WATER RESOURCE MANAGEMENT IN A MINING AREA OF MAHARASHTRA

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Abstract

In the mining areas, where mineral excavation is carried out water resources management involving both surface water and ground water are extremely important as the quantum of water involved is very large. This paper presents water resource management and ground water recharge in Naokari limestone mining areas, located in Chandrapur District of Maharashtra, India. The ground water present in study area is in the unconfined condition and surface water has likely chances of pollution as the BOP Nala, a seasonal nala, flowing in the middle of the mine lease divides the deposit in two separate parts. Hence, appropriate surface water management suggestions for partial diversion of BOP Nala in the mine lease is suggested as the various related hydro-geological factors permit it. The need for mineral conservation can also be met suitably if the suggestion is implemented. With further deepening of mine, ground water management will be crucial and more important compared to that of surface water therefore its management and recharge should be done effectively and accordingly.

Introduction :

The importance of water, its conservation and management is well recognised these days as it is a precious resource which concern to all. Particularly, in urban locales and industrial set up it is a scarce commodity too. Needless to say it should be managed judiciously. The first national level assessment of groundwater (as a resource) was made during 1976 and it was estimated that 350 Billion Cubic Metre ground water is available for use (Chadha, 2006). The accelerated industrialization and infrastructure development of groundwater resources necessitated the proper evaluation and estimation on scientific lines using the approved Groundwater Estimation Committee Methodology -1997 (NABARD, 2006). The industries in various sectors were asked to plan and manage the ground water resources in a so that it can be conserved for future.

Naokari Limestone Mine of M/s Ultratech Cement (formerly L&T) is the captive mine of Awarpur Cement Work (ACW) is situated in one of the industrial belt of Maharashtra. Beside ACW, there exist other cement production units also namely, Manikgarh Cement, Maratha Ambuja Cement and ACC- Ghughus. Some coal mines of Western Coalfields Limited (WCL) are also located in nearby areas. Therefore, it is an obvious fact as well as need that maintaining ecological balance while taking up developmental activities is very essential for the region in general and study area in particular. This paper is an attempt to report the water resource management in this mining area to improve the various environmental aspects related to water and judicial water management. Both for mine planning and mineral exploitation point of view a scientific study was conducted by the principal author at his institute CIMFR (erstwhile ,Central Mining Research Institute) and outcome of this study has been presented in the technical paper.

Study area :

The study area is located between latitude 19°47'0" to19°48'0"N and longitude 79°07'30" to 79°11'0"E. The mine site is located 30 km east of Rajura (block town of mine) and lies in Korpana tehsil of Chandrapur district. Naokari limestone mine is being worked by opencast mechanized method and the limestone production of the mine is 50 lakh tonnes per annum (Fig. 1A).

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The mine lease area has been divided into two blocks for operational convenience. These have been defined as Block 'A' and Block 'B'. Block 'A' is separated from block 'B' by a seasonal nallah called *Bop Nallah* flowing along S-N and cutting across the deposit. Block 'A' lies to the west of the nallah and block B to the east of it (Fig.1.B). Block 'A' is being mined since 1982 whereas mining activity in block 'B' has been initiated in 1997. At present, Block B & A both are being worked for production of limestone (since 2003).

Physiography/Topography (Regional /Local) :

The region (Chandrapur district as a whole) can be divided into the *plain fertile region and the upland hilly region*. In the south-western parts of the district the hills are known as *Gadchandur* and *Manikgarh hills*. The altitude in general rises to 500m and above the mean seal level. The area of the Naokari limestone deposit is mostly a vast, flat, plain terrain covered by cultivated field interspersed with barren wastelands. The surface terrain shows a gradual slope to the north. The altitude ranges from 200 to 225 m above MSL.

Climate :

The area is characterized by sub-tropical climate. Summers are severe and day temperature reaches to as high as 47^0 in May and June months. Winters are pleasant and average temperature ranges to 10^0C. The south-west monsoon season extends from June to September.

Rainfall : The average annual rainfall of the district ranges from about 1200 mm to about 1450mm normally. Based on the analysis of available rainfall data (for the past 14 years period 1991-2005), the average yearly rainfall for the present study area is computed as about 1278 mm .The maximum annual rainfall is recorded in the year 1995 as 1762mm and the minimum as 700mm in the year 2004 (Table 1).

Geology and geomorphology :

Geologically, Chandrapur district presents a variety of stratigraphic units right from Achaeans to recent alluvium and laterites as given in the following Table 2.

Local geology : Geologically, the *Penganga beds* of the *Vindhyan system* cover the area of Central India largely. Elongated cement grade limestone deposit is sandwitched between the faulted shale, limestone/shale in the south and dolomitic limestone in the north and it has maximum length of 5 km almost along east-west and maximum width of 900 m almost along north-south direction. The area is covered by thin film of soil (0.5 m approximately) followed by weathered limestone mantle of about 2.0 m thickness, which is underlain immediately by highly fractured cement grade limestone. The presence of cement-grade limestone formations in ACW had been confirmed on the basis of extensive exploration done during project inception stage (ACC, 1980) and on the basis of exploratory boreholes drilled down to a depth of 125 m. In the mine area, the limestone is highly fractured and jointed with gentle folds.

Drainage and watershed : The entire area of the mine and district falls in the *Godavari basin*. Broadly, three rivers namely, *Wardha, Wainganga and Penganga* forms the major watersheds. *Penganga river* (on the east) and *Wardha river* (on the west), which are tributaries of *Godavari river* mainly drains the study area.

Fig.1(A) : Location map of the study area.

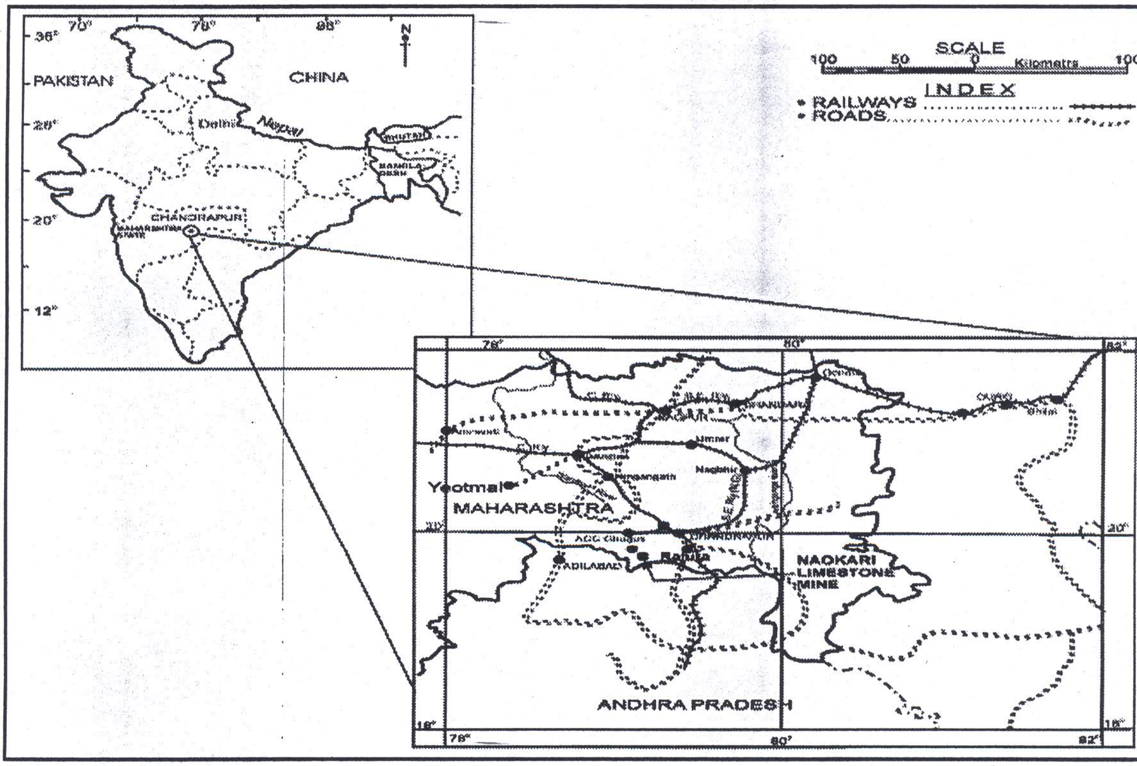


Fig.1(B) : Conceptual diagram illustrating mining blocks of Naokari limestone mine.

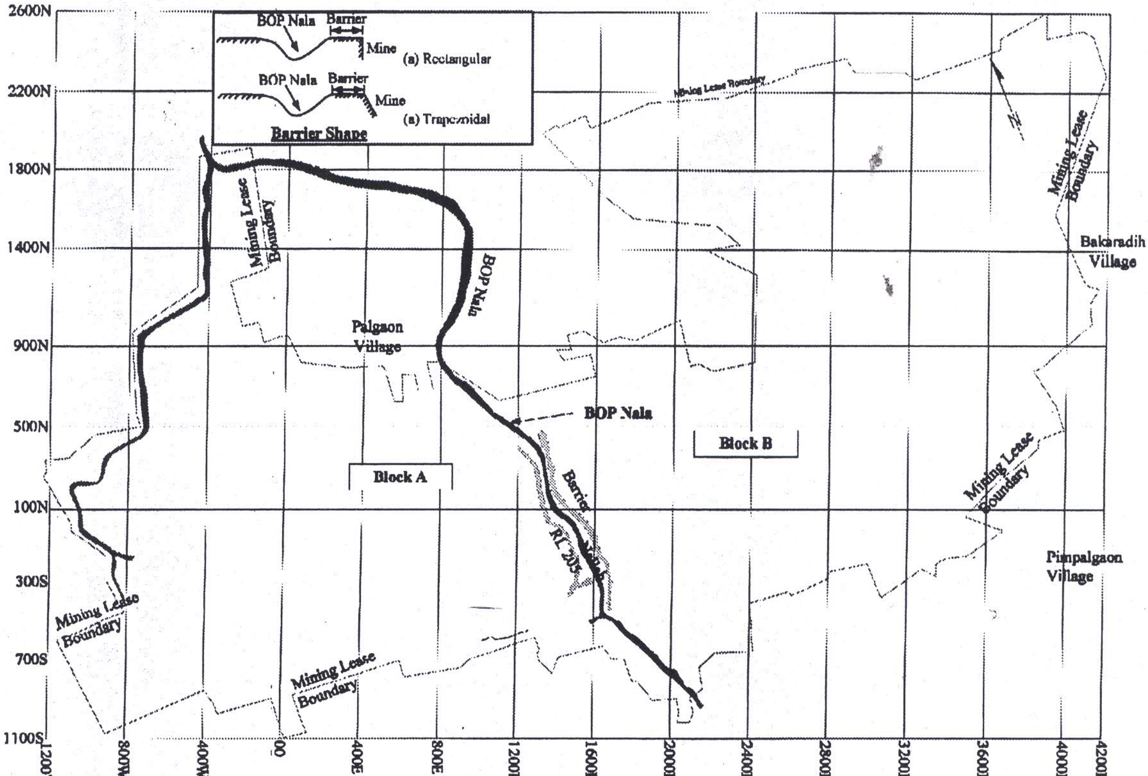
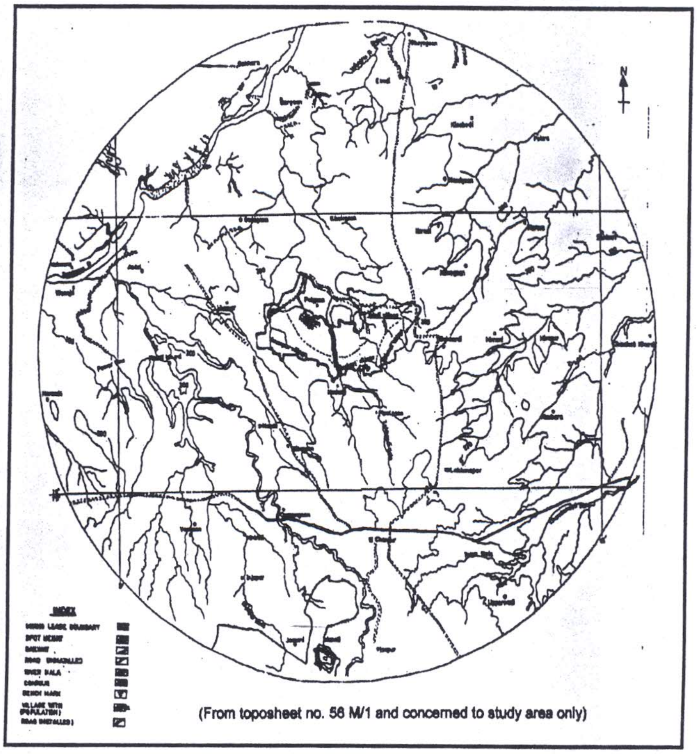


Fig.2 : Drainage map of the study area.



(From toposheet no. 56 M/1 and concerned to study area only)

Table 1: Yearly rainfall data of Naokari limestone mine area.

Months / Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1991	-	-	-	12.8	-	251.6	352.3	257.4	37.1	-	-	-	911.2
1992	-	-	-	18.3	19.4	257.6	149.0	778.9	178.4	-	-	-	1401.0
1993	-	-	34.2	-	-	159.00	359.3	136.9	129.2	69.8	-	13.4	901.8
1994	-	24.0	-	-	-	193.4	522.9	457.0	74.3	74.1	-	-	1345.7
1995	112.6	-	-	17.0	33.8	249.7	349.1	457.0	243.3	299.6	-	-	1762.0
1996	-	-	-	63.0	-	111.2	440.4	253.2	266.9	16.6	-	-	1133.3
1997	22.0	-	50.6	77.7	2.2	120.7	174.4	273.8	244.9	161.8	8.0	99.9	1236.0
1998	25.0	40.6	3.6	13.6	60.6	253.2	416.7	202.3	315.8	186.0	54.00	-	1566.4
1999	-	20.5	-	-	107.0	261.9	167.6	356.4	182.4	80.1	-	-	1191.1
2000	-	-	-	-	205.7	367.1	370.2	416.7	31.2	-	-	7.0	1388.2
2001	-	-	23.8	23.8	10.0	511.2	120.2	649.4	96.9	89.2	11.8	-	1541.5
2002	19.3	-	-	-	-	390.5	251.0	478.6	133.6	46.5	-	-	1319.5
2003	-	6.8	53.2	53.2	-	145.5	665.4	479.0	135.6	80.4	-	2.0	1567.9
2004	64	-	4.0	4.0	57.0	130.9	186.2	137.0	96.7	15.0	-	-	700.0
2005	88.9	1.4	35.3	35.3	1.2	124.7	607.1	328.0	-	-	-	-	1204.5

Naokari mine area falls in the micro - watershed of BOP Nallah of *Penganga sub-basin* of *Godavari*. The drainage of the area is dendritic and tends northwards due to the gradual northerly slope of the terrain. Drainage map of the area is shown in Fig.2. Tributaries of the BOP nallah drain the mine area and they are ephemeral in nature. The highest flood level (HFL) of the BOP Nala is 205.20 m above mean sea level. It may be noted, that BOP nala is the only major nallah (seasonal water body) flowing across the limestone deposit, which account for hydrology of the study area. But, it has monsoon and post-monsoon flow / drainage only for limited period in a year.

Table 2 : Regional geology

Age	Formation	Rock Types
Recent to sub-recent	Alluvium, soils laterites	Sand, clay, silt, soils & laterites
Lower Eocene to Upper Cretaceous	Deccan Traps	Basalts, weathered, vesicular and massive basalts
Triassic	Upper Gondwanas group *(Malaris)*	Clay, shales, sandstones
Lower Triassic to Upper Carboniferous	Lower Gondwanas Group:	
	Kamathis	Reddish brown sandstone, shale, clay
	Barakars	Light grey to white feldspathic sandstones, carbonaceous shales, coal seams and clay
	Talchirs	Greenish to dark olive green colored shales and coarse-grained sandstones.
Pre-cambrian	Vindhyans	Shales, sandstones, flaggy & massive limestone and sandstones of variegated colours
Achaeans	Crystallines and older metamorphics	Gneisses, quartzites, schists with acid and basic instrusives

The Naokari limestone mine area is located in the recharge zone of watershed PG1, having 314.9 sq. km. of area, which has minimum ground water development activities. The ground water withdrawal is taking place for domestic water only. Industrial uses of ground water are very less.

Water resources of Naokari limestone mining area :

Naokari, the captive mining area of ACW has vast limestone resources of cement grade and provides raw material feed for the production of 3.6 million ton cement production unit. ACW is considered as an important and large industrial unit of the region. Hence, water and its usages as a resource are extremely important.

Surface water resources : A seasonal nallah, also called Bop nallah flows in the core zone (mine lease area). This nala flows down the escapement and drain into the *Penganga river. Penganga is* a major river located at about 18 km north of the mine lease area. *Lokhandi nala (near Pipalgaon village)* on south side of the mine lease area is yet another feeder water channel to Bop Nala, marked on the toposheet No. 56 M/1. Both these seasonal drains / nala remains dry during the summer season. Down stream side of Bop Nala, towards *Palgaon* village carries the discharge of Naokari limestone mine (both A & B blocks).

Ground water resources : Groundwater, an important replenishable resource, is typically governed by geological formations or strata. The study area is a part of Vindhyan formations (with limestone as basic unit) and in its immediate vicinity there lies the *Gondwana formations* (with unconformities), which are water charged formations. Hence, the presence / availability of ground water is evident. These formations will have good water potentiality too from resource extraction point of view. The economic extraction of ground water in the area is done in the form of open wells / dug wells, hand pumps and tube wells. In and around the mine, limestone and host rock forms the aquifers. In general, ground water table is not very deep and aquifer replenishment / recharge is occurring due to rainwater spread, good drainage network and elongated nature of watersheds. Water table related facts are as given below:

• Observed Range of Water Table Depth	0.3m to 11.0m (Min and Max)
• Water Level Fluctuations (Average)	3.0m to 8.0m
• Depth of Dug wells (Average)	4.8m to 11.0m

Resource evaluation : An analysis :

It is generally apprehended that the mining operation (s) may results into changes in surface water regime by attaining altered drainage pattern in an area. The problem further aggravates, if, the recharge area also coincides with mineral bearing area. Therefore, careful and meticulous planning is required for resource evaluation which in turn culminates into its management. There is no major river or flowing water body within the buffer zone (10 km aerial radius) of the mining area except Bop nallah (a seasonal nala in the core zone of mine lease area) and *Lokhandi nala (near Pipalgaon village and* on south side of the mine lease area). In respect of irrigation resources or projects the study area is destituted though, Chandrapur district as a whole has agricultural economy. Irrigation schemes / projects present in the area are either small or medium scale projects and include *Amal Nala Irrigation Dam* located near the Manikgarh Cement limestone mine.

Geo-hydrological studies has prima facie indicated that since BOP nala is a dry seasonal nala its course in the lease area can be altered partially to provide convenience for mining (Soni, 2007). The scientific facts also reflect that there exists feasibility for diversion of BOP Nala. This diversion should be partial and not full. In this regard points mentioned below needs attention

a) Only one village namely Palgaon Village nearby the immediate vicinity *of* lease area, having 700 800 population, lies enroute to the proposed diversion. Thus, BOP nala neither feed to any village or habitat as water source nor used for irrigation purposes.

b) The Naokari mine's Surface map study shows that alternate route is available for diversion of BOP nala which, if selected will cause least disturbance to natural surroundings like village displacement / drainage pattern of the area etc.

c) Study of various ground elevation levels makes it is clear that the diversion is feasible though it will require a sizable financial investment.

The ground water resources have been evaluated from different angle on regional as well as local basis e.g. development potential (regional), impact due to mining and predicted impact on ground water due to depth or expansion of mine (local) as these are essential for a mine or mining organization for perspective planning. The reason for analysis on the regional scale is that the ground water does not know any man made boundaries whether industrial or otherwise.

It is observed that ground water development of the study region i.e. Chandrapur is 7% command area wise (Table 3). Comparing it with the stage of development of ground water resources for Rajura alone this figure is slightly more i.e. 10.2 % before the year 2,000 (CGWB, 1995 and GSDA, 1998). This can be attributed mainly due to the industrial development, particularly private cement plants in *Rajura* area due to the availability of cement grade (good quality) limestone. The ground water structures feasible in the district are 55579 (CGWB, 1995). There is no dark or gray watershed in the district. All the watersheds fall under white category (i.e. ground water development less than 65%). Ground water in the district is mainly developed by dug wells and bore wells for domestic and irrigation use. During last 25 years G.S.D.A. has drilled number of bore wells for village survey and later on they are utilized for water supply. The net utilizable ground water balance in the district is 83369 ha m which is available for ground water development in the district. Thus, the scope and potential of development of utilizable ground water resources in the district is more.

Table 3 : Ground water resources of Chandrapur district, Maharashtra.

S.No.	Description	Non-command area (ha m)	Command area (ha m)	Total area (ha m)
1.	Net recharge by rainfall	149180	18039	165219
2.	Net recharge by other sources	140	5451	5291
3.	Total net recharge (1+2)	149320	21490	170810
4.	Net recharge in forest area	81168	---	81168
5.	Total net utilizable recharge (3-4)	68152	21490	89642
6.	Net withdrawal	5947	1326	6273
7.	Net utilizable balance	62205	21164	83369
8.	Ground water development (%)	← 7.00% →		
9.	Ground Water Structures	← 55579 →		

Source : CGWB (1995) and GSDA (1998)

The above mentioned analysis has been done so that mine planning can match with district/ state / central government level planning.

Impact on ground water due to mining activity :

In the present case study impact on ground water due to mining activity is anticipated. This situation will arise only when the mining production is expanded from present level. At the current level of production and at the present mining depth since the water table is not intercepted impact of mining on ground water would be either absent or very-very less. Only the seepage water, that is available at the pit bottom, is likely or may be affected. Water percolation into the mine, through BOP Nala barrier, a natural barrier consisting of limestone and host rocks, will be encountered. The study shows that this seepage may be very less due to more barrier thickness and seasonal nature of BOP nala. During dry season there will be no water percolation. Massiveness of natural rocks in the vicinity of nala is also a responsible factor for less seepage.

The study area essentially comprises of weathered limestone at shallow depth and hard limestone formations at depth. The dug wells are located in weathered limestone formations and the dug-cum-bore wells and bore wells are tapping water from the deeper hard lime stone formations. The present mining activity is limited to about 40m depth below the ground level at both the mining blocks (Block 'A' and Block 'B') with a possibility of going up to 55m depth. CIMFR (erstwhile CMRI) has observed that ground water utilization is the study area is very low. A review of CGWB records also shows the similar observations. As per the Master Plan of Maharashtra, 2000 (CGWB, 2000) the study area does not falls into green area meaning that ground water resources are satisfactory. The depth to the water level in the study area in general ranges between 4.8 m to 11.00 m, during post-monsoon and pre-monsoon period respectively which is also not very low and well above the present mine working levels. The ground water level in and around the mine lease area varies from 2.1 to 3m (maximum) to 11-12m (minimum) approximately during different period in a year.

Though, limestone mining does not cause chemical pollution in terms of dissolution of toxic elements into the ground water. But, its presence increases the total hardness. Therefore every effort should be made to avoid contamination of ground water.

The above mentioned analysis indicates that mining operation has no adverse effect on the local ground water regime.

Predicted impact on ground water regime due to depth or expansion of mine :

The water accumulation in open pit mines is a common phenomenon. Such problem is likely to occur either due to excessive rainfall or seepage / percolation through adjoining strata or when water table is intercepted. In each of these situations, Dewatering is the most practical as well as economical way to keep the work places dry. Desired or enhanced production can be achieved and the operational efficiency of man and machine can be maintained by dewatering if the quarry has wet bottom. In order to make near accurate prediction of impact of dewatering on ground water regime of the area in *Manikgarh Cement Limestone Mine* situated in the vicinity of *Naokari Limestone Mine* has been studied. Though, the strata conditions are different but water condition in mines seems to be exactly similar. Naokari limestone mine workings are at a depth ranging from 25 to 50 m from the surface in block 'A' and less than 10m in block 'B'. M/s Ultratech Cement wants to extend the depth of operation beyond 55 m in their expansion programme to meet out the production requirement. The local geological conditions indicate that the present mining is confined to single type of formation (limestone of *Lower Vindhyan system, Pre- Cambrian period*).

Under the present working conditions and with the proposed expansion programme, the same limestone formation will be available for quarrying operation. Thus, prevailing measures taken for dewatering and disposal of mine water would be continued in the expansion stage also. If, similar practices are followed and principles of sustainable development is adopted it could be realised that by quarrying additional volume of limestone at greater depth (i.e. mine pit beyond 55 m depth bgl) would not create any negative impact on local ground water regime. As the mine progresses towards depth it is envisaged that more dewatering would be required. The water so encountered is largely ground water. Rate of seepage at different depth and period has been estimated in Table 4. The values shown are predicted values only. Slight departure from reported figures is obvious.

Surface water and ground water management :

On the basis of scientific investigation (CMRI, 2006) it is envisaged that current mining has no adverse impact on hydrological regime of the area in general.Barring some local temporary impacts, which are quite obvious the ground water potential in the study area is satisfactorily as the overall ground water utilization is low.

Table 4: Rate of seepage from mine at different depths and period.

Depth Range below GL (m)	Quantity of Water (TCM/Day)										
	July to Sept (92 days)		Oct. to Nov. (61 days)		December (31 days		Jan. to Feb. (59 days)		March to June (122 days)		Annual Total
	TCM /Day	Total in (92 days) TCM	TCM/ Day	Total in (61 days) TCM	TCM/ Day	Total in (31 days) TCM	TCM/ Day	Total in (59 days) TCM	TCM/ Day	Total in (122 days) TCM	TCM
0-8 206-198	2.0	184.0	5.00	305.00	2.50	77.50	1.50	88.50	0.20	24.40	679.40
8- 16 198 – 90	3.6	331.2	9.00	549.00	4.50	139.50	2.70	159.30	0.36	43.92	1223.00
16 –24 190 – 82	4.8	441.6	12.00	732.00	6.00	186.00	3.60	212.40	0.48	58.56	1630.60
24 – 32 182 –177	5.6	515.2	14.00	854.00	7.00	217.00	4.20	247.80	0.72	87.84	2125.16
32 – 40 177 – 69	6.2	570.4	15.50	945.50	7.75	472.75	4.65	240.25	0.78	95.16	2358.20
40 – 48 169 - 161	6.6	607.2	16.50	1006.50	8.25	255.75	4.95	292.05	0.82	100.04	2261.50
48 – 56 161 – 53	6.8	625.6	17.00	1037.00	8.50	263.50	5.10	300.90	0.822	100.30	2327.30

Since such conditions may are not exist in future due to enhance- exploitation of aquifer. Considering this, the water management is suggested. The management of water will help in the followings.

- Provide addition water to the limestone mining company which is saved;
- Enhance awareness about water conservation;
- Conserve water for future generations;
- Deepening of mining operation will be more environmentally sustainable.

By adopting the methods described below judicious management of water can be done.

1. Topographical condition of the mineral (Limestone) with respect to wells, lakes, stagnated water body and streams in the vicinity, drainage pattern of the area , average and seasonal rainfall statistics, proportion of run off and time period during the year when the maximum rate of runoff occurs and its duration, condition of strata below the ground surface and structural features which serve as a channel for the water passages and porosity of rock masses in the vicinity of mine workings shows that if the BOP nala is partially diverted (out of the mine lease area) the surface water resources can be better managed. Such diversion has other obvious advantages too and they are :

   - The limestone locked in nala bed i.e. between Block 'A" and 'B' could be extracted.
   - The mine planning could be streamlined and made comparatively easier. (Absence of water body from the lease area will simplify/ratify number of things pertaining to administrative and statuary clearances etc.
   - There will be an overall gain in transportation cost thereby reducing the overall cost of limestone production.

2. Mine water at *Naokari which is* available at the pit during non- monsoon months is an important water source for Awarpur Cement Works (ACW) in addition to ground water and pumped water from various nearby resources such as *Amal Nala dam*. Therefore, Naokari *Mine* water should be conserved which is simply pumped into the BOP nala. This water will reduce the dependency of farmers on rainfall to some an extent if it is made available for irrigation during dry periods. Mine water may also be utilised by the surrounding villagers for miscellaneous and general uses.

3. In the region, the Naokari mine itself also acts as a water recharge structure and plays an important role in water conservation and management. Limestone mining has a beneficial impact on the water resources in the area, as the pumped out water is being made available for various local uses and recharging of the ground water table of the area.

4. Ground water recharge structures must be made in suitable areas. In Maharashtra, the various methods in use are - a) Percolation Tanks, b) Subsurface Structures (Bandharas- Kolhapur type), c) Cement Plugs, d) Recharge Shafts, e) Existing Dug Wells, f) Nala Bunding, g) Contour trenching h) Gabbion structures etc. Therefore, in ACW's mine and cement plant areas also similar structures (at suitable geological and topographical locations where maximum recharge occurs) can be created and artificial recharge can be increased. This could be adopted into practice as a social obligation by ACW.

5. To manage water during monsoon a separate *'Water Danger Plan'* is required in the mine statutorily to guard against any danger of mine inundation. The plan shall be kept ready all the time and communicated / advertised through various office orders, training schemes, notices, display publicity etc.

Conclusions :

Geo-hydrological studies (including water balance studies) of any mining site where commercial or production activity is planned or being done provides an opportunity to analyze and retrospect requirements and budgeting of existing water resources. Since, water is a fast depleting, yet renewable natural resource, such studies are helpful in resource conservation. In the present study it is evaluated that -

1. Surface water of Naokari Limestone mine can be managed effectively and judiciously by partial diversion Bop Nala.
2. The mine area is a closed basin of ground water and it is confirmed that groundwater exists under unconfined conditions.
3. The mining activities at Naokari are not adversely affecting the water scenario as far as quality and quantity are concerned but requires judicious use of ground and surface water resources. Temporary decline in water levels in the immediate vicinity of mine (At Palgaon Village) is a local effect and will continue to prevail.
4. The seepage of water into the Naokari mine is inevitable.
5. The careful and meticulous planning is required for management of water resources in a mining area whether it is surface water or ground water. It is analyzed that impact of mining on ground water resources, due to mine deepening (depth wise expansion or lateral expansion) will not be very severe.
6. Overall ground water utilization in the region and in the study area is very low.
7. The limestone mining area is in the recharge / midslope region of the Penganga sub-basin. There exist a need for water recharge structures in and around the studied area therefore such structures should be built by ACW management for ground water replenishment not as a compulsory requirement but as social obligation of industrial organisation.

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