munitions maintenance, proofing and lot acceptance of ammunition.
From July 1992 to December 1995, Mr Zeeman worked at AECI Explosives Ltd. Initial work involved testing science on small scale laboratory work and large-scale field work. Later, work entailed managing various testing facilities and testing projects. Due to restructuring of the Technical

Department, Mr Zeeman was retrenched but fortunately was able to take up an appointment with AECI Explosives Ltd.'s Pumpable Emulsion Explosives Group for underground applications.
From December 1995 to June 1997 Mr Zeeman provided technical support to the Underground Bulk Systems Technology business unit and performed project management on new products.
Mr Zeeman started Blast Management & Consulting in June 1997. The main areas of focus are Pre-blast monitoring, Insitu monitoring, Post-blast monitoring and specialized projects.

Mr Zeeman holds the following qualifications:

1985 - 1987	Diploma: Explosives Technology, Technikon Pretoria
1990 - 1992	BA Degree, University of Pretoria
1994	National Higher Diploma: Explosives Technology, Technikon Pretoria
1997	Project Management Certificate: Damelin College
2000	Advanced Certificate in Blasting, Technikon SA

Member: International Society of Explosives Engineers

Blast Management & Consulting has been active in the mining industry since 1997, with work being done at various levels for all the major mining companies in South Africa. Some of the projects in which BM&C has been involved include:
Iso-Seismic Surveys for Kriel Colliery in conjunction with Bauer & Crosby Pty Ltd.; Iso-Seismic surveys for Impala Platinum Limited; Iso-Seismic surveys for Kromdraai Opencast Mine; Photographic Surveys for Kriel Colliery; Photographic Surveys for Goedehoop Colliery; Photographic Surveys for Aquarius Kroondal Platinum – Klipfontein Village; Photographic Surveys for Aquarius – Everest South Project; Photographic Surveys for Kromdraai Opencast Mine; Photographic inspections for various other companies, including Landau Colliery, Platinum Joint Venture – three mini-pit areas; Continuous ground vibration and air blast monitoring for various coal mines; Full auditing and control with consultation on blast preparation, blasting and resultant effects for clients, e.g. Anglo Platinum Ltd, Kroondal Platinum Mine, Lonmin Platinum, Blast Monitoring Platinum Joint Venture – New Rustenburg N4 road; Monitoring of ground vibration induced on surface in underground mining environment; Monitoring and management of blasting in close relation to water pipelines in opencast mining environment; Specialized testing of explosives characteristics; Supply and service of seismographs and VOD measurement equipment and accessories; Assistance in protection of ancient mining works for Rhino Minerals (Pty) Ltd.; Planning, design, auditing and monitoring of blasting in new quarry on new road project, Sterkspruit, with Africon, B&E International and Group 5 Roads; Structure Inspections and Reporting for Lonmin Platinum Mine Limpopo Pandora Joint Venture 180 houses – whole village; Structure Inspections and Reporting for Lonmin Platinum Mine Limpopo Section - 1000 houses / structures.

BMC have installed a world class calibration facility for seismographs, which is accredited by Instantel, Ontario Canada as an accredited Instantel facility. The projects listed above are only part of the capability and professional work that is done by BMC.

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