



6th March, 2020
UTCL/EC/BKT-2/2019-20/406

To,

Secretary,
State Level Expert Appraisal Committee (SEAC),
Gujarat Pollution Control Board,
Paryavaran Bhavan, Sector – 10 – A,
Gandhinagar,
Gujarat – 382010.

Sub: Submission of reply for the queries made during 438th meeting of SEAC, Gujarat on dated 03/10/2018 for the proposal of Babarkot Limestone Area of M/s. UltraTech Cement Limited (Unit: - Narmada Cement – Jafarabad Works) of village Babarkot, Tal: Jafarabad, Dist.: Amreli, Gujarat (Mine Lease Area: - 14.2045 Ha.) (Proposal No: SIA/GJ/MIN/17237/2016).

Ref: 1) Minutes of the 438th meeting of the State Level Expert Appraisal committee held on 03/10/2018 at GPCB, Sector 10A, Gandhinagar.

2) Minutes of the 363rd meeting of the State Level Expert Appraisal committee held on 03/01/2018 at Geer Foundation, Sector 9, Indroda Park, Gandhinagar

Respected Sir,

This is with respect to the aforementioned subject and reference, we would like to bring to your kind notice the following chronology

After consideration of our proposal for EC in 363rd meeting of SEAC dated 3rd January, 2018. SEAC sought further details on 09 points as mentioned in Minutes of meeting of 363rd meeting. We had submitted request letter to extend the timeline for submission of our reply along with partial point wise submission of details vide our office letter no. JFD/MN/EC/14 Ha. / 2018-19 of dated 4th July, 2018. In concurrent to this, we have submitted detailed replies of all queries raised during 363rd meeting of SEAC vide our office letter no. JFD/MN/EC/14 Ha. /2018-19 of dated 25th September, 2018.

Our replies were discussed in 438th meeting of SEAC dated 3rd October, 2018 and committee has considered our submission, but sought additional details on few points which are mentioned in minutes of 438th meeting of SEAC dated 3rd October, 2018. We would like to inform your good office that all the queries raised during 438th meeting of SEAC of dated 3rd October, 2018 has been satisfactorily accomplished by UTCL as illustrated in below mentioned table

Sl. No	Committee sought following details from the project proponent	Our Submission	Status
1	Approved conservation plan of Flora and fauna from the competent authority with appropriate budgetary provision for conservation of wild life.	Revised conservation plan of flora and fauna (R-3) has been approved by Chief Wild Life Warden (Gujarat state) Gandhinagar office vide their office letter no. WLP/32 C/1015/2019 – 20 of dated 18 th February, 2020 (Enclosed herewith as Annexure 1).	Completed.
2	No objection certificate of forest department (DFO) regarding proposed operation of Mine lease considering mine lease location and movement of wild life in an area.	Patient hearing conduct by APCCF (Wild Life) - Gandhinagar for NOC from forest department and MoM of meeting is annexed hereby as Annexure - 2 . As per MoM point no. TOR 12, there is no any forest land involvement in project area. So NOC for project land area is not applicable to us (Project Proponent).	Completed.



UltraTech Cement Limited

Unit : Narmada Cement - Jafarabad Works

Corporate Identification Number (CIN) : L26940MH2000PLC128420

P.B.No. 10, Jafarabad, Dist. Amreli, Gujarat - 365540, India | T: +91 2794 245107 | F: +91 2794 245357 | W: www.ultratechcement.com

Registered Office : Ultratech Cement Limited, 'B' Wing, 2nd Floor, Ahura Centre, Mahakali Caves Road, Andheri (E), Mumbai - 400 093 | T: 022 6691 7800

		As per MoM of patient hearing by APCCF (Wild Life) - Gandhinagar, total 03 recommendation raised and it should be include in conservation plan. We have covered all the above mentioned three points in our revised conservation plan (R-3) and simultaneously financial forecast for the said activity has been taken.	
3	Based on inference drawn by CSIR in report on salinity ingress study, implementation and mitigation measures by the project proponent based on inference of the report to curb salinity ingress.	Salinity Ingress Mitigation Measures Implementation Plan has been authenticated by Central Salt & Marine Chemical Research Institute (CSMCRI) - Bhavnagar, Gujarat & Project proponent is hereby giving undertaking to implement all mitigation measures as per FINAL REPORT. Final report is annexed herewith as Annexure - 3 .	Completed.

We also hereby undertake to implement and comply all the conservative and mitigation measures up to end of mine life.

We would like to humbly request your good office to kindly consider our application to obtain Environment Clearance for proposed mining lease over an area 14.2045 ha.

Thanking you and with regards,

Yours faithfully,



For UltraTech Cement Limited
Unit: Narmada Cement – Jafarabad Works

Encl: -

1. Minutes of the 438th meeting of the State Level Expert Appraisal Committee held on 03/10/2018 at GPCB, Sector 10A, Gandhinagar (Reference).
2. Approval letter of Chief Wild Life Warden (Gujarat state), Gandhinagar for Revised Conservation Plan of Flora and Fauna (Annexure – 1).
3. MoM of patient hearing conducted at PCCF office – Gandhinagar on dated 6th December, 2019 (Annexure – 2).
4. Detailed report along with final plan of Salinity Ingress Mitigation Measures Implementation by CSMCRI – Bhavnagar (Annexure – 3).

Minutes of the 438th meeting of the State Level Expert Appraisal Committee held on 03/10/2018 at GPCB, Sector 10A, Gandhinagar.

The 438th meeting of the State Level Expert Appraisal Committee (SEAC) was held on 03rd October 2018 at GPCB, Sector 10 A, Gandhinagar.

Following members attended the meeting:

1. *Dr. Dinesh Misra, Chairman, SEAC*
2. *Shri S. C. Srivastav, Vice Chairman, SEAC*
3. *Dr. V.K. Jain, Member, SEAC*
4. *Shri A.K. Muley, Member, SEAC*
5. *Shri R.J. Shah, Member, SEAC*
6. *Shri R.I. Shah, Member, SEAC*

Following proposals have been considered for the additional details sought during SEAC meeting held on 03/01/2018.

1. **M/S. Babarkot Limestone Area with Production capacity of 2,50,000 MTPA(ROM) of Limestone by unit: Narmada Cement-Jafrabad Works of M/S Ultratech Cement Limited located at S.No:217, 218, 219, 220,221 of village Babarkot, Tal: Jafrabad, Dist: Amreli, Gujarat (Mine Lease Area:14.2045 Ha), (Proposal NO:SIA/GJ/MIN/17237/2016).**

With reference to additional details sought by the SEAC on 03/01/2018 and reminding letter to PP for submission of said details on 20/06/2018, Ultratech Cement Limited has submitted the letter to SEAC for extension of timeline for further 90 days to submit the query reply before 4th July 2018. PP submitted reply on 03/10/2018 which is as below:.

Sr. No	Information sought by SEAC	Our Submission

1	Approved conservation plan of flora and fauna from the competent authority with appropriate budgetary provision for conservation of wild life.	We have submitted Conservation Plan for flora & fauna to the Deputy Conservation of Forest, Dhari for approval vide our letter No. JFD/MN/EC/14/17-18/120 dated 01.02.2018 and also revised conservation plan as per the opinion of DCF, with modified budgetary provisions is re submitted vide letter dated 23.03.2018. We are waiting for approval from DCF office, Dhari. Copies of letters are attached as Annexure 1 & 1A but as the approval is time taking procedure we request SEAC to recommend for grant of the EC and UltraTech is giving Undertaking stating UltraTech is bound to follow all terms and condition mentioned in approved conservation plan and will be agreed on the Budget approved by the chief wildlife warden. The Undertaking is attached as Annexure 1 B. The opinion of Range Forest Officer, Una based on his site visit Is also attached herewith.
2	To re-address TOR Nos:12,13,16.	To re-address TOR – point, no. 12, 13 & 16 application made to DCF, Dhari, vide our letter no. JFD/MN/EC/14/17-18/120, dated 01.02.2018. We are waiting for clearance on applicable points from office of the DCF, Dhari. Copy of letter is attached as Annexure-1 but as the approval is time taking procedure we request SEAC to grant the EC and UltraTech is giving Undertaking stating UltraTech is bound to follow all terms and condition mentioned in approved conservation plan and will be agreed on the Budget approved by the chief wildlife warden. The Undertaking is attached as Annexure 1 B. The opinion of Range Forest Officer, Una based on his site visit Is also attached herewith which clearly state that there is no forest land involved in this lease area and there is no virgin forestland involved.
3	No Objection Certificate of forest department regarding proposed operation of Mine lease considering mine lease location and movement of wild life in an area.	For No Objection Certificate application vide our letter No. – JFD/MN/EC/14/17-18/120 dated 01.02.2018 and completed field survey by ACF, Dhari. He has recommended for NOC DCF sought information regarding actions will be taken by project proponent to separate movement of wild life from mining lease. We have submitted letter detailing the necessary precautions

		on 27.08.2018. Also submitted co-ordinates to DCF Dhari office as per his instructions on 14.08.2018 Submitted lease grant order and other necessary detail as sought by DCF Dhari office on 05.09.2018 but matter is pending at DCF level. Copy of letter is attached as Annexure – 1 The opinion of Range Forest Officer, Una based on his site visit is also attached herewith.
4	Correct declaration by the Head of accredited consultant organization with reference to the Mining lease for the area 14.2045 Ha.	Correct declaration by the Head of accredited consultant organization is attached as Annexure-2
5	Salinity ingress study including detailed impact of rain water harvesting due to the proposed mining to recede the salinity in ground water as per the approved post closure mine plan.	For the salinity ingress study has been completed by the expert scientists of Central Institute of Mining & Fuel Research(CIMFR), Nagpur. The Report is attached as Annexure-3
6	Undertaking for not carrying out intersection of ground water table and correction in final EIA report showing water table & proposed working depth.	The Letter of Undertaking is attached as Annexure-4
7	Undertaking for not carrying out blasting for the proposed Mine lease operation.	The Letter of Undertaking is attached as Annexure-4
8	Detailed action plan for all the issues raised during public hearing including complaints received in written form by the Project proponent.	We would like to mention that as per the latest EIA notification amendment no. SO 3977(E) dated 14th August 2018, all the mine lease less than 100Ha area will be considered as a B category mine and EC will be granted by SEAC/SEIAA. The Detailed action plan for all the issues raised during public hearing including complaints received in written form by the Project proponent is attached as Annexure 5. As per Office Memorandum of Corporate Environmental Responsibility dated 1st May 2018,,Ultratech Cements limited is bound to spend budget as per the circular issued by MoEF&CC.

Referring to reply and attached annexure committee found that reply is not satisfactory and asked PP to submit the reply including following details

1. Approved conservation plan of flora and fauna from the competent authority with appropriate budgetary provision for conservation of wild life.
2. No Objection Certificate of forest department (DFO) regarding proposed operation of Mine lease considering mine lease location and movement of wild life in an area.
3. Based on inference drawn by CSIR in report on salinity ingress study , implementation and mitigation measures by the project proponent based on inference of the report to curb salinity ingress.

After deliberation, committee asked PP to submit the aforementioned details at the earliest to decide the proposal.

2. **M/S. Babarkot Limestone Area with Production capacity of 2,50,000 MTPA(ROM) of Limestone by unit: Narmada Cement-Jafrabad Works of M/S Ultratech Cement Limited located at S.No:110/1, 111/1, 111/2, 112/1, 114, 119/1, 126/1, 101, 102/1, 102/2, 102/1/1, 105, village Babarkot, Tal: Jafrabad, Dist: Amreli,Gujarat (49.8454 Ha), (Proposal NO:SIA/GJ/MIN/17292/2016).**

With reference to additional details sought by the SEAC on 03/01/2018 and reminding letter to PP for submission of said details on 20/06/2018, Ultratech Cement Limited has submitted the letter to SEAC for extension of timeline for 90 days to submit the query reply before 4th July 2018. PP submitted reply on 03/10/2018 which is as below:

S. No.	Information sought by SEAC	Our Submission
1	To submit approved mine plan after deletion of S. No. 110/1 proposed in EC application.	Modified mining plan has been approved With considering no working and mining proposed in Survey no. 110/1 and mining will not be proposed till the final Judgement of Hon'ble High court of Gujarat Approved mining plan approval letter is attached as Annexure - I

438th meeting of SEAC-Gujarat, Dated 03.10.2018

2	Approved conservation plan of flora and fauna from the competent authority with appropriate budgetary provision for conservation of wild life	We have submitted Conservation Plan for flora & fauna to the Deputy Conservation of Forest, Dhari for approval vide our letter No. JFD/MN/EC/49/17-18/119 dated 01.02.2018 and also revised conservation plan as per the opinion of DCF, with modified budgetary provisions is re submitted vide letter dated 23.03.2018. We are waiting for approval from DCF office, Dhari. Copies of letters are attached as Annexure 2 & 2A but as the approval is time taking procedure we request SEAC to grant the EC and UltraTech is giving Undertaking stating UltraTech is bound to follow all terms and condition mentioned in approved conservation plan and will be agree on the Budget approved by the chief wildlife warden. The Undertaking is attached as Annexure 2 B. The opinion of Range Forest Officer, Una based on his site visit is also attached herewith.
3	To re-address TOR Nos: 12,13,16	To re-address TOR – point, no. 12, 13 & 16 application made to DCF, Dhari, vide our letter no. JFD/MN/EC/49/17-18/119, dated 01.02.2018. We are waiting for clearance on applicable points from

		office of the DCF, Dhari. Copy of letter is attached as Annexure-2 but as the approval is time taking procedure we request SEAC to grant the EC and UltraTech is giving Undertaking stating UltraTech is bound to follow all terms and condition mentioned in approved conservation plan and will be agree on the Budget approved by the chief wildlife warden. The Undertaking is attached as Annexure 2 B. The opinion of Range Forest Officer, Una based on his site visit is also attached herewith which clearly state that there is no forest land involved in this lease area and there is no virgin forestland involved
4	No objection Certificate of forest department regarding proposed operation of Mine lease considering mine lease location and movement of wild life in an area.	For No Objection Certificate application vide our letter No. – JFD/MN/EC/49/17-18/119 dated 01.02.2018 and completed field survey by ACF, Dhari. He has recommended for NOC DCF sought information regarding actions will be taken by project proponent to separate movement of wild life from mining lease. We have submitted letter detailing the necessary precautions on 27.08.2018. Also submitted co-ordinates to DCF Dhari office as per his instructions on 14.08.2018 Submitted lease grant order and other necessary detail as sought by DCF Dhari office on 05.09.2018 but matter is pending at DCF level. Copy of letter is attached as Annexure –

		2 The opinion of Range Forest Officer, Una based on his site visit is also attached herewith.
5	Correct declaration by the Head of accredited consultant organization with reference to the mining lease for the area 49.8454 Ha.	Correct declaration by the head of accredited consultant organization is attached as Annexure - 3
6	Salinity ingress study including detailed impact of rain water harvesting due to the proposed mining to recede the salinity in ground water as per the approved post closure mine plan.	For the salinity ingress study field work has been completed by the expert scientists of Central Institute of Mining & Fuel Research (CIMFR), Nagpur. The report is attached as Annexure – 4
7	Undertaking for not carrying out intersection of ground water table and correction in final EIA report showing water table & proposed working depth.	The letter of Undertaking is attached as Annexure – 5
8	Undertaking for not carrying out blasting for the proposed Mine lease operation.	We have proposed drilling & blasting in the EIA and mining plan in this lease and same point was explained to SEAC during EC presentation.
9	Detailed action plan for all the issues raised during public hearing including complaints received in written form by the Project proponent.	We would like to mention that as per the latest EIA notification amendment no. SO 3977(E) dated 14th August 2018, all the mine lease less than 100Ha area will be considered as a B category mine and EC will be granted by SEAC/SEIAA. The Detailed action plan for all the issues raised during public hearing including complaints received in written form by the Project proponent is attached as Annexure – 6. As per Office Memorandum of Corporate Environmental Responsibility dated 1st May 2018,,Ultratech Cements limited is

438th meeting of SEAC-Gujarat, Dated 03.10.2018

		bound to spend budget as per the circular issued by MoEF&CC.
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Referring to reply and attached annexure committee found that reply is not satisfactory and asked PP to submit the reply including following details

1. Approved conservation plan of flora and fauna from the competent authority with appropriate budgetary provision for conservation of wild life.
2. No Objection Certificate of forest department (DFO) regarding proposed operation of Mine lease considering mine lease location and movement of wild life in an area.
3. Based on inference drawn by CSIR in report on salinity ingress study , implementation and mitigation measures by the project proponent based on inference of the report to curb salinity ingress.

After deliberation, committee asked PP to submit the aforementioned details at the earliest to decide the proposal.

The meeting was concluded with thanks to Chair and members.

1.	Dr. Dinesh Misra,Chairman,SEAC	
2.	Shri S. C. Srivastav,Vice Chairman,SEAC	
3.	Dr.V.K.Jain,Member,SEAC	
4.	Shri A K Muley, Member,SEAC	
5.	Shri R.J.Shah, Member,SEAC	
6.	Shri R.J.Shah, Member,SEAC	

No. WLP/32/C/ 1015 /2019-20
Office of the
Principal Chief Conservator of forests
Block No. B/1, Aranya Bhavan,
Ch-3 Circle, Sector - 10/A,
Gujarat State, Gandhinagar.
Dated: 18.02.2020

To,
M/s. Narmada Cement -Jafrabad Works,
C/o Ultratech Cement Limited,
Unit-Narmada Cement-Jafrabad Works
Jafrabad-365540, Dist: Amreli, Gujarat

Sub:- Request for approval of the Revised Conservation Plan of Flora & Fauna & NOC in respect of our New Granted Mining Leases for Mineral Limestone over 49.8454 Ha. & 14.2045 Ha. Granted to M/s UltraTech Cement Ltd. Unit:- Narmada Cement-Jafrabad Works in Village-Babarkot, Taluka Jafarabad in Amreli Dist. Of Gujarat.

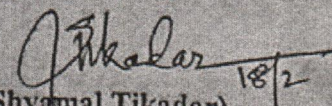
Ref :- Your letter no. JFD/MN/FC/19-20/373, dt.11/12/2019

Dear Sir,

Vide letter under reference, we have received request for approval of the Conservation Plan of Flora & Fauna & NOC in respect of our New Granted Mining Leases for Mineral Limestone over 49.8454 Ha. & 14.2045 Ha granted to M/s UltraTech Cement Ltd. Unit - Narmada Cement - Jafarabad Works in village - Babarkot, Taluka- Jafarabad in Amreli Dist of Gujarat through CCF, Wildlife Circle Junagadh for final approval. The said plan is approved in-principally and is under consideration for finalizing the modalities of execution in consultation with local field officers and user agency. Principally we agree with the mitigation measures and activities for conservation of flora and fauna suggested in the plan. The final approval to the conservation plan will be issued as early as possible.

Thanking You,

Your Sincerely


(Shyamal Tikadar)
Chief Wildlife Warden
Gujarat State, Gandhinagar

કાર્યવાહી નોંધ :-

તા. ૬/૧૨/૨૦૧૮ના રોજ અગ્રમુખ્ય વન સંરક્ષકશ્રી (વન્યજીવ)ના કમિટીરુમમાં અલ્ટ્રાટેક સીમેન્ટ લી. દ્વારા બાબરકોટ વિસ્તારમાં ૪૯.૮૪૫૪ હેક્ટર એરીયા અને ૧૪.૨૦૪૫ હેક્ટરના SEIAA દ્વારા આપેલ TOR મુજબ વન વિભાગ પાસેથી આપવાની થતી માહિતીનું પ્રેઝન્ટેશન કરવામાં આવેલ જેમાં નીચે મુજબના અધિકારીશ્રીઓ હાજર રહેલ હતા :-

૧. શ્રી એસ.પી.સીસોદિયા, અધિક અગ્ર મુખ્ય વન સંરક્ષકશ્રી (વન્યજીવ)
૨. શ્રી ડી.ટી.વસાવડા, મુખ્ય વન સંરક્ષકશ્રી, વન્ય પ્રાણી વર્તુળ, જૂનાગઢ
૩. શ્રી પ્રદિપસિંહ, મુખ્ય વન સંરક્ષકશ્રી, વન્યજીવ, ગાંધીનગર
૪. શ્રી દિગ્વિજય જાડેજા, અલ્ટ્રાટેક સીમેન્ટ
૫. શ્રી ભરત ગોખરુ, નર્મદા સીમેન્ટ, જાફરાબાદ વર્કસ

કંપની તરફથી કરવામાં આવેલ પ્રેઝન્ટેશન અંગે નીચે મુજબ માહિતીની સ્પષ્ટતા કરવામાં આવેલ:-

TOR ની શરત 12 મુજબ પ્રોજેક્ટ વિસ્તારમાં વન જમીન આવેલ છે કે કેમ તેની સ્પષ્ટતા કરવા જણાવેલ. કંપની દ્વારા નકશા ઉપર જણાવેલ છે કે, પ્રોજેક્ટ વિસ્તારમાં વન જમીન આવતી નથી. મુખ્ય વન સંરક્ષકશ્રીના પત્ર ક્રમાંક જમન/ટે. ૧૪/અ/૩૬૧૪-૧૫/૨૦૧૮-૧૯ તા. ૭-૩-૨૦૧૮માં પણ જણાવેલ છે કે, પ્રોજેક્ટ વિસ્તારમાં વન જમીન આવતી નથી.

TOR ની શરત 13 મુજબ વન વિસ્તાર હોય તો NPA અને CA આપવાની થાય છે પરંતુ વન વિસ્તાર આવતો ન હોવાથી શરત લાગુ પડતી નથી.

TOR ની શરત 14 મુજબ FRA હેક્ટરનો વિસ્તાર હોય તો જણાવા થાય છે પરંતુ સદર વિસ્તારમાં વન જમીન ન હોવાથી શરત લાગુ પડતી નથી.

TOR ની શરત 15 મુજબ RF /PF વિસ્તારની વનરાજીની વિગત આપવાની થાય છે પરંતુ સદર વિસ્તારમાં વન જમીન ન હોવાથી શરત ચાલુ પડતી નથી.

TOR ની શરત 16 મુજબ માર્શનીંગ વિસ્તારના વન્યજીવો તેમજ નજીકના PA ઉપર થતી અસરનો અભ્યાસ કરવાનો થાય છે, જે અભ્યાસ કરેલ છે અને બજેટ પ્રાવધાન પણ કરેલ છે.

TOR ની શરત 17 મુજબ નેશનલ પાર્ક, અભયારણ્ય, બાયોસ્ફીયર રીઝર્વ, રામસર સાર્ટ, વાઘ અભયારણ્ય વિગેરે ૧૦ કિ.મી.ની અંદર હોય તો તેનો નકશો બનાવવાનો રહે છે અને નેશનલ બોર્ડ ઓફ વાઈલ્ડ લાઈફની પરવાનગી લેવાની થાય છે. ૧૦ કિ.મી.ની અંદર રક્ષિત વિસ્તાર આવતો ન હોય, શરત ચાલુ પડતી નથી તેમ પ્રેઝન્ટેશનમાં નકશા ઉપર જણાવેલ છે. મુખ્ય વન સંરક્ષકશ્રીના પત્ર ક્રમાંક જમન/ટે. ૧૪/અ/૩૬૧૪-૧૫/૨૦૧૮-૧૯ તા. ૭-૩-૨૦૧૮ થી પણ સદર વિસ્તાર ૧૦ કિ.મી.ની અંદર અભયારણ્ય આવેલ નથી તેમ જણાવેલ છે અને નકશો રજૂ કરેલ છે, જેથી આ શરત ચાલુ પડતી નથી.

TOR ની શરત 18 મુજબ ૧૦ કિ.મી.ના વિસ્તારમાં બાયોલોજીકલ સ્ટડી કરી શેડયુલ સ્પીસીસની માહિતી આપવા જણાવેલ છે.તે વિસ્તારમાં શેડયુલ-૧ પ્રાણી આવતા હોય તો બજેટ પ્રાવધાન સાથે પ્લાન આપવાનો રહે છે.

TOR ની શરત 16 અને 18 મુજબ જીવ સૃષ્ટિ ઉપર થતી અસરો અને તેના શમન માટે પ્લાનની ચકાસણી કરવામાં આવેલ જેમા નીચે મુજબના મુદ્દાઓ થયેલ :-

- મીતીયાળા, બાબરકોટ, વાંઢ, વારાસ્વરુપ ગામો નજીક આવેલ છે ત્યાં ૧૦૦ % પેરાપેટવોલ બનાવવાની કામગીરીનો સમાવેશ કરવાનો રહેશે.
- મીતીયાળા અને બાબરકોટમાં ખેડૂતો માટે માચડાની વ્યવસ્થા કરવાની રહેશે.
- વાહન વ્યવહાર સંભાળતા ડ્રાયવરને અવરનેશ માટે ટ્રેનીંગની વ્યવસ્થા કરવાની રહેશે.

આમ, ઉપર મુજબ નિર્ણય કરી મીટીંગની કાર્યવાહી પુરી કરવામાં આવી.

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**UltraTech Cement Ltd.,
Narmada Cement Jafrabad
Works, Amreli (Gujarat)**

Salinity Ingress Mitigation Measures and Implementation Plan

Final Report



**CSIR-Central Salt & Marine Chemicals Research Institute
G.B. Marg, Bhavnagar (Gujarat)**

December 2019



सीएसआईआर-सीएसएमसीआरआई
CSIR-CSMCRI

सीएसआईआर-केन्द्रीय नमक व समुद्री रसायन अनुसंधान संस्थान
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Dr. Amitava Das, F.A.Sc.; F.NA.Sc.; F.NA.
Director J. C. Bose National Fellow

CERTIFICATE

This is to certify that CSIR-Central Salt & Marine Chemicals Research Institute has carried out **“Salinity ingress mitigation measures and implementation plan for UltraTech Cement Ltd., Narmada Cement Jafrabad Works, Amreli (Gujarat)”**.

The mitigation measures and implementation plan for the mining areas were prepared on the basis of the reports by CSIR-Central Institute of Mining and Fuel Research, Dhanbad and Royal Environment Auditing & Consultancy Services (REACS), Rajkot provided by UltraTech Cement Ltd., Amreli (Gujarat).

CSIR-Central Salt & Marine Chemicals Research Institute, Bhavnagar (Gujarat) is a constituent laboratory of Council of Scientific and Industrial Research (CSIR), New Delhi working in the diverse fields of Chemical, Biological Science and Engineering.

Date: 30.12.2019



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सीएसआईआर-सीएसएमसीआई
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EXECUTIVE SUMMARY

UltraTech Cement Ltd. has applied for the Environmental Clearance (EC) to the State Environmental Appraisal Committee (SEAC) in respect of two mining leases of 14.2045Ha. and 49.8454 Ha and eventually granted EC in Month & Year.

The salinity ingress by CSIR-Central Institute of Mining & Fuel Research (CIMFR) was prepared for the existing mining lease of 565 Ha in the village- Babarkot, Tal-Jafarabad, Dist.- Amreli (including study area of 10 km buffer zone).

For the new site, CSIR-CIMFR has recommended to prepare two separate reports for 14.2045 Ha. and 49.8454 Ha. Indicating mitigation measures based on inference of the salinity ingress report of CSIR-CIMFR. As per CSIR-CIMFR's suggestion, UltraTech Cement Ltd., approached Royal Environment Auditing & Consultancy Services (REACS), Rajkot; a NABL accredited agency to prepare salinity ingress report from the inference of CSIR-CIMFR report. However, during presentation to SEAC, the committee suggested to get the report certified or prepare the mitigation measures based on the CSIR-CIMFR report from the reputed institutes in the field like CSIR-CSMCRI, Bhavnagar.

Therefore, UltraTech Cement Ltd. requested CSIR-CSMCRI to prepare salinity ingress mitigation measures and implementation plan or certification of the report prepared by REACS, Rajkot with necessary amendment.

The present report deals with certifications of the report of mitigation measures for salinity ingress prepared by REACS, Rajkot for the two new mines areas in and around Narmada Cement Mine, Jafarabad Works (NCJW), which is located in Amreli district of Gujarat state and owned by M/s UltraTech Cement Ltd.

The team of Scientists from CSIR-CSMCRI visited the old and new mining area during September 2019 and the piezometers station. The piezometric head near to new mining area in North and East pit of old mines area were recorded during on-site field visit. The water sample from the well near to North block pit was collected for further verification of data measured by REACS, Rajkot.

Further, the rain water harvesting ponds, structures and reservoirs area were visited to check the water storage efficiency on-site. The monthly and yearly data of the piezometers installed near to the water harvesting ponds were acquired to understand the effect of water harvesting structure in increasing the water table in ground water aquifer recharging.

The scope of work includes; (i) in depth study of the report prepared by the REACS, Rajkot (ii) ground truth/revaluation of the data collected by REACS, Rajkot (iii) site visit and determination of soil salinity level in some selected sites and (iv) determination of ground water quality with respect to common physio-chemical parameters.

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1. INTRODUCTION

Narmada Cement-Jafrabad Works a unit of UltraTech Cement Ltd. had setup a cement clinkerisation unit at village Babarkot, Taluka-Jafarabad in Dist. Amreli of Gujarat having capacity of 1.5 million TPA commissioned in 1981. UltraTech Cement Ltd., a flagship of Aditya Birla Group, is today the youngest and one of the most dynamically growing cement companies in India and has always been proud of its part in nation-building. UltraTech Cement Ltd. is the largest manufacturer of grey cement, Ready Mix Concrete (RMC) and white cement in India. The company has consolidated capacity of 117.35 Million Tonnes Per Annum (MTPA) of grey cement. UltraTech Cement has 23 integrated plants, 1 clinkerisation plant, 27 grinding units and 7 bulk terminals. Its operations span across India, UAE, Bahrain, Bangladesh and Sri Lanka. UltraTech Cement is also India's largest exporter of cement reaching out to meet the demand in countries around the Indian Ocean and the Middle East. UltraTech Cement Ltd. and its subsidiaries have a presence in 5 countries through 12 integrated plants, 1 white cement plant, 1 clinkerisation plant, 19 grinding units, 2 wall care putty plants, 7 bulk terminals and more than 100 RMC plants.

2. LOCATION AND ACCESSIBILITY

The details of the mining lease (ML) area and the location map is presented in Table 1 and Figure 1

Table 1. Lease details of ML area 49 Ha and 14 Ha

Lease details	ML Area: 49.8454 ha	ML Area: 14.2045 ha
Name of mine/ applied area	Babarkot Limestone Mine I	Babarkot Limestone Mine II
Lease No.	Survey Nos.: Various (Details of village wise survey no. falling in applied ML area is shown in Table 2 and Location Plan is shown in Figures 1-2.)	Survey Nos.: Various (Details of village wise survey falling in ML area is shown in Table 2 and Location Plan is shown in Figures 1 and 3.
Location of mine/ area Village, Tehsil, Police station - District	Village – Babarkot Taluka – Jafarabad District – Amreli (Guj.)	Village- Babarkot Taluka– Jafarabad District - Amreli (Guj.)
Forest (Specify)- Protected	No forest land involved	No forest land involved
Non Forest a) Waste land(Govt.) b) Grazing Land c) Agriculture land d) Others (private)	a) 0.172 b) Nil c) Nil d) 49.6734 Ha Village wise survey distribution of applied ML area has been tabulated below in Table 2.	a) Nil b) Nil c) Nil d) 14.2045 Ha Village wise survey number distribution of ML area has been tabulated below in Table 2.
Khasra no./ survey no.	Details have been enclosed as Table 2.	Details have been enclosed as Table 2.
Whether the area falls under Coastal Regulation Zone (CRZ)? if yes, details Thereof	No part of applied ML area has been reported to fall under Coastal Regulatory Zone (CRZ) as they are 2.8 km from sea (Aerial distance).	No part of ML area has been reported to fall under Coastal Regulatory Zone (CRZ). The

		part of open series maps No F42X5 and satellite imagery is being produced here showing relative position of ML boundary, CRZ boundary and Forest boundary.
Existence of public road/railway line, if any nearby and approximate distance	The applied area is located east of Jafarabad town, in the Amreli district of Gujarat. The whole applied area falls in revenue area of Babarkot village. Jafarabad is approachable by State Highway SH-34 which branches off from National Highway 8E (NH 8E) near Rajula. Rajula Railway junction is about 30 km from the applied area and is the terminus of broad gauge railway line from Ahmedabad. The road to Babarkot branches off from SH 34 about 3 km before Jafarabad town. The area is located about 2 km down this road. The nearest airport is Diu (65 km) and Bhavnagar (160 km) is connected by daily air service to Mumbai.	The ML area is located east of Jafarabad town, in the Amreli district of Gujarat. The whole area falls in revenue area of Babarkot village. Jafarabad is approachable by State Highway SH-34 which branches off from National Highway 8E (NH-8E) near Rajula. Rajula Railway junction is about 30 km from the ML area and is the terminus of broad gauge railway line from Ahmedabad. The road to Babarkot branches off from SH 34 about 3 km before Jafarabad town. The area is located about 2 km down this road. The nearest airport is Diu (65 km) and Bhavnagar (160 km) is connected by daily air service to Mumbai.
Topo sheet No. with latitude & longitude of all corner boundary point/ pillar	The area falls in topo sheet no. 41P/5 (Open Series Map No. F42X5 as per new nomenclature) which has been restricted by 5 competent authority of the area. The extension of applied ML area is: Latitude 20°53'13.20"N to 20°53'53.3"N & Longitude 71°23'00.10"E to 71°24'32.40"E. Boundary pillars latitude & longitude has been tabulated below.	The area falls in toposheet no. 41P/5 which has been restricted by competent authority of the area. The extension of ML area is: Latitude 20°55'55.40"N to 20°52'38.5"N & Longitude 71°24'26.6"E to 71°24'11.1"E. Open Series Map No. F42X5 as per new nomenclature is available which is being produced herewith for confirmation Boundary pillars latitude & longitude has been tabulated below.

Table 2. Khasra No/ Survey No. falling in two new mining area of 49 Ha and 14 Ha

Land Details of ML – 49.8454 Ha.				Land Details of ML – 14.2045 Ha	
Survey No.	Area in Ha.	Survey No.	Area in Ha.	Survey No.	Area in Ha.
83	1.5580	110/1	3.6522	217	2.0437
83	1.5479	111/2	0.7689	218	1.032
88	2.6710	111/1	0.1720	219/2	1.5783
89	2.8531	112/1	1.5985	219/3	1.7097
90	1.4468	114	2.4787	219/4	0.9712
90	2.4281	119/1	6.2524	220/1	1.4973
92	5.5037	126/1	0.7588	220/2	1.4872
92	1.6187	101	0.0304	221	2.3067
93	2.2157	102/1	1.6067	Total	14.2045
95	1.8211	102/2	1.6086		
96	0.9309	102/1/1	1.6086		
108	1.9425	105	1.5682		
109	1.2039	Total	49.8454		

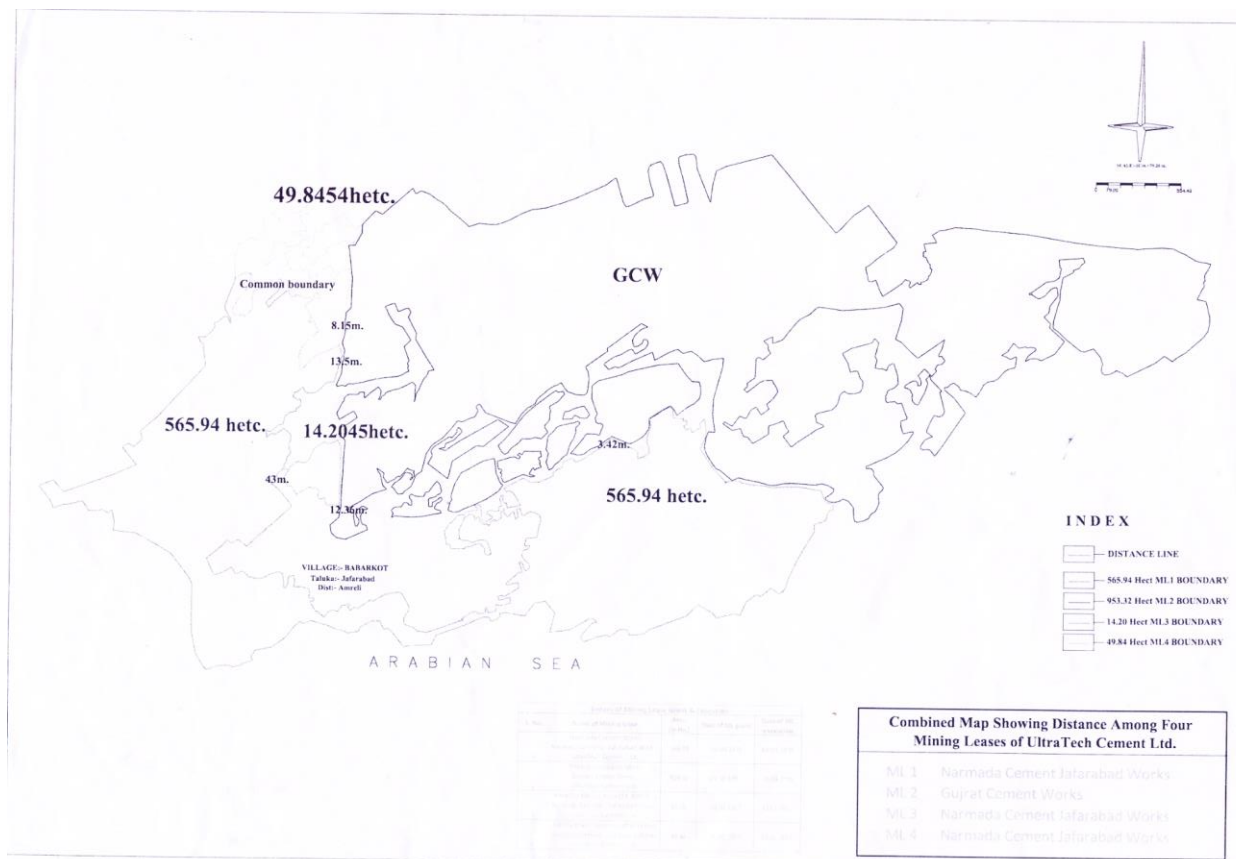


Figure 1. Map showing new mining area of 49 Ha and 14 Ha and old mining area of 565.94 Ha

FINAL REPORT ON
SALINITY INGRESS MITIGATION MEASURES AND IMPLEMENTATION PLAN FOR ULTRA TECH CEMENT LIMITED, NARMADA CEMENT
JAFARABAD WORKS, AMRELI (GUJARAT)



Figure 2. Location map of new mining area of 49 Ha with reference to coastal line



Figure 3. Location map of new mining area of 14 Ha with reference to coastal line

3. GEOLOGY AND EXPLORATION

Topography & Drainage Pattern

The area has generally flat to gently undulating topography and there are limestone cliffs along the sea coast near Jafarabad and Babarkot villages. There is large mud flat forming marshy land connected by Jafarabad creek. The highest contour at 48 m runs in south eastern area and lowest contour of 30 m runs in southern part of the applied area.

The applied area and even the surroundings are exposed as comparatively sub-undulating terrain of limestone dominated by the milliolitic limestone. The applied area is surrounded by two working and captive mines of UltraTech Cement Ltd., Narmada Cement-Jafarabad Works & Gujarat Cement works. The surrounding mining leases are under active working feeding to its two clinkerisation units. The applied area is lying in between these mining leases and geologically no changes observed.

There are three old pits viz., OP-1, OP-2 & OP-3 near boundary pillar no. 14, 33 & 55 respectively which are covered by windblown sand. There is neither any perennial nor seasonal drainage system existing within the applied area. In the area drainage is developed by Raidi river which is ephemeral in nature and roughly flowing north to south at a distance of 8 km in a NE direction and eventually merges into Jafarabad creek. General slope towards south & west direction and rainwater flows along slope.

Climate & Rainfall

The climate of the area is characterized by general dryness (except during the south-west monsoon season) and hot summer. The temperature ranges from 9.4 to 42.2 °C. The rainy season extends from mid-June to mid-September. The mean annual rainfall has been recorded as 819 mm and the relative humidity is generally high during June to September and is least during January to February.

The predominant wind direction from May to September is from West and South West while in the post monsoon and winter it is from South West to North East. In April to June the sky remains cloudless and moderately clouded during July to September.

Vegetation

The applied ML area is not having any indications of good vegetation and is generally devoid of large trees., *Acacia nilotica*, *Acacia ninuata* and *Prosopis juliflora* are some of the common species. Besides common trees, natural vegetation grows mostly during monsoon and fades away with the onset of summer. The area does not have any rare and endangered species.

Regional Geology of the Area

The Deccan-trap-covered coastal region of Saurashtra had experienced a number of marine transgressions and regressions during the late tertiary period. The rich limestone beds of the region were deposited by the accumulation of calcium-rich forameniferal (Miliolitic) crust and chemical precipitation of carbonates from the shallow sea. Land derived material from volcanic constituted the impurities in the limestone deposit. The regional geological set up of the Coastal Saurashtra Region is given in Table 3.

Table 3. Regional stratigraphic sequence of rocks

Age	Formation	Lithology
Holocene	Recent	Wind-blown sand, Fluvio-marine deposits.
Sub-recent to Pleistocene	Porbandar Beds	Miliolitic limestone, Marl, Calcareous shale, etc.
Pleistocene to Pliocene	Dwarka Beds	Cherty limestone, Clay, Silt.
Pliocene to Miocene	Gaj Beds	Variegated clay, Marl, Impure limestone, etc.
Eocene	Supratrappean	Impure limestone, Calcareous sandstone, Lateritic rock.
Eocene to Cretaceous	Deccan Trap and Intertrappean	Basaltic rock, with minor Intertrappean clay.

Traps: Deccan traps occupy most of the area and they include several types of volcanic rocks, which have come up through fissures in several eruptive phases. The main rock types encountered are intermediate types of basalt, trachyte, diorite, rhyolite, etc. The hilltops generally contain the hard and tough, compact massive flows, whereas the soft type occupies the valley floors and the plains. The hard flows stand out, whereas the softer ones are weathered to form low areas. The entire trap rocks show shearing and multi-directional fracturing.

Gaj Beds: Gaj beds occur as isolated outcrops at the margin of traps towards coast and as small mounds in the alluvium. They are marine sediments, comprising fossiliferous yellow marly limestone with clay.

Miliolite Limestone: The limestone deposits of the area are termed as "Coastal deposits" and it is marine limestone commonly known as Miliolite Limestone which occurs as thick cross-laminated beds. The name "miliolite" has apparently been derived from the Miliolidae, belonging to the common foraminifera present in the rock. Occurrence of such distinctive type of rocks is reported only along the Saurashtra (Kathiawar) coast and Kutch in Gujarat.

Recent Deposits: The youngest deposits in the district are represented by various types of soils, alluvium, windblown sand, fluvio-marine mud deposits of tidal flats and shell and shingle deposits of shore area.

Shape and size of the deposits and lithology

Stratigraphic sequence of the applied ML area is as under:

1. Wind Blown Sand
2. Miliolitic limestone intermixed with Marl construe
3. Deccan traps (basalt)

Windblown Sand

The younger most geological formation in the ML is windblown sand constitutes the overburden with an average thickness varying from 0.5 to 4.0 m occupying the flatter grounds, the thickness of overburden is comparatively more towards Kovaya and Vandh village while the thickness decreases towards village Babarkot which is on higher ground.

Miliolitic limestone

Just below the windblown sand, miliolitic limestone occurs as compact limestone & marl of varying thickness which can be average out to 25 m. With depth, there is general deterioration in the quality of limestone accompanied by soft, friable layers & lenses of marl. The limestone is buff, yellow or pinkish in colour, while the weathered surfaces show sooty to brownish appearance. The main constituent of the limestone is the calcic shell fragments of Miliola and related organisms. The limestone deposit shows enrichment in calcium content at the upper layers, due probably to leaching out of silica, calcium enrichment by capillary action and re-deposition in crevices. The limestone is generally compact, hard and bouldery in nature at many places. The average quality of limestone is varying in terms of CaO: 40.0 to 48.00, SiO₂: 4.0 to 7.5, Al₂O₃: 1.5 to 3.0 and Fe₂O₃: 1.0 to 2.5.

Deccan trap (basalt)

Below the limestone, Deccan traps occupy most of the area and it includes several types or volcanic rocks, which have come up through fissures in several eruptive phases. The main rock types encountered are intermediate types of basalt, trachyte, diorite, rhyolite, etc. The entire trap rocks show shearing and multi-directional fracturing.

Structural Features

The limestone of this area is miliolitic limestone, which follows general strike N700 ES700 W and dips gently in NNW-SSE direction. Minor vertical and inclined joints are present and can be observed all along the mine face.

4. COMPARATIVE OBSERVATION AND SUGGESTIONS

Following action plan suggested by REACS, Rajkot to prevent salinity ingress for two new mines areas in and around UltraTech Cement Limited (Unit: Narmada Cement – Jafarabad Works) Narmada Cement Mines.

4.1. Seawater should be prevented from intruding into the mainland as far as possible.

(a) Suggestions by CSIR-CIMFR:

Based on the Resistivity Survey, Water Quality Analysis and the Ground Water Modelling (SEAWAT-2000) it is concluded that the sea water intrusion (SWI) or salinity ingress is extended up to the East Pit and North Pit of NCJW limestone mine in 2017. The most positive aspect is that it is present at depth more than the planned mining depth.

It is found that though there is progress of salinity ingress in this coastal region, which is a natural phenomenon occurring in any coastal environment globally but the progress of plume is very less and steady. Probably the concerted efforts of the UltraTech Cement Ltd. and mine management through artificial recharge, water harvesting and sustainable water conservation measures adopted since the inception is the reason for this trend. It is estimated that the water table lies in the range of 14.00 to 17.0 m (approximately) in the core zone i.e. near the mine lease area and around the Babarkot village. Average depth of water table (DWT) in the dug wells of study area has recorded variations from place to place.

Water level fluctuations (WLF) in the study region lies in the range of 0.15 to 9.87 m BGL. The depth to water level varies from 1.0 to 21.36 m (BGL) in the pre-monsoon period (May, 2017) and varies from 0.35 to 20.26 m (BGL) in the post-monsoon period (November, 2016). Average flow of ground water is towards the seacoast.

It is concluded that mining in future (i.e. with deepening of mine further and expansion of mine production) can be done up to (-) 08 m MRL safely and conveniently because 'intrusion zone' lies at a depth of more than 20 to 22 m below ground level (observation of ERT results). Cross-section of pits at different pit depth and ERT analysis of SWI clearly concludes that mining is feasible and safe.

Based on CSIR-CIMFR study it is concluded that mining in future (i.e. with deepening of mine further) can be done up to (-) 08 m RL because 'intrusion zone' lies at a depth of more than 20 – 22 m (observation of ERT results). As a rule of thumb, if the low-resistivity zone (SWI zone) lie below the actual excavation level, mining can be done safely and conveniently.

Seawater should be prevented from intruding into the mainland as far as possible by adopting 'control measures' as described in this report. Sea water can also be contained naturally by maintaining a higher head of fresh water creating hydraulic gradient towards the sea. Simultaneously in the study area,

both deep and shallow coastal aquifers should be protected. It is recommended to make use of scientific principle only for restricting ground water pollution.

(b) Suggestion by REACS, Rajkot:

The mining will be above ground water level with no ground water intersection during mining period. As per mining plan the maximum ultimate depth of mining pit will be 0 m RL. The ground water level in core zone and buffer zone is as below.

Pre-Monsoon: (-) 2 m RL to (+) 4 m RL

Post-Monsoon: 0 m RL to (+) 6 m RL

Hence, no ground water intersection.

(c) Observation and suggestions by CSIR-CSMCRI:

According to study of CSIR-CIMFR report, the depth for future mining is allowed in range of up to (-) 4 m to (-) 8 m MRL in old existing mining area which is adjacent to the new mining area of 49 Ha and 14 Ha and within 100 m distance. Based on that it is found feasible and safe for new mining area. The present excavated average depth of mining is maximum 2.5 m in old mining area as per data provided by UltraTech Cement Ltd. and excavation RL map submitted by client is safe for mining. Based on the surface plan of new mining area 49 Ha and 14 Ha, the area is approximate ranging from (+) 30 to (+) 46 m RL and from (+) 10 to (+) 22 m RL which is quite higher than mean sea level according to surface plan with contour map submitted by the client. Based on the Approved Mining Plans issued by the Indian Bureau of Mines, Gandhinagar, the mining depth of (+) 0.00 m AMSL is safe for new mining area of 14 Ha and in case of 49 Ha, the maximum ultimate level of working upto 18.00 m AMSL. It is suggested to maintain/monitor the monthly piezometer data in 2 to 3 locations far from water harvesting ponds and 2 to 3 points close to water harvesting structure in both the ML area to understand the ground water level variation and to initiate the steps towards mitigation measures in advance. Further, the consumption of ground water in the study area and mine is not very high because of brackishness nature of ground water.

4.2. Seawater can be contained naturally by maintaining a head of fresh water above sea water

(a) Suggestions by CSIR-CIMFR:

Seawater should be prevented from intruding into the mainland as far as possible by adopting 'control measures' as described in this report. Sea water can also be contained naturally by maintaining a higher head of fresh water creating hydraulic gradient towards the sea. In the study area, both deep and shallow coastal aquifers should be protected. It is recommended to make use of scientific principle only for restricting ground water pollution.

It is recommended that recharging of the aquifer, either through 'mined out pits' or through 'dug out depression area' of topography shall be done to the maximum possible extent. From the modelling

analysis, it is concluded that the pace of salinity ingress is very-very slow over the years which means that the 'water management' measures at Narmada Cement Mine are playing positive role in salt water intrusion (SWI) containment. Surface water storage should be encouraged and alternatively some additional arrangements for the recharge structures may be made in the lease area or in the surroundings.

(b) Suggestion by REACS, Rajkot:

It is proposed to create four water storages during the mine life and these rainwater storages will cover an area of 17.64 Ha. Total 0.1361 MCM (for 49.8454 Ha. Lease) and 10.935 Ha. Total 0.0847 MCM water will be stored in harvested rain pits and this water storage will create head of fresh water above the sea water and will help to prevent the salinity ingress (Appendix-II).

(c) Observation and Suggestions by CSIR-CSMCRI:

The team of Scientists of CSIR-CSMCRI has visited new mining areas; 49 Ha and 14 ha with existing 565.94 Ha mining area of UltraTech Cement Limited (Unit: Narmada Cement - Jafarabad works) (Figure 4). The water harvesting structures and ponds mentioned in Report of REACS, Rajkot were visited and verified at mining site by CSIR-CSMCRI team. The data submitted by CSIR-CIMFR report and REACS, Rajkot for Piezometer head near to water harvesting structure were collected and analyzed.



Figure 4. Site visit by CSIR-CSMCRI to old and new mining sites having 565.94 Ha area

Actual Piezometer level has studied and found that there are no major changes of fall and rise variations in the ground water level due to draining out of ground water because of parallel slow recharging of aquifer during the monsoon season through efforts of UltraTech Cement Ltd. of constructing rain water harvesting ponds in mined out pit.

Very less post monsoon piezometer data are available for recharge studies and it is recommended to maintain the seasonal monthly data of sufficient piezometers, installed at various location near to harvesting ponds and mining areas. Considering the average rainfall of last 5 years 2015-2019 as 813 mm, based on rainfall data provided by client, the water harvesting through runoff and recharge ponds are

considered as 6% of average annual rainfall for total area of recharge ponds according to ground water recharge guidelines. In the present mining area, the average 5 years' rainfall is 0.813 m and area of recharge pond is 17.64 ha x 10,000 = 1,76,400.0 sq. m. Considering 6% of avg. rainfall as recharge depth, the recharge water is estimated to be 176400 sq. m x 0.813 m = 8605 cum = 0.008605 MCM considering the total area of all existing recharge ponds near to mining area. The actual ground water recharge may be calculated by UltraTech Cement Ltd. using actual piezometer data near to water harvesting pond with dug wells inside. The ground water recharge is considered as 50% of storage capacities of total volume of water harvesting pond by REACS, Rajkot which is not supported by any guidelines, standard literatures, but considering 20% of recharge capacities of total volume of water harvesting ponds will also increase ground water table in pervious aquifer in future years. Further, the consumption of ground water in the study area and mine is not very high because of brackishness of ground water so and it helps in maintaining water table of the area.

UltraTech Cement Ltd. has adopted measures to reduce salinity ingress and conservation of sweet water in this water scarce region. It is suggested that excavated area will be un-reclaimed and will be leftover as a water reservoir. The mining area covering 20.14 ha shall be gradually developed and exploited for limestone. Part of the mined out area is envisaged for backfilling with the available overburden sand measuring to 2.50 ha. It is proposed to create four water storages during the mine life. These rainwater storages will cover an area of 17.64 ha according to the report submitted by REACS, Rajkot. Rain Water Harvesting will be suggested in Mine Sump created in completely mined-out area that will cover approximate 17.64 ha area. In North Block pit of existing mining lease of UltraTech Cement Limited (Unit: Narmada Cement – Jafarabad Works), having water holding capacity of 6.50 Lakhs m³ which holds water throughout the year, and in East Block pit of the lease mined out area hold the recharge water during the monsoon. A network of drains / garland drains, culverts and earthen check bunds have been made by UltraTech Cement Ltd. To guide surface run-off to this artificial lake, to prevent fresh water from flowing into the sea. Water from this lake is suggested to use for consumption in clinker plant and for raising plantation along with drinking purpose.

4.3. Recharging of the aquifer, either through 'mined out pits' or through 'dug out depression area' to maximum possible extent by adopting scientific ground water management approach

(a) Suggestions by CSIR-CIMFR:

It is recommended that recharging of the aquifer, either through 'mined out pits' or through 'dug out depression area' of topography shall be done to the maximum possible extent.

From the modelling analysis, it is concluded that the pace of salinity ingress is very-very slow over the years. It means that the 'water management' measures at Narmada Cement Mine are playing positive role in SWI containment. Surface water storage should be encouraged and alternatively some additional arrangements for the recharge structures may be made in the lease area or in the surroundings.

(b) Suggestion by REACS, Rajkot:

The company has taken remarkable steps for rain water harvesting in surrounding area for rain water harvesting. Total ground water recharge by five percolation ponds having storage capacities of 0.52, 0.897, 0.085, 0.5 and 0.015 MCM respectively has suggested according to report submitted by REACS, Rajkot. Total 1.492 MCM rain water will be stored and by taking 50% of recharge than 0.746 MCM water will be recharge (Appendix-II).

(c) Observation and Suggestions by CSIR-CSMCRI:

As evident from CSIR-CIMFR's investigation that salinity ingress is taking place in the area and effective water management will pave the way to contain it. Therefore, following management measures are of immense importance and therefore suggestive. For the present scenario, the augmentation of ground water recharge, through simple and economical means is beneficial in future. This can be implemented by;

- (a) Rain water harvesting in mining pits (direct artificial surface recharge).
- (b) Creating recharge structure and creating head towards sea for containment of intrusion.
- (c) Adopting scientific ground water management approaches.

The above ground water management includes proper scientific investigations aimed at assessing source for artificial recharge, studies on effect of recharge structures on variation of static water level before and after the implementation of the recharge structures, possibilities of recycling and reuse of waste water for ground water recharging and exploring effective ground water recharging techniques and planning and management for utilizing for crop water requirement for irrigation fields nearby rural land area according to "Manual of Artificial Recharge Of Ground Water" published by Central Ground Water Board, New Delhi.

Rainwater was harvested and accumulated in the lower most benches/ level of mined out pits. Accumulated rainwater is acting as ground water recharge structure & water harvested has used for plantation, drinking purpose, dust suppression and consumption in clinker plant according to report submitted by REACS, Rajkot.

Existing Babarkot Mines percolation pond-1 in the mine

Old mine pit covering an area of 6.5 hectares which was formed during the period from 1979 to 2000 and diversion of surface runoff from the surroundings area in the old pit. Narmada Cement Mine has also constructed a recharge open well in this pond (refer Figure 5).

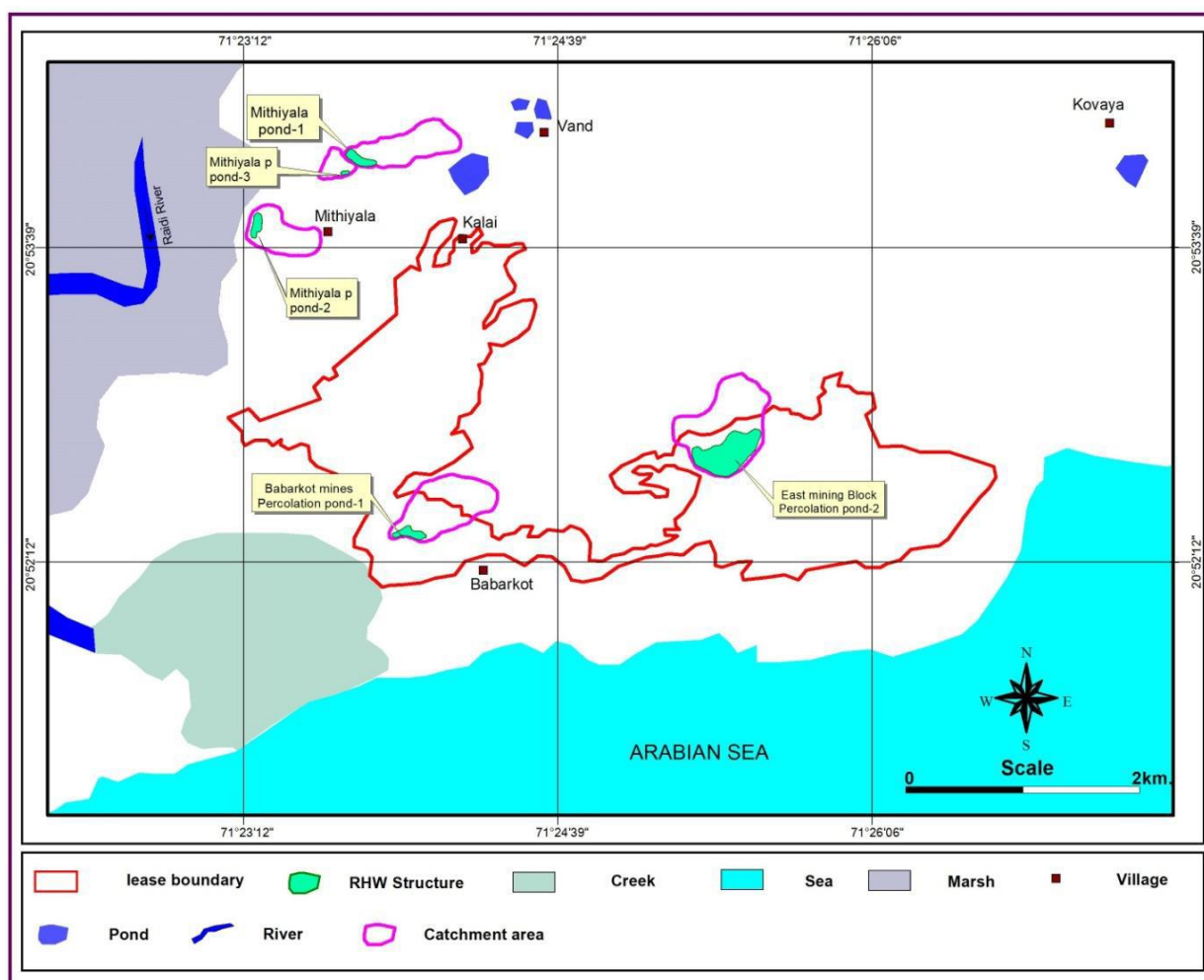


Figure 5. Map showing the location of existing five percolation ponds
(Source: Report prepared by REACS, Rajkot)

The team of Scientists of CSIR-CMSCRI has verified the water harvesting ponds and structure on existing and new mining site which has shown by report of REACS, Rajkot, the harvesting storage ponds are maintained near to existing and new mining area of Narmada Cement Jafarabad works as shown in Figure 6. CSIR-CSMCRI team has visited the new mining site and verified the efforts of UltraTech Cement Ltd. for rain water harvesting at excavated mining area (Figure 7). The piezometer head was collected for various locations such as in North block and East block. The Piezometer head in 3 locations were measured by CSIR-CSMCRI and found as 12.83 m, 8.9 m and 13.27 m for point location of North block and East block near sea cost belonging to existing mining area. Further, based on REACS, Rajkot report percolation pond was deepened by Narmada Cement – Jafarabad Works as a part of corporate social responsibilities (CSR) with average 1.5 meters deepening depth in nearby villages (i.e. Babarkot & Mitiyala). So, incremental water storage benefit is achieved by pond deepening which in turn will help in increasing storage capacity and contribute to artificial recharging of ground water aquifer.



Figure 6. Visit near to coastal boundary within existing lease and observation well-5



Figure 7. Water harvesting ponds developed in mined out pit at existing lease area

Total ground water recharge by five percolation ponds having storage capacities of 0.52, 0.897, 0.085, 0.5 and 0.015 MCM respectively has suggested by REACS, Rajkot should be maintained by UltraTech Cement Ltd. so that total 1.492 MCM rain water will be stored and will help in ground water recharging of the area.

4.4. Installation of Piezometers in sufficient numbers

(a) Suggestions by CSIR-CIMFR:

Operational / functional 'Piezometers' is recommended to be installed in sufficient number around the mining pits (*i.e.*, near North Pit) and the entire lease area shall be covered with such installations.

(b) Suggestion by REACS, Rajkot:

The company has already installed of Piezometers (06 nos.) in core zone to measure the ground water level and ground water quality during pre-monsoon and post monsoon (Appendix-II).

(c) Observation and Suggestions by CSIR-CSMCRI:

CSIR-CSMCRI team visited below mentioned Piezometer locations and water samples were collected from observation open well during visit from mining site. The regular monthly data collected from all installed piezometers were suggested to monitor the possibilities of ground water and salt water intrusion. It is recommended to maintain other 2-3 piezometer station near to new mine area from existing piezometers from map submitted by client. The comparison of the past and present Piezometer head data shows that point located near to rain water harvesting ponds area (PZM 4, 5) having increased water level means depth of ground water table from ground level has decreased. (refer, Table 4 and 5). Table 4 shows the piezometer data which means average ground water depth (of all three seasons) from surface provided by client for year 2011 to 2016. The decreased depth of ground water from surface shows the rise in water table over the period of 6 years. Table 5 shows the comparison of present data collected from mining site for selected piezometer station and observation well with past record maintained by Client. The on field piezometer data collected by CSIR-CSMCRI from Point PZM-1, PZM-4 and PZM-5 are shown in Figures (8-10) respectively. The location of piezometer points and observation well from where data and sample collected for verification of data provided in report of REACS, Rajkot is shown in Figure 11.

Table 4. Seasonal average ground water depth from surface (in meters) provided by UltraTech Cement Ltd.

Year	PZM- 1	PZM- 2	PZM- 3	PZM- 4	PZM- 5	PZM- 6
2011	25.95	-	7.13	24.73	15.11	14.98
2012	-	-	7.31	24.35	15.35	14.63
2013	-	-	5.45	-	13.75	15.20
2014	-	-	6.70	-	14.43	15.07
2015	11.88	10.72	6.20	13.42	12.90	14.89
2016	11.53	10.40	5.60	12.83	13.27	14.70
2018	12	9.67	2.90	8.9	13.78	14.12

Table 5. Comparison of past and present Piezometer head data collected from mining site by CSMCRI

No.	Piezometer	Location	Latitude	Longitude	Past data of Piezometer head (m)	Present Piezometer head (m)
1.	PZM-1	View point of North block Mines	N 20° 53' 14'8"	E 71° 23' 51'3"	11.53 m (2016 data)	12.0 m
2.	PZM-4	Traffic point of Eastern block Mines	N 20° 52' 34'29"	E 71° 25' 21'92"	12.83 m (2016 data)	8.9 m
3.	PZM-5	Near Varahswaroop road well	N 20° 52' 35'73"	E 71° 25' 40'98"	13.27 m (2016 data)	13.78 m
4.	Well-5	Near Varahswaroop road (Adjacent to PZM-5)	N 20° 52' 33'33"	E 71° 25' 30'01"	-	Well sample collected for quality analysis

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Figure 8. Piezometer head Measurement (PZM-4) in Eastern Block Mines by CSIR-CSMCRI



Figure 9. Piezometer head Measurement (PZM-5) near Varahswaroop road well by CSIR-CSMCRI



Figure 10. Piezometer head Measurement (PZM-1) in North Block Mines

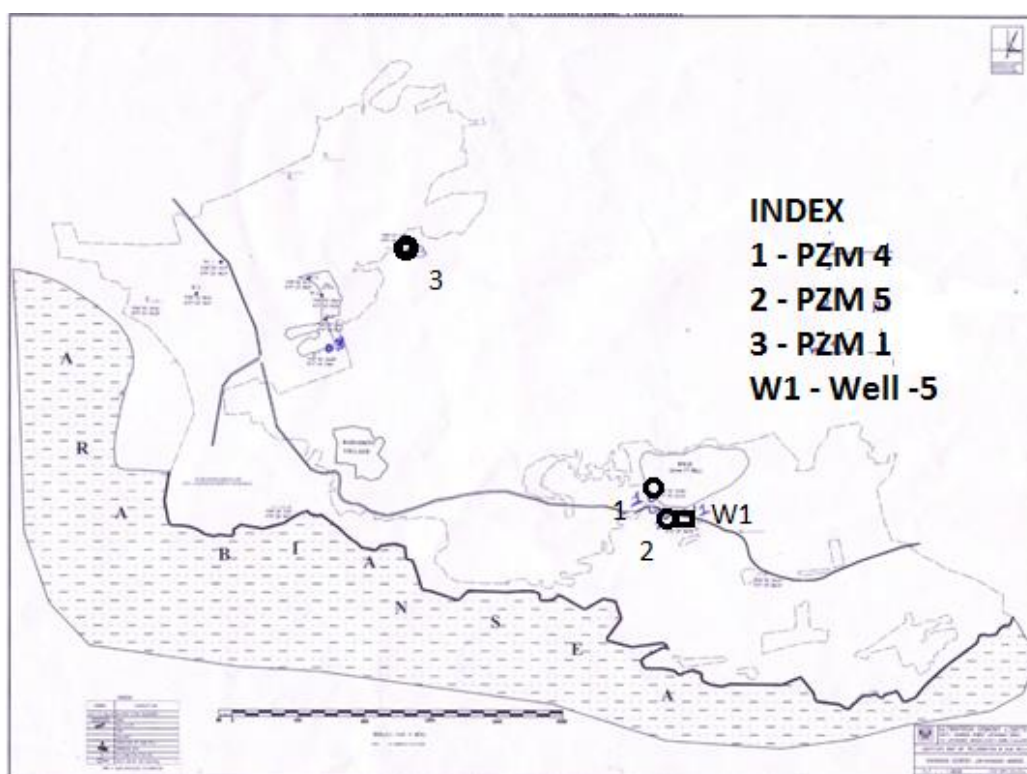


Figure 11. Map showing the data collected from Piezometer points by Team of CSMCRI during site visit as shown in Table 5

4.5. Regular ground water monitoring in Core zone and buffer zone for TDS, Na, Chloride etc.

(a) Suggestions by CSIR-CIMFR:

Periodical monitoring of total dissolved solid (TDS), sodium and chloride concentration in ground water is recommended for measurement in all season of the year. In view of presence of SWI, it is recommended that caution be exercised while continuing mining operation at depth below ground level.

However, mining at restricted depth, up-to the depth range of (-) 4m to (-) 8m RL, will be safe depending on the practical conditions encountered.

(b) Suggestion by REACS, Rajkot:

The company has already installed 06 nos. of Piezometers in core zone to measure the ground water level and ground water quality during pre-monsoon and post-monsoon. In addition to this the company is regularly monitoring the surrounding 05 km wells for ground water quality and its level as per CGWA Guideline (Appendix II for Pre-monsoon/Post monsoon water Quality reports).

(c) Observation by CSIR-CSMCRI:

It was verified from UltraTech Ltd., that pre-monsoon and post-monsoon ground water quality data such as TDS, pH, alkalinity, Na and Cl were regularly monitored. CSIR-CSMCRI has collected water quality analysis data from company. Further, data measured in the report of REACS, Rajkot has also compared with data collected from site by team of CSIR-CSMCRI. It is found that UltraTech Cement Ltd., is regularly monitoring the well data suggested by CSIR-CIMFR for ground water quality and they are in line with actual sample collected from site during mines visit and reported by REACS, Rajkot in their report.

The team of Scientists of CSIR-CSMCRI has collected well water sample from Narmada Cement Mine site as shown in Figure-12 for comparison of well water quality data provided by REACS, Rajkot and the results were compared and the values in compliance and satisfactory. Further, the water quality parameters analyzed from sample collected from site, shown in Table 6 have found in line with data submitted by REACS, Rajkot. The brackishness of water in open well sample confirm with report submitted by CSIR-CIMFR and data submitted by REACS, Rajkot Report (Table6). Table 7 shows that the water quality analysis data collected from the client and it is recommended to monitor ground water level data for Well-2,3,4 and 6 regularly for pre-monsoon, monsoon and post-monsoon season in future years similar to other well no. 1,5,7,8 and 9.

Table 6. Comparison of quality of well water collected by CSIR-CSMCRI with past data for Narmada Cement Mine lease area of UltraTech Cement Ltd.

No.	Parameter	Present Quality of Well -5 water sample collected from site	Method	Past data of Well-5 (Near Varahswaroop road (Adjacent to PZM-5))
1	TDS	1145 mg/L	APHA (23 rd Edition) 2540 C: 2017 (Gravimetric)	1880 mg/L
2	Salinity	2241 mg/L	In-house method	-
3	Electrical Conductivity	4080 μ S/cm	APHA (23 rd Edition) 2510. B: 2017 (Electrochemical)	3462 μ S /cm
4	pH	8.247 (no unit)	APHA (23 rd Edition) 4500-H+ B:2017 (Electrometric)	7.82
5	Alkalinity	320 mg/L	APHA (23 rd Edition) 2320 B: 2017 (Titrimetric)	350 mg/L
6	Calcium	405 mg/L	In-house method	132 mg/L
7	Magnesium	174 mg/L	APHA (23 rd Edition) 3125-B:2017 (ICP-MS)	184 mg/L
8	Chloride	433.86 mg/L	APHA (23 rd Edition) 4500-Cl-B:2017 (Argentometric)	428.46 mg/L
9	Potassium	12.0 mg/L	APHA (23 rd Edition) 3125-B:2017 (ICP-MS)	15.3 mg/L
10	Sodium	405.6 mg/L	APHA (23 rd Edition) 3125-B:2017 (ICP-MS)	542 mg/L

Well sample data collected from near to mining area and near to coastal region and data submitted by REACS, Rajkot are well within the actual field data collected by team of scientist of CSIR-CSMCRI.



Figure 12. Observation well water sample collected from Well-5 near Varahswaroop road (Adjacent to PZM-5) during site visit of CSIR-CSMCRI

Table 7. Water Analysis report of Observation wells as submitted by UltraTech Cement Ltd.

Well No	May-18								Aug-18				
	Units	Requirement (Acceptable Limit)	Permissible limit in absence of alternate sources	W-1	W-5	W-7	W-8	W-9	W-1	W-5	W-7	W-8	W-9
TD (mts)	Mtr	--	--	15.35	17.50	22.00	18.00	22.80	15.35	17.50	22.00	18.00	22.80
S.W.L. (mts) PZM head	Mtr	--	--	13.34	14.68	20.55	16.58	13.58	8.46	14.00	19.96	15.79	12.98
EC	µmhos / cm	--	--	1175	3883	6575	5919	2969	1428	3462	5987	6528	2857
pH	-	6.5-8.5	No Relaxation	7.64	7.93	7.65	8.22	7.75	7.43	7.82	7.38	7.70	7.00
Total Dissolved Solid (TDS)	mg/L	500	2000	649	2180	3756	3388	1573	758	1880	3192	3598	1588
Calcium (as Ca)	mg/L	75	200	24	68	373	140	72	128	132	280	269	96
Magnesium (as Mg)	mg/L	30	100	49	136	138	129	44	17	61	100	100	22
Sodium (as Na)	mg/L	-	-	143	246	508	226	246	104	542	931	1148	448
Potassium (as K)	mg/L	-	-	3.6	17.9	14.9	1.5	7.4	4.0	15.3	10.5	24.4	6.6
Ammonia (as total ammonia-N)	mg/L	0.5	No Relaxation	0	0	0	0	0	0	0	0	0	0
Phosphate	mg/L	-	-	0.020	0.088	0.132	0.112	0.045	0.065	0.091	0.145	0.113	0.105
Fluoride (as F)	mg/L	1	1.5	0.54	0.83	0.48	0.53	0.50	0.97	0.89	0.82	1.00	0.80
Carbonate (as CO ₃)	mg/L	-	-	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Bi-Carbonate (as HCO ₃)	mg/L	-	-	330	360	580	290	380	310	350	300	510	400
Sulphate (as SO ₄)	mg/L	200	400	47	57	80	164	64	51	128	168	134	108
Nitrate (as NO ₃)	mg/L	45	No Relaxation	-	-	-	-	-	9.50	18.30	25.30	28.30	18.50
Chloride (as Cl)	mg/L	250	1000	139.12	942.94	1737.7	1576.06	597.2	103.62	428.462	1222.71	932.6	397.2
Sodium Absorption Ratio (SAR)	-	-	-	33.40	34.40	44.90	27.50	45.70	17.20	78.00	95.50	119.70	82.50
Soluble Sodium Percentage (SSP)	-	-	-	66.20	54.60	49.90	45.60	68.00	41.60	73.70	71.00	75.70	79.20

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Residual Sodium Carbonates (RSC)			-	-	-	257.30	155.80	69.00	21.00	264.2	164.80	157.10	40.20	142.00	282.00
Kelly's salt Ratio (KSR)			-	-	-	1.96	1.21	0.99	0.84	2.12	0.71	2.81	2.45	3.12	3.80
Puri. Salt Index(PSI)			-	-	-	-32.70	-246.40	-2184.20	-788.20	275.30	-823.20	-413.80	-1093.00	-792.60	-247.80
Cl	CO ₃ + HCO ₃			-	-	0.42	2.62	3.00	3.43	1.57	0.33	1.22	4.08	1.83	0.99
Hardness	Ca	CaCO ₃	mg/L	-	-	60.38	169.66	927.63	349.3	179.64	319.36	329.34	697.34	668.65	239.52
	Total		mg/L	200	600	260	730	1500	880	360	390	580	1110	1080	330
P-Alkalinity		CaCO ₃	mg/L	-	-	0	0	0	0	0	0	0	0	0	0
T-Alkalinity			mg/L	200	600	330	360	580	290	380	310	350	300	510	400

5. Study of Coastal Regulation Zone Mapping of the area

Figure 13 and 14 shows the CRZ mapping of Narmada Cement Mine lease area and location of 49 Ha and 14 ha new mining area along with 500 meters CRZ line in Babarkot region. The CRZ map confirms that both the new mining area of 49 ha and 14 ha are beyond the 500 m limit of CRZ. No part of applied ML area has been reported to fall under Coastal Regulatory Zone (CRZ), where both the lease area (49 Ha and 14 Ha) are situated nearby sea coast but beyond the 500 m limit of CRZ so no danger is envisaged this regard. Observation from nearby wells & bore wells in the area reveal that depth of water table is below the mean sea level. Except for the scanty rainfall in this semiarid region, there is no source of water that is likely to be encountered in the pits. Rainwater was harvested and accumulated in the lower most benches/ level of mined out pits. Accumulated rainwater is acting as ground water recharge structure & water harvested has used for plantation, dust suppression and consumption in clinker plant according to report submitted by REACS, Rajkot.

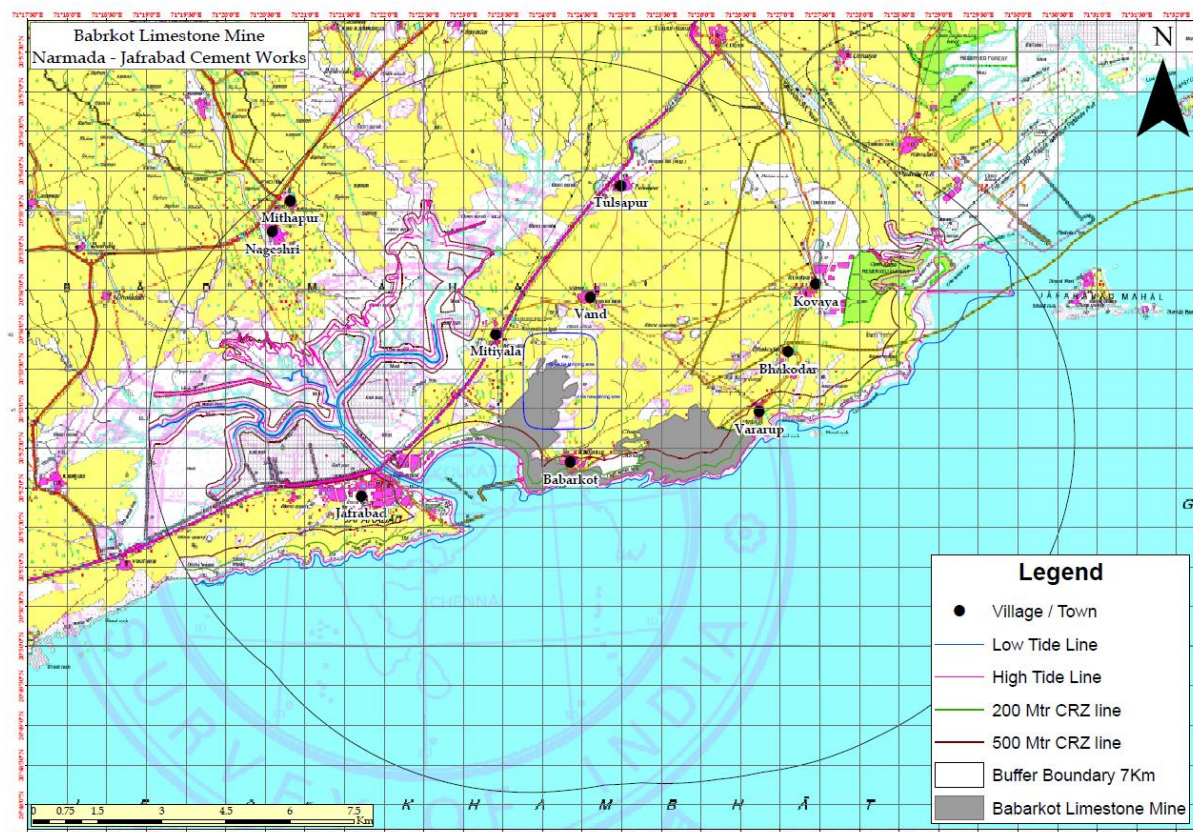


Figure 13. CRZ mapping of Narmada mines area provided by UltraTech Cement Ltd. for Amreli district

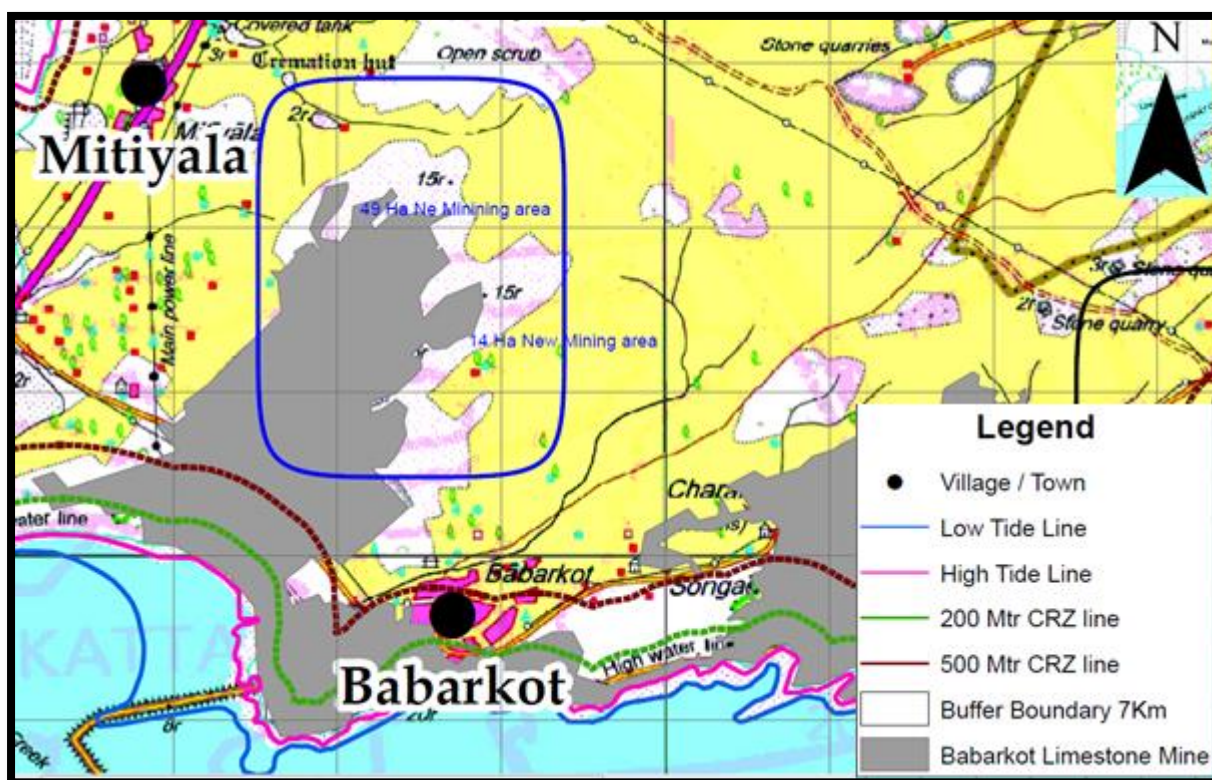


Figure 14. New lease mining area of 49 Ha and 14 Ha in CRZ mapping for Babarkot area (area highlighted in blue line)

6. SUGGESTIONS

Every mine needs to be planned in a way that the useable mineral is extracted to the maximum extent without causing severe irreversible environmental damages. As the area is facing scarcity of water hence found useful to convert the mined out area into rainwater storage. A water body will be a pleasing addition. This will avoid any chance of salinity ingress into the groundwater.

Additionally, the rainwater harvested in mined out area shall induce freshwater recharge, thereby improving the quality of the groundwater in the upstream areas. In view of the above, it would be appropriate to convert the mine into a mix of water bodies to stabilize the groundwater with green belt area for ecological and aesthetic restoration. The mine planning and land reclamation shall be carried out to achieve the above activity.

It is recommended to plant trees to develop greenbelt at the end of mining plan. Further, it is expected to harvest and store water bodies. The disturbed land will be fully reclaimed/rehabilitated before abandoning the mine. The excavated areas will be beneficial to human being, flora and fauna, in this water starved region of Amreli district of Gujarat state.

7. RECOMMENDATIONS

- From the CSIR-CIMFR modelling, it is arrived that the pace of salinity ingress is very-very slow over the years. It means that the 'water management' measures are playing positive role in Sea Water Intrusion containment. The ground water flow direction in the study area is towards the seacoast. This is due nos. of rainwater harvesting structures created by NCJW in and around the mining lease area over a last many years.
- It is recommended that recharging of the aquifer, either through 'mined out pits' or through 'dug out depression area' of topography shall be done to the maximum possible extent. Surface water storage should be encouraged and alternatively some additional arrangements for the recharge structures may be made in the lease area or in the surroundings. As the area is facing scarcity of water hence found useful to convert the mined out area into rainwater storage. This will avoid any chance of salinity ingress into the groundwater.
- Very less post monsoon piezometer data are available for recharge studies. It is recommended to maintain the seasonal monthly data of sufficient piezometers, installed at various location near to harvesting ponds and mining areas.
- According to study of CSIR-CIMFR report, the depth for future mining is allowed for old mining area in range of up to (-) 4 m to (-) 8 m MRL in old existing mining area which is adjacent to the new mining area of 49 Ha and 14 Ha and within 100 m distance. Based on that it is found feasible and safe for new mining area. The present excavated average depth of mining is maximum 2.5 m in old mining area as per data provided by UltraTech Cement Ltd. and excavation RL map submitted by client is safe for mining.
- Based on the surface plan of new mining area 49 Ha and 14 Ha, the area is approximate ranging from (+) 30 to (+) 46 m RL and from (+) 10 to (+) 22 m RL which is quite higher than mean sea level according to surface plan with contour map submitted by the client. The mining depth of 0 m RL is safe for new mining area of 49 Ha and 14 Ha considering suggestion from REACS, Rajkot report and CSIR-CIMFR data of water table for pre-monsoon and post-monsoon season considering similar geological conditions and ground water table. It is suggested to maintain/monitor the monthly piezometer data in 1 to 2 location far from water harvesting ponds and 2 to 3 points close to water harvesting structure to understand the ground water level variation and to initiate the steps towards mitigation measures in advance. Further, the consumption of ground water in the study area and mine is not very high because of brackishness nature of ground water.
- It is also recommended to maintain other 2-3 piezometer station near to new mining area of 49 ha and 14 Ha from existing working piezometers which can be identified from PZM location map submitted by client. It is suggested to maintain monthly piezometer data in 2 to 3 locations far from water harvesting ponds and 2 to 3 points close to water harvesting structure for ground water level variation study and estimating recharging capacity of the nearby area of harvesting structures and to initiate steps towards mitigation measures in advance wherever water table is depleting. Regular monitoring of these data through some specialize institute should be carried out and

their recommendation can be implemented time to time. Some important piezometer locations can be converted to automatic type in place of manual for easy operation during data collection. By establishing Piezometer network in both the new mines of 49 Ha and 14 ha and surrounding area the ground water table fluctuation and quality should be monitored.

- As evident from CSIR-CIMFR's investigation that salinity ingress is taking place in the area and effective water management will pave the way to contain it. Therefore, following management measures are of immense importance and therefore suggestive. For the present scenario, the augmentation of ground water recharge, through simple and economical means is beneficial in future. This can be implemented by;
 - (a) Rain water harvesting in mining pits (direct artificial surface recharge).
 - (b) Creating recharge structure and creating head towards sea for containment of intrusion.
 - (c) Adopting scientific ground water management approaches.
- Rainwater was harvested and accumulated in the lower most benches/ level of mined out pits. Accumulated rainwater is acting as ground water recharge structure & water harvested has used for plantation, dust suppression and consumption in clinker plant according to report submitted by REACS, Rajkot.
- Very less post monsoon piezometer data are available for recharge studies and it is recommended to maintain the seasonal monthly data of sufficient piezometers, installed at various location near to harvesting ponds and mining areas. Considering the average rainfall of last 5 years 2015-2019 as 813 mm, based on rainfall data provided by client, the water harvesting through runoff and recharge ponds are considered as 6% of average annual rainfall for total area of recharge ponds according to ground water recharge guidelines. In the present mining area, the average 5 years' rainfall is 0.813 m and area of recharge pond is 17.64 ha x 10,000 = 1,76,400.0 sq. m. Considering 6% of avg. rainfall as recharge depth, the recharge water is estimated to be 176400 sq. m x 0.813 m = 8605 cum = 0.008605 MCM considering the total area of all existing recharge ponds near to mining area. The actual ground water recharge may be calculated by UltraTech Cement Ltd. using actual piezometer data near to water harvesting pond with dug wells inside. The ground water recharge is considered as 50% of storage capacities of total volume of water harvesting pond by REACS, Rajkot which is not supported by any guidelines, standard literatures, but considering 20% of recharge capacities of total volume of water harvesting ponds will also increase ground water table in pervious aquifer in future years. Further, the consumption of ground water in the study area and mine is not very high because of brackishness of ground water so and it helps in maintaining water table of the area.
- UltraTech Cement Ltd. has adopted measures to reduce salinity ingress and conservation of sweet water in this water scarce region. It is suggested that excavated area will be un-reclaimed and will be leftover as a water reservoir. The mining area covering 20.14 ha shall be gradually developed and exploited for limestone. Part of the mined out area is envisaged for backfilling with the available overburden sand measuring to 2.50 ha. It is proposed to create four water storages during the mine life. These rainwater storages will cover an area of 17.64 ha according to the report submitted by

REACS, Rajkot. Rain Water Harvesting will be suggested in Mine Sump created in completely mined-out area that will cover approximate 17.64 ha area. In existing mining lease, having water holding capacity of 6.50 Lakhs m³ which holds water throughout the year, and in East Block pit of the lease mined out area hold the recharge water during the monsoon. A network of drains / garland drains, culverts and earthen check bunds have been made by UltraTech cement Ltd. To guide surface runoff to this artificial lake, to prevent fresh water from flowing into the sea. Water from this lake is suggested to use for consumption in clinker plant, drinking purpose and for environmental activities like afforestation.

- Total ground water recharge by five percolation ponds having storage capacities of 0.52, 0.897, 0.085, 0.5 and 0.015 MCM respectively has suggested by REACS, Rajkot should be maintained by UltraTech Cement Ltd. so that total 1.492 MCM rain water will be stored and will help in ground water recharging of the area.
- It is recommended to restore the soil once mining get completed by scientific tree plantation which help to restore soil fertility and ameliorate microclimatic conditions and return of sustainable ecosystem to former degraded land. This will also help to reduce PM_{2.5} and PM₁₀ concentration in the ambient air environment. The revegetation of mine spoil by tree cover stabilizes an ecosystem for the long term via their ameliorative effects on soil quality improving both potential commercial and aesthetic values. UltraTech Cement Ltd. has already developed and reclaimed land with green belt with beautiful reclaimed grader area as visited by team of CSIR-CSMCRI after completing portion of old mining area. Similar practice should be planned after completing the both new mining area of 49 Ha and 14 Ha with refilling of Loosely grade topsoil for plant growth and applying proper tree planting techniques.
- It was verified during visit of mines that pre monsoon and post monsoon ground water quality data such as TDS, pH, alkalinity, Na, Cl were regularly monitored by UltraTech Cement Ltd. Periodical monitoring of total dissolved solid (TDS), sodium and chloride concentration in ground water is recommended for measurement in all season of the year. It is recommended to monitor ground water level data for Well-2,3,4 and 6 data regularly for pre-monsoon, monsoon and post monsoon season in future years similar to other well no. 1,5,7,8 and 9.
- An alert and responsible mining with best management practices can evolve sustainable development of new mining area. During mining the heavy pumping of water from the pit shall not be done as a precautionary measure. It is also understood that there is no question arises for over-draft situation till the mining will not reach below the ground level but it may arise in future. When such condition is observed less or no ground water exploitation shall be done.

8. APPENDIX

Appendix-I:

Technical report on Salinity ingress study with special reference to hydro- geological regime in and around Narmada Cement-Jafarabad Works (NCJW), UltraTech Cement Limited, Village-Babarkot, Taluka-Jafarabad, District-Amreli (Gujarat) submitted by CSIR-CIMFR (no. CNP/N/4445/2016-17).

Appendix-II:

- i) Report of "Proposed action plan to control the salinity ingress due to 49 ha. proposed mining by Narmada Cement Jafarabad works unit: UltraTech Cement Ltd., Village: Babarkot, Ta: Jafarabad, Dist. Amreli" submitted by Royal Environment Auditing & Consultancy Services (REACS), Rajkot.
- ii) Report of "Proposed action plan to control the salinity ingress due to 14 ha. proposed mining by Narmada Cement Jafarabad works unit: UltraTech Cement Ltd., Village: Babarkot, Ta: Jafarabad, Dist. Amreli" submitted by Royal Environment Auditing & Consultancy Services (REACS), Rajkot.

CSIR - CIMFR



CNP/ N / 4445 /2016-17

Technical Report on

Salinity Ingress Study with Special Reference to Hydro-Geological Regime in and around Narmada Cement-Jafarabad Works (NCJW), UltraTech Cement Limited, Village-Babarkot, Taluka-Jafarabad, District-Amreli (Gujarat)

Sponsored by

**ULTRATECH CEMENT LIMITED,
NARMADA CEMENT- JAFARABAD WORKS (NCJW) ,GUJARAT**



Submitted by

**CSIR - Central Institute of Mining and Fuel Research
(Council of Scientific & Industrial Research, Govt. of India)
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SEPTEMBER, 2017

Technical Report on

Salinity Ingress Study With Special Reference to Hydro-Geological Regime in and around Narmada Cement - Jafarabad Works (NCJW), UltraTech Cement Limited, Village-Babarkot, Taluka-Jafarabad, District- Amreli (Gujarat)



Project No. - CNP / N / 4445 / 2016-17

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September, 2017

This technical report on 'Sea Water Intrusion Study for Narmada Cement Jafarabad Works (NCJW), GUJARAT' is a joint collaborative work of two CSIR labs namely CSIR-CIMFR , Nagpur and CSIR-NEERI, Nagpur.

(Pl see team constitution at the back of the report)

EXECUTIVE SUMMARY

This report deals with Salinity Ingress / Sea water intrusion / Saltwater intrusion (abbreviated as- SWI) investigation for the Narmada limestone mine of Narmada Cement-Jafarabad Works (NCJW), which is located in Amreli district of Gujarat state and owned by M/s UltraTech Cements Limited of Aditya Birla Group.

Study area and mine : The study area covers mine lease area of Narmada Cement mine (NCM) which is an open cast mine. It is surrounded by villages namely *Babarkot, Bhakodar, Varaswarup, Vand and Kovaya and lies on the Gujarat Coast of India*. Mine area under investigation can be traced on the Survey of India toposheet No. 41 P/5 (F42X5 - New edition, 2010) and has location co-ordinates as N 20°52' & N 20°54' (Latitude) and E 71°23' & E 71°27' (Longitude).

The mining of limestone is being carried out at this mine in combination with *conventional mining* and '*Surface Miner*' above 0m MRL. Due to restricted depth the horizontal expansion of mine is large. There is no (or very-very less) overburden cover present at the limestone deposit. From crusher to plant, the conveyor belt transports the ROM. NCM mine has two limestone blocks namely 'east pit' and 'north pit', producing nearly 1,50,000 tonnes of limestone per month. Total limestone produced is consumed by its captive Narmada cement plant.

Approach of Investigation: Multidisciplinary approach has been adopted for this investigation as the problem has multiple dimensions that involves geological / hydrological / laboratory and modeling results based on different parameters. Thus, the study area is investigated using geophysical methods (ERT / Resistivity Image Profiling) and 'groundwater modeling techniques' is applied to know the future scenario (based on the watershed concept). ERT has been undertaken in selected profiles at representative locations to examine the signatures of seawater intrusion. *Groundwater Modelling* has been done using the Visual MODFLOW Professional Software (Version 4.1) : SEAWAT -2000 module .

This investigation entails “density dependent flow” of ground water. The *miscible transport approach* and finite difference grids are used in ground water modeling



and simulation exercise. The study area is modeled considering three boundaries of the watershed namely ridge on the west (*Raidi*), the *Dhatarwadi River* on the east and the Arabian Sea on the south. Predictive assessment for future scenario has been done for 05 years and 20 years.

The inverted data of the proven *Resistivity Image Profiling* technique are examined for signatures of seawater intrusion (SWI) by dividing the range of resistivity into four zones, which are as follows:

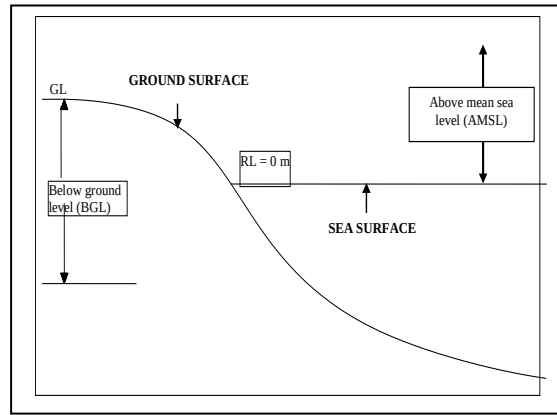
❖ Very low	:	0 - 3 ohm-m
❖ Low	:	3 - 45 ohm-m
❖ Intermediate	:	45 - 250 ohm-m
❖ High	:	> 250 ohm-m

As seawater has very low resistivity (0.2 ohm-m) and it will be trapped inside the limestone aquifer (the aquifer of the study area) it is decided to treat the *very low* resistivity zone in the range of 0-3 ohm-m as the '*confirmed zone*', affected by seawater intrusion. The zones characterized by *low* and *intermediate resistivity* values is considered as '*possible zone*' of intrusion and this zone possess mixture of fresh water as well as seawater in the rock pores. The presence of seawater in the *high resistivity zone* (i.e. > 250 ohm-m) is considered as the zone free from SWI, but its possibilities are very less. Total absence of SWI in such zones cannot be ruled out as it lies in the close proximity of inflicted area.

The inverted resistivity sections in east pit and north pit indicated that the SWI / very low resistivity zone (0-3 ohm-m) is present at 20-22 m depth below ground level (Pl see conclusion section below). It is present in the area as a natural phenomenon occurring in any coastal aquifer or ground water bearing zone in immediate vicinity of the sea.

Sea water Intrusion (SWI), mining and mine planning: The seawater, if present in the ground water, has different flow pattern because of the fact that the water mixture contains high quantity of total dissolved solids (TDS) and has varying density too. In the NCJW study area the basic concept of SWI holds true (please see figure given below).





Geological condition of NCJW aquifer (miliolitic limestone) permits the transmission of ground water as it has presence of secondary porosity. Mixing of ground water and sea water is taking place in the study area causing brackishness of water. For hydrological purpose, miliolitic limestone of the area is an aquifer but marl is not an aquifer.

Based on CIMFR study it is concluded that mining in future (i.e. with deepening of mine further) can be done up to (-) 08 m RL because 'intrusion zone' lies at a depth of more than 20m - 22m (observation of ERT results). As a rule of thumb, if the low-resistivity zone (SWI zone) lie below the actual excavation level, mining can be done safely and conveniently.

SWI is since a natural phenomenon and bound to occur in any coastal area, the simulation results and resistivity survey will provide useful technical input to plan the mine in future whose details are described in various chapters of this technical document (Chapter 3, 4 & 5). Following are the conclusion and recommendation of this study.

Conclusions of Study

- 1) Based on the *Resistivity Survey, Water Quality Analysis* and the *Ground Water Modelling* (SEAWAT-2000) it is concluded that the sea water intrusion (SWI) or salinity ingress is extended up to the East Pit and North Pit of NCJW limestone mine in 2017. The most positive aspect is that it is present at depth more than the planned mining depth.

It is found that though there is progress of salinity ingress in this coastal region, which is a natural phenomenon occurring in any coastal environment globally but the progress of plume is very less and steady. Probably the concerted efforts of the UltraTech Cement Ltd. and mine management through artificial recharge, water harvesting and sustainable



water conservation measures adopted since the inception is the reason for this trend.

- 2) The groundwater quality analysis results of the study region have shown very high values of TDS, chloride (Cl) and sodium (Na), which has confirmed linkages with seawater intrusion. The ratio of Chloride : Bicarbonate of more than 01 value has been observed at most of the surveyed places which signifies the presence of sea water intrusion.

- TDS values = > 2000 mg/L = CONFIRMED sea water intrusion.
- TDS values = > 1500 mg/L = POSSIBLE sea water intrusion.
- Arabian Sea water TDS Value = 32,000 mg/L

- 3) The resistivity survey has indicated zones or patches of low resistivity (0-3 ohm-m) values at various locations in the study area. These are present at varying depths as given in table below.

Profile No.	Total imaging Depth (m)	Sea Water Intrusion Depth (m)		Inference Drawn (Safe/vulnerable)
		Confirm (Very Low)	Possible (Low & Intermediate)	
JERT 1	39.4	33 -39.4	39.4	Safe
JERT 2	39.4	34 - 39.4	39.4	Safe
JERT 3	39.4	- Not Present -	39.4	Safe
JERT 4	78.8	24 - 39	78.8	Safe
JERT 5	23.6	- Not Present -	07-23.6	Safe
JERT 6	39.4	03-39.4	03-39.4	Vulnerable
JERT 7	47.3	40	47.3	Safe
JERT 8	23.6	- Not Present -	23.6	Safe
JERT 9	78.8	24 -78.8	24	Vulnerable

Note : All values are BGL (below ground level) values unless stated. For MRL please refer table 3.5.

- 4) The modeling results clearly indicated that salt water intrusion (**interface line**) has extended up to **1.28 Km -1.29 Km** inside the coastline and towards mainland at current scenario. Thus, NCJW mining pits will have vulnerability from the SWI now and in future i.e. 2017 and beyond.
- 5) From the modeling analysis it is concluded that the pace of salinity ingress is very-very slow over the years. It means that the 'water management' measures at NCJW are playing positive role in SWI containment.
- 6) The shoreline on which NCJW plant and mine situated is stable and environmentally safe and excavation of minerals from the 'open **PIT** mine'



can be done. As a whole, the mining operation up to a limited depth is safe and feasible.

- 7) It is estimated that the water table in NCJW area lies in the range of 14.00 m to 17.0 m (approximately) in the core zone i.e. in the mine lease area and at the *Babarkot* village. Average depth of water table (DWT) in the dug wells of study area has recorded variations from place to place.
- 8) Water level fluctuations (WLF) in the study region lies in the range of 0.15m to 9.87m BGL. The depth to water level varies from 1.0 m to 21.36 m (BGL) in the pre-monsoon period (May, 2017) and varies from 0.35 m to 20.26 m (BGL) in the post-monsoon period (November, 2016).
- 9) The ground water flow direction in the study area is towards the seacoast.

In brief, CSIR- CIMFR has concluded that 'pit mining' at Narmada cement for limestone extraction is feasible. Important reasons for continuing mining in a pit form are -

- (a) Salinity ingress has already occurred in the area and bound to occur as it is a natural phenomenon.
- (b) Sea and *mining* both are the dynamic entities. Ground water flow mechanism in coastal aquifer and very near to the shore line differs greatly from the mainland whether it is a unconfined or semi-confined aquifer. The density-dependent ground water flow mechanism is affected by the high tidelines of sea.
- (c) Narmada cement mine and its host rocks are limestone which is a sedimentary formation with adequate porosity for ground water flow. Such formations causes continuous dissolution of calcium in water causing higher TDS concentration of water. Because of *continuous dissolution* taking place at both shallow and deep levels such formation's TDS levels of water are always high irrespective of the corrective measures.
- (e) The consumption of ground water in the study area and mine is not very high because of brackishness of ground water.



Recommendations of study

- ◆ Seawater should be prevented from intruding into the mainland as far as possible by adopting 'control measures' as described in this report. Sea water can also be contained naturally by maintaining a higher head of fresh water creating hydraulic gradient towards the sea.
- ◆ In the study area, both deep and shallow coastal aquifers should be protected. It is recommended to make use of scientific principle only for restricting ground water pollution.
- ◆ It is recommended that recharging of the aquifer, either through '*mined out pits*' or through '*dug out depression area*' of topography shall be done to the maximum possible extent. Surface water storage should be encouraged and alternatively some additional arrangements for the recharge structures may be made in the lease area or in the surroundings.
- ◆ Operational / functional 'Piezometers' is recommended to be installed in sufficient number around the mining pits (i.e. near East Pit and North Pit). Entire lease area shall be covered with such installations.
- ◆ Periodical monitoring of Total Dissolved Solid (TDS), Sodium and Chloride concentration in ground water is recommended for measurement in all season of the year.
- ◆ In view of presence of SWI it is recommended that caution be exercised while continuing mining operation at depth below ground level. However, mining at restricted depth, up to the depth range of (-) 4m to (-) 8m RL, will be safe depending on the practical conditions encountered.

Summarily, CIMFR study has concluded that SWI is present in the study area and '*Seawater - freshwater interface*' can be kept controlled by augmenting water management measures such as less ground water draft and by maintaining adequate ground water recharge. The ground water draft should be maintained as low as possible to avoid or restrain the formation of hydraulic gradient towards mainland. To meet out the ground water requirement of industrial activity and manage the SWI, control (management) measures as described in the report should be adopted and implemented into practice. Status quo of the 'safe ground water development zone' (as per CGWB norms) shall be maintained by the company.



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I on behalf of CIMFR and whole project team of investigators would like to put on record my sincere gratitude to the management of M/s UltraTech Cement, NCJW, Jafarabad (Gujarat) for providing financial support to execute this scientific investigation, which has a significant research content in it.

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On my personal behalf, I honestly acknowledge the valuable contribution made by all my colleagues of Nagpur office and all members of the investigating team of CSIR-NEERI, who helped, guided and provided support to me whenever it was needed for this particular project.

(Dr. A. K. Soni)

Chief Scientist and Lead Principal Investigator (PI)

CSIR - CIMFR, Nagpur



ABBREVIATIONS USED

❖ NCJW	=	Narmada Cement Jafarabad Works
❖ NCM	=	Narmada Cement Mine
❖ SW	=	Sea Water Intrusion (<i>also referred as 'salt water intrusion'</i>)
❖ GCW	=	Gujarat Cement Works
❖ CIMFR	=	Central Institute of Mining and Fuel Research
❖ CSIR	=	Council of Scientific and Industrial Research
❖ CGWB	=	Central Ground Water Board
❖ GWRDCL	=	Gujarat Water Resource Development Corporation (State organisation for ground water survey, development and planning)
❖ GSI	=	Geological Survey of India
❖ IMD	=	Indian Meteorological Department
❖ M / m	=	meter
❖ mm	=	millimetre
❖ NA	=	Not Available
❖ BGL	=	Below Ground Level
❖ MSL	=	Mean Sea Level
❖ RL/ MRL	=	Reduced Level (<i>also referred as MRL</i>)
❖ MT	=	Metric Ton
❖ MHz	=	Million Hertz (a unit of frequency)
❖ MPa	=	Mega Pascal (a unit of pressure)
❖ Mg / L	=	Milligram per litre
❖ kN/m	=	Kilo Newton per Meter
❖ DWT	=	Depth to Water Table
❖ LPS	=	Litres per second
❖ N,S,E,W	=	North ,South, East and West
❖ KL /day	=	Kilo Litres Per Day
❖ MCM	=	Million cubic Metre
❖ TCM	=	Thousand Cubic Metre
❖ WLF	=	Water Level Fluctuation (in m)
❖ WT	=	Water Table



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CHAPTER – 1

INTRODUCTION

1.1 BACKDROP

It is well known that limestone is the main and essential *raw material* for cement manufacturing. The cement industry is the biggest consumer of limestone besides other user industries namely, iron and steel, fertilizer, chemical and metallurgy. Nearly 75% to 80% limestone is consumed in cement industry alone.

Narmada Cement-Jafarabad Works (NCJW) a unit of UltraTech Cement Ltd. was setup (commissioned in the year 1981) at village Babarkot, taluka-Jafarabad in Amreli district of Gujarat having capacity of 1.5 million tons per annum. UltraTech Cement Limited is a flagship of Aditya Birla Group, is today the youngest and one of the most dynamically growing cement companies in India. The company's contribution in nation-building is well known in industrial circle. UltraTech is India's single largest producer with 93.00 MTPA capacity with market share of 24% and also the largest exporter of cement clinker spanning over to export markets in countries across the Indian Ocean, Africa, Europe and the Middle East. It is among the leading cement manufacturer in the world.

UltraTech and its subsidiaries have a presence in 5 countries through 18 integrated plants, 1 white cement plant, 1 clinkerisation plant, 25 grinding units, 2 wall care putty plants, 7 bulk terminals and more than 100 RMC plants. The company increased its market share with its acquisition of JP Associates 21.20 MT capacity.

The Narmada Cement Mine (NCM), operating since 1981 is the captive limestone mine of M/s UltraTech Cement Limited feeding raw material to NCJW - its cement manufacturing unit. To maintain a balance among the conservation of mineral resources and environment, the company has adopted scientific approach to solve the technical problems of their mines and plants. With this attitude in mind, M/s UltraTech Cement approached CSIR-Central Institute of Mining & Fuel Research (CIMFR), A CSIR constituent of Govt. of India, to investigate the 'Sea water intrusion problem' of the NCJW mine area as the mine is planned to be deepened below the ground level i.e. below 0m MSL /MRL. This report is emerged with this background and prepared for the technical and statutory requirement of the sponsoring organisation i.e. UltraTech Cement.



1.2 OBJECTIVE AND SCOPE OF STUDY

Objectives:

- a) Salinity Ingress determination with respect to interference of ground water table.
- b) Impact of mining on groundwater quality and effect of salinity.
- c) Predictive assessment through ground water modelling.
- d) Ameliorative measures to combat adverse impact of mining on GW quality.

The above-mentioned objectives are required to be executed through detailed geo-hydrological study and perspective mine planning thereby enabling the mine management to plan for deepening the quarry in future and help in optimum and judicious utilization of available water resources.

Scope: The scope of the present study is limited to the study area covering entire lease area of *Narmada Cement Limestone Mine* i.e. core zone and buffer zone (5 km / 10 km radius from the mine centre).

1.3 APPROACH / METHODOLOGY

The ensuing R&D study is approached from various angles, as the problem has multiple dimensions involving geological / hydrological / laboratory and modeling parameters. The designed methodology for the study area has following broad work elements –

1. Identification of zone of influence (Core Zone / buffer zone)
2. Selection of macro and micro-watershed in and around the study area.
3. Base line data collection for active mining area (i.e. particulars about geology, geomorphology, rock types, production, method of mining and existing environmental conditions).
4. Surface and ground water resources details for the lease area and watershed areas. (These are part of field studies and include data for regional and local water scenario. It encompasses water resource data i.e. static water level data , *Piezometer* data, precipitation (rainfall) data, evaporation assessment data, run-off data, hydrological pattern, drainage data for different watershed etc. which is derived from dug well /bore well census and basically meant for surface water and ground water estimation i.e. draft estimation etc.)



5. Field survey work i.e. taking profiles of resistivity survey; pre-monsoon and post-monsoon water sampling and base line data collection for analysis.
6. Laboratory analysis of water samples for salinity determination (Samples are collected during pre and post monsoon season of 2016-17 and covered one year period).
7. Ascertaining the condition of aquifers using 'Resistivity Image Profiling' method to derive ground water modeling input parameters.
8. Analysis and interpretation of resistivity data obtained from primary sources.
9. Ground water modelling to study sea water intrusion and salinity of ground water bin in the study region i.e. predictive assessment /simulation study etc.
10. Preparation of TDS contour map, Sodium (Na), chloride (Cl⁻), carbonate (CO₃) and bicarbonate (HCO₃) concentration map for the ground water of study area.
11. Perspective planning for future mining below mean sea level by assessment of ground water scenario around the study area.
12. Validation of ground water modelling results through actual field data.
13. Framing of conclusion and recommendations of study which also includes guidelines for water management.
14. Preparation of project report and its submission.

The input data for this study is based on primary field monitoring data and secondary data supplied by M/s UltraTech Limited. Only authentic data sources namely Gujarat Water Resource Development Corporation (GWRDC) data; CGWB(Central Ground Water Board) data ; Geological Survey of India (GSI) data etc. have been used in this study. Strata formations of various types, which is the representative for whole area, formed the basis for different hydrological and engineering solutions.

1.4 IMPORTANCE OF STUDY

Followings are the significant points with respect to the importance of study –

- The sea-water intrusion study will assess the possible effect of limestone mining on hydrological regime of the area i.e. pollution related.
- The study has linkages with 'statutory compliance'.



- Technical help for further deepening of the mine including production of limestone with safe practices.
- Ground water modelling study will make an assessment of the ground water pollution problem in particular the *salinity of water*.
- With detailed scientific data analysis the surface water and ground water resource management can be done effectively and conveniently for the study region.

The investigated mine of NCJW is an operative mine and the company owning it has keenness and concerns towards environment protection. Various environmental aspects related to water and water management in the study area adjoining the mine can improve the water scenario in the studied region, if implemented into practice. The CIMFR investigation, reported here, addresses the specific objective in totality and it is expected that the mine management will be benefitted by CIMFR study and utilize the results in mine planning and production.



CHAPTER – 2

STUDY AREA DETAILS

Narmada Cement Mine (NCM) is the captive mine of its clinkerisation unit Narmada Cement- Jafarabad Works. It is an operative limestone mine, near the Babarkot village of Jafarabad taluka and has started commercial production in September, 1981. The mine is located at a distance of about 0.8 km from the plant. Major part of the mine lease area of NCJW lies near the shore line of *Arabian Sea*. The area forms part of the limestone belt of *Saurashtra Region* along the coast of *Gulf of Khambat*.

2.1 LOCATION OF THE STUDY AREA

The study area lies in the administrative jurisdiction of Amreli district of Gujarat state (Fig. 2.1). The mine is approachable at a road distance of 4.5 km from Jafarabad town which is the nearest urban locality. Its distance from other nearby towns are : at about 25 Km from *Rajula* town ; 152 Km from *Bhavnagar* ; 215 Km & 95 Km from *Rajkot* town and *Amreli* town respectively. The study area can be traced on the Survey of India toposheet No. 41 P/5 (F42X5 - New edition, 2010) and has following location co-ordinates -

- Latitude - N 20°52' and N 20°54'
- Longitude - E 71° 23' and E 71° 27'

The nearest airport is *Diu*, which lies at a distance of 67km (approx.) from NCJW, and nearest railhead is *Rajula* on *Bhavnagar-Rajula* section of Western Railway.

Considering the watershed concept of resource planning, the study area is bounded by the *ridge* on west (W), the *Dhatarwadi River* on the east (E) and the *Arabian Sea* on the south (S). The watershed boundaries is spread in between latitudes N 20° 50' to 21.00° and longitudes E 71° 29' to 71° 23' (Fig. 2.2) and the mine lease area is surrounded by number of villages namely *Babarkot*, *Varahswarup*, *Bhakodar*, *Kovaya*, and *Vand* etc. The NCM includes two pits viz. *North Block* & *East Block*, where mining operation is going on presently (Fig. 2.3).



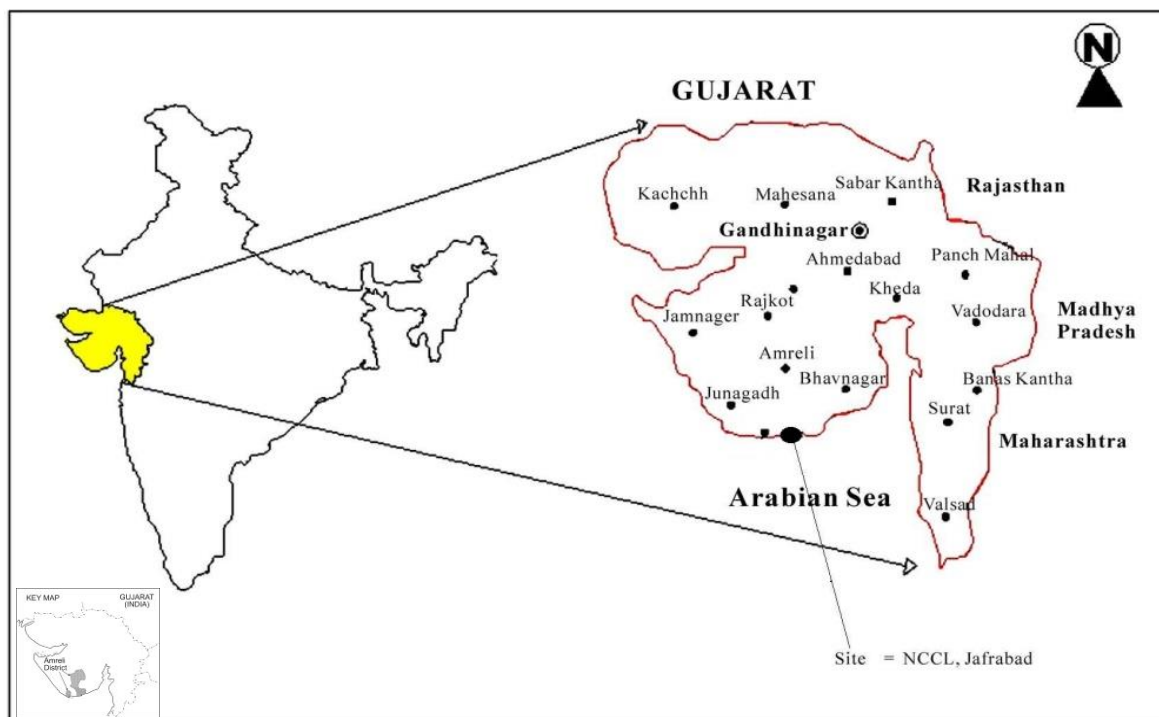


Fig. 2.1 : Location Map of Study Area (District - Amreli , Gujarat ,India)

2.2 PHYSIOGRAPHY

The state of Gujarat is broadly divisible into six principal physiographic units namely - *Southern Aravallis and adjoining hilly tract* ; *Deccan plateau & adjoining tract of S-E Gujarat* ; *Central Plains*; *Saurashtra Peninsula*; *Kutch Peninsula and the Rann of Kutch* (Physiography map of Gujarat). The '*Saurashtra Peninsula*' and '*Deccan Plateau*' best describe the physiography of the study region in general. The physiography around the mine area resembles to the physiography of *Saurashtra Peninsula*.

The *Saurashtra Peninsula* comprises of a high level, dissected lava plateau and flat top hills of sandstone in the north east. In S-E, a broad zone of low-level dissected plateau intervene the high level plateau and the flat, broad coastal erosional plains in the *Saurashtra Peninsula*. In the southern part of this peninsula, number of hills ranges are therefore predominant (e.g. *Barda hills*, *Alech hills*, *Girnar hills* and *Gir ranges*). The *Saurashtra Peninsula* has a radial drainage pattern. The prominent rivers are the *Bhadar*, the *Shetrunji*, the *Dhatarwadi*, *Machhu* and the *Aji*. The *Bhadar* and *Dhatarwadi* river flows into the Arabian sea, the *Shetrunji* into the Gulf of *Khambat*, *Machhu* into the little Rann and the *Aji* into the *Gulf of Kachchh*.

'Deccan Plateau' and adjoining tract of SE Gujarat has a wide and high level dissected plateau fringed by the alluvial plain and fairly broad coastal erosional plain in the west. Several rivers are the dominant features of this physiographic unit, the most prominent being *Narmada* and *Tapi*, which dissect the tract in E-W direction. Coastal southern plains are occupied with igneous intrusions and they are found in the form of solid boulders of varying sizes. These boulders have rounded edges, which may be due to seawater erosion forces or due to weathering or intense transportation.

The physiography of the mine area and surroundings has younger most geological formations. Windblown sand constitutes the overburden with an average thickness of one meter. Occupying the flatter grounds, the thickness of overburden is comparatively more towards *Kovaya* and *Vandh* villages while the thickness decreases towards village *Babarkot* which is on comparatively higher ground. Just below the windblown sand, miliolitic limestone occurs as compact limestone and low grade limestone of varying thickness, average being 25m approximately. With depth, there is general deterioration in the quality of limestone accompanied by soft, friable layers & lenses of low grade limestone. The limestone is buff, yellow or pinkish in colour, while the weathered surfaces show sooty to brownish appearance. The main constituent of the limestone is the calcic shell fragments of miliolitic variety. The limestone deposit shows enrichment in calcium content at the upper layers, formed probably due to leaching out of silica, calcium enrichment by capillary action and re-deposition in crevices. The limestone is compact, hard and bouldery in nature the study area at many places. The average quality of limestone varies in terms of CaO : 40% - 48%; SiO₂ : 4% - 7.5 %; Al₂O₃ : 1.5% - 3 % and Fe₂O₃ :1% - 2.5 % which is cement grade.

In general, the physiography of this region resembles to that of any coastal region. Land derived material from volcanic activities constituted the impurities in the limestone deposit and various types of soils, alluvium, windblown sand, fluvio-marine mud deposits of tidal flats and shell & shingle deposits of shore area are commonly occurring.

The highest elevation in the mine lease area is 35.25 m AMSL towards N-W. Miliolitic limestone is the major water bearing formation in the study area.



2.3 TOPOGRAPHY AND DRAINAGE

The study area has flat to gently undulating topography. Limestone cliffs all along the sea coast near *Jafarabad* and *Babarkot* villages are clearly visible. There is large flat, muddy and 'marshy land' connected by the *Jafarabad Creek* which forms the part of the topography of the study area. 'Salt Panes' are located in the Jafarabad areas.

The flat to gently dipping topography of the region has varying elevation from 0 m (AMSL) to 36m (AMSL). As one moves away from the sea coast and approaches outward i.e. the inland elevation increases gently. Near the sea coast, the elevation varies from 0m to 10m AMSL in general and max being 24 m AMSL. Drainage of both the coastal area and inland area is mostly controlled by the topography.

The drainage pattern of the area is a combination of *dendritic* and *parallel*. There are two main drainage channels in the study region, namely 'Dhatarwadi' and 'Raidi'. Both of them are the seasonal streams draining the study area and carries maximum water in the monsoon and post-monsoon season particularly during June to December. During summer months these channels have negligible flow. Small drainages (tributaries) converge finally with the *Dhatarwadi River*, making 'Dhatarwadi' bigger compare to 'Raidi'. All drainages forming various patterns, joins the Arabian Sea. Except rainfall, there is no other source of water that may be encountered in pits in this coastal region. Therefore, sea-water assumes special significance w.r.to the topography & drainage pattern of the study area.

Dhatarwadi River flows in southern direction changing its course towards S-E passing near the village of *Uchaiya* and *Rampara* before joining the sea. From mine lease the closest distance of this river is 3 Km in the NE direction. *River Raidi* flows in S-SE direction joining the backwaters of *Jafarabad creek* at village *Nageshri* about 8Km N-W of the mine lease boundary.



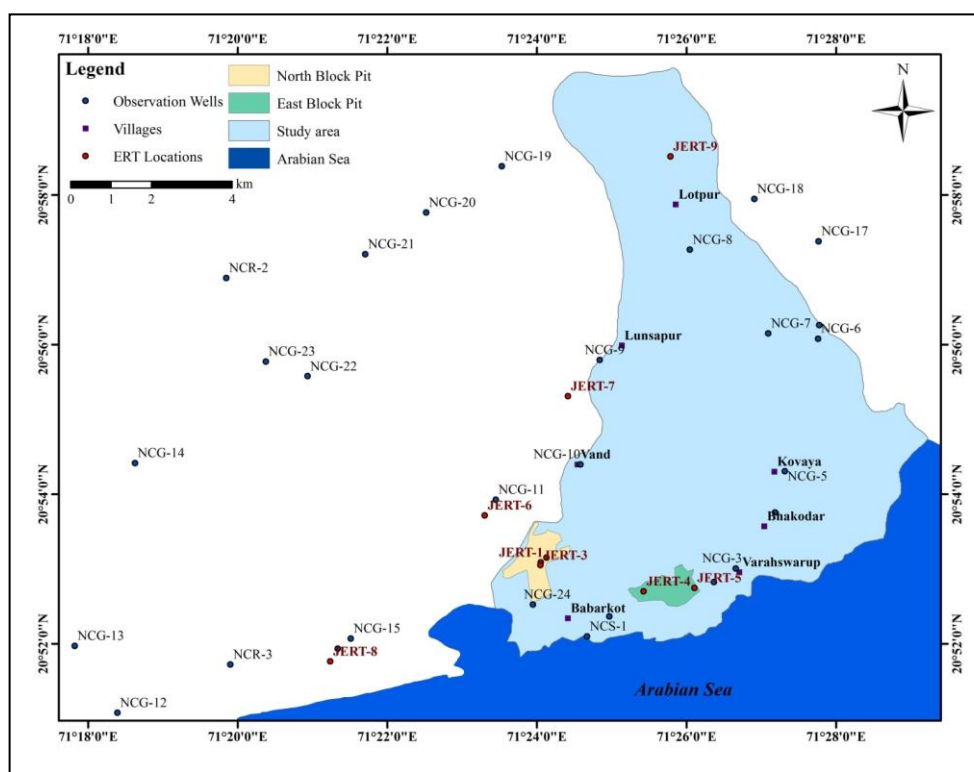


Fig.2.2 : Base map of NCJW study area with mining pits

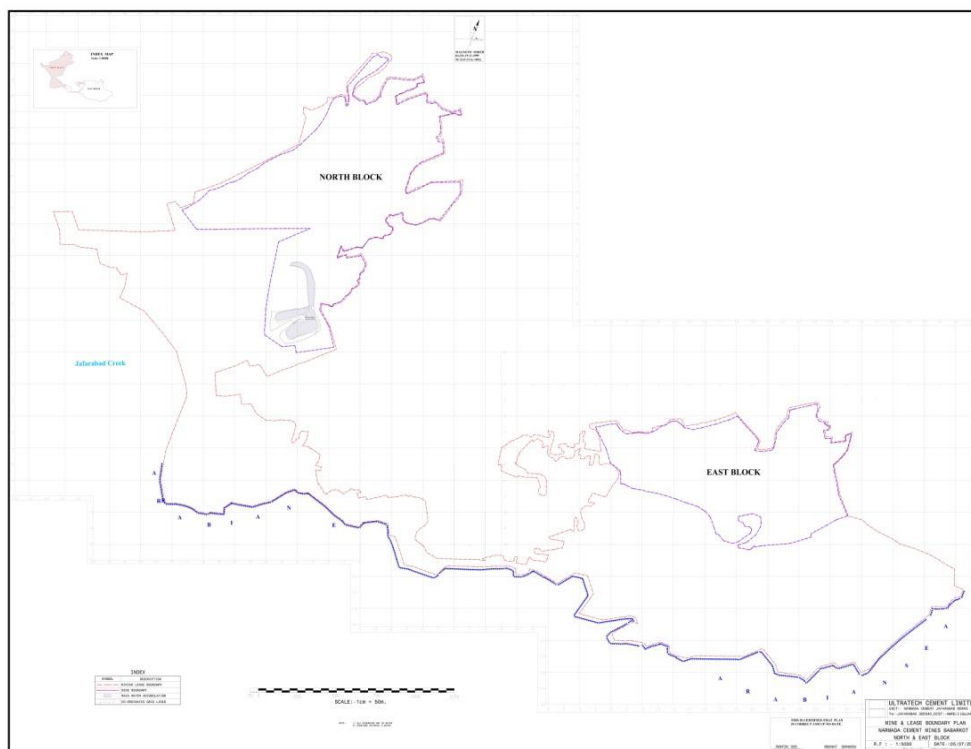


Fig. 2.3: Key map of NCM pits showing *north block* and *east block*

2.4 GEOLOGY

Sea water intrusion analysis needs the detailed geological and hydrological information of the study region and mine area. Considering this focus in mind, in-depth details are described about geology. The regional and local geological description given here is an abridged version of various involved agencies namely Geological Survey of India (GSI) and Directorate of Geology and Mining (DGM), Government of Gujarat. It may be noted that ACC Ltd (now Holcim Co. Ltd.) and L&T were involved in the exploration programme in the region in early 1970's and the information derived from their exploration programmes has been appropriately incorporated.

2.4.1 Regional Geology

The regional geology of the study area can be very well understood with the geological features of the state and district as a whole (Fig. 2.4). The study region lies in the Amreli district of Gujarat, which is located in the southern part of *Saurashtra Peninsula*. The district of *Amreli* occupies an area of 6,760 Sq. Km having population strength of 15,14,190 people, as per 2011 Census of India. It is bounded in the north by the *Rajkot district*, in the east by the *Bhavnagar district*, on the west by the *Junagarh district* and to the South by *Arabian Sea*. Flood plain of the *Shatrunji River* in the central part divides the undulating hilly terrain of the North & South. The southern part is occupied by the coastal plains. The *Shatrunji* and the *Kalubhar River* flows towards the east into *The Gulf of Khambat* while the *Dhatarwadi River* towards south into the *Arabian Sea*. The district is divided into ten talukas namely *Babra, Lathi, Amreli, Vadia-kukavav, Lilia, Dhari, Khamba, Bagsara, Rajula, Jafarabad and Savarkundala*. The district is well connected with all-weather roads but lacks railway network. *Bhavnagar-Rajula* section of Western Railway, which is a metre gauge section, is on up-gradation to broad gauge rail section for better and uniform connectivity with other part of India. In future, NCJW, and its nearest railhead i.e. *Rajula*, is likely to be connected with rail under the rail-network expansion programme, benefitting NCJW as well as Jafarabad for transport.

Except the coastal part, the entire district is occupied by the *Deccan Volcanics* represented by the flow of *basalt, rhyolite, dacite and felsite* along with basic and acid intrusive. The rhyolite / dacite flows are restricted to the *Rajula* area while the felsite flows are exposed to the east of *Babra*. Dykes of basalt and dolerite are quite common. The rhyolite / dacite flows are restricted to the *Rajula* area



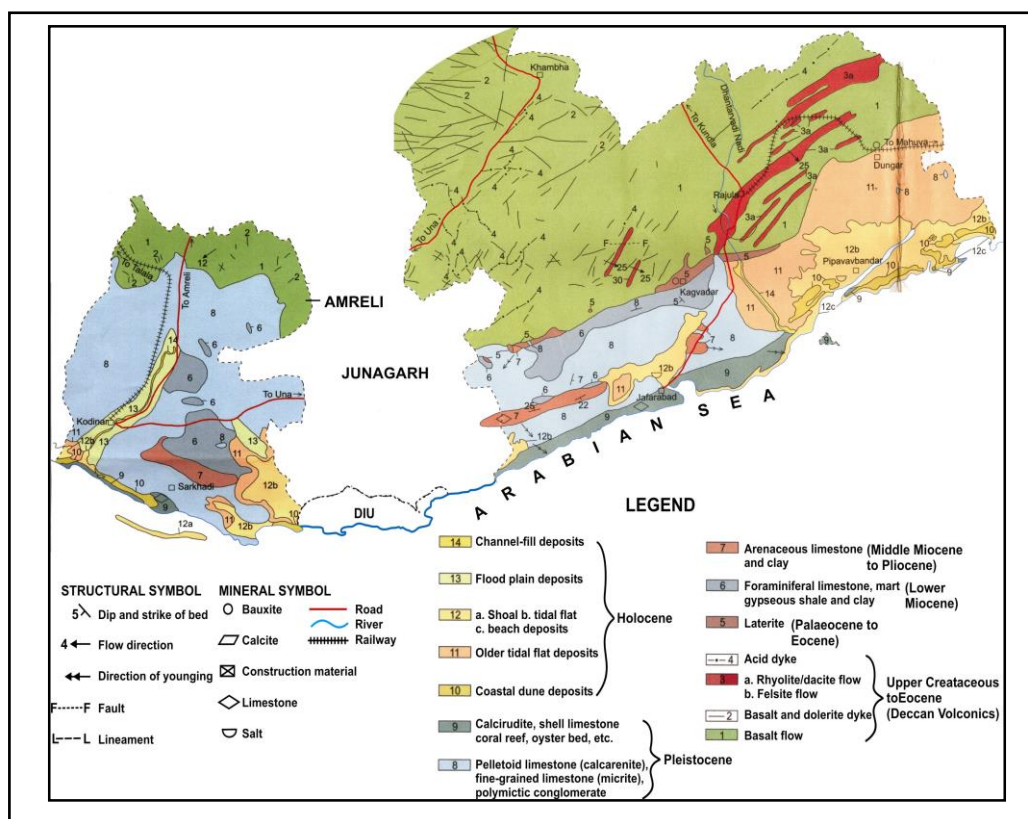


Fig.2.4 : Geological map of a part of Amreli district covering study area
(Source : GSI, 2002)

while the felsite flows are exposed to the east of *Babra*. Dykes of basalt and dolerite are quite common as compared to the acid dykes, which are restricted in the vicinity of acid flows. The Deccan volcanics are overlain by laterites of the *Bhatia formations* and calcareous and argillaceous sediments of the *Gaj and Dwarka formations* or the *Miliolite formations* of the *Porbandar group* in different areas. The *Chhaya formations* is restricted to the coastal part. The *Holocene* sediments comprise coastal dune deposits (Aeolian) of the *Akhaj formations*, marine deposits of the *Rann clay* and the *Mahuva formations* and fluvial deposits of the *Katpur and Varahi formations*. The Gujarat state, exposes rocks belonging to the *Precambrian, Mesozoic and Cenozoic* eras. Hard rock covers about 49% of the total area of Gujarat and the rest being occupied by sediments of quaternary period. The hard rock comprises of *Pre-cambrian, metamorphites and associated intrusives, sedimentary rocks of Mesozoic and Cenozoic eras* and the traps / flows constituting *Deccan Volcanics* of Cretaceous-Eocene age. Generalized Stratigraphy of Gujarat is given in **Table 2.1**. The regional geological succession and age of rocks particularly found in the Amreli district is given in **Table 2.2**.

Table 2.1 : Generalized stratigraphy of Gujarat

Era	Period	Epoch	Super group	Group / Formation	Intrusives / Extrusives
CENOZOIC	QUATERNARY	HOLOCENE		Undifferentiated sediments/ Rann deposits	
		PLEISTOCENE		Chhaya Formation / Miliolite Formation	
	TERTIARY	PLIOCENE MIO-PLIOCENE		Sandhan Formation Dwarka Formation, Jhagadia Formation	
		MIOCENE		Gaj Formation, Kand Formation, Babaguru Formation	
		OLIGOCENE		Maniara Fort Formation	
		OLIGOCENE-MIOCENE		Kharnadi Formation	
		EOCENE-OLIGOCENE		Tarkeshwar Formation	
		EOCENE		Fulra Formation Kakdinadi Formation Nummulitic Formation Vagadkhol Formation	
		PALAEOCENE-EOCENE		Bhatia Formation Salod Formation	
		PALAEOCENE		Matanomadh Formation	
MESOZOIC-CENOZOIC		CRETACEOUS-EOCENE		Deccan Traps, associated volcanic and inter-trappeans	
MESOZOIC		CRETACEOUS	Upper	Lameta Formation Bagh Formation	
			Lower- Middle	Wadhwan Group Bhuj Formation	
			Lower	Dhrangadhra Group Himmatnagar Formation	
		JURASSIC-CRETACEOUS		Katrol (Jhuran) Formation	
		JURASSIC	Upper	Chari (Jumara) Formation	
Middle	Pachcham (Jhurio) Formation				
PROTEROZOIC		NEO-PROTEROZOIC		Syn-to Post -Delhi intrusives	Idar Granite, Erinpura Granite & Gneiss, Godhra Granite and Gneiss
		PALAEO-PROTEROZOIC MESO-PROTEROZOIC	Delhi Super-group	Sirohi Group	Sendra-Ambaji Granite and Gneiss Phulad Ophiolite complex
				Kumbhalgarh Group	
				Gogunda Group	
		PALAEO-PROTEROZOIC	Aravalli Super-group	Champaner Group, Lunavade Group, Jharol Group, Udaipur Group	Dadhaliya Ultramafic Suite
ARCHAEAN-PROTEROZOIC				Pre-Lunavada Gneissic Complex, Pre-Champaner Gneissic Complex	

Source : GSI , 2001



Table 2.2 : Regional geological succession and age of the rocks in Amreli district, Gujarat

Lithology	Formation	Group	Age
Channel Fill Deposits	Varahi Formation (FE)		Holocene
Flood plain Deposits	Katpur Formation (FE)		
Shoal/Tidal Flat beach deposits	Mahuva Formation (ME)		
Older tidal flat deposits	Rann Clay Formation (ME)		
Coastal dune deposits	Akhaj Formation (AE)		
Calcareous, shell limestone, coral reef, oyster bed etc.	Chaya Formations	Porbandar Group	Pleistocene
Peletoid limestone (calcarenite), fine-grained limestone micrite, polymictic conglomerate	Miolite Formation		
Arenaceous limestone and clay	Dwarka Formation		Middle Miocene to Pliocene
Foraminiferal limestone, marl, shale mixed with gypsum, clay	Gaj Formation		Lower Miocene
Laterites	Bhatia Formation		Paleocene to Eocene
Acid Dyke (Rhyolite /dacite flow) ; felsite flow		Deccan Volcanics	Upper Cretaceous to Eocene
Basalt and Dolerite Dyke and Basalt Flow			

Note : ME = Marine Environment; FE = Fluvial Environment; AE = Aeolian Environment.

All Holocene formations are broadly coeval.

The deccan trap covered coastal region of Saurashtra had experienced a number of marine transgressions and regressions during the late Tertiary Period. The rich limestone beds of the region were deposited by the accumulation of calcium-rich foraminiferal (Miliolitic) crust and chemical precipitation of carbonates from the shallow sea. Land derived material from volcanic constituted the impurities in the limestone deposit. The stratigraphic sequence and local geological set up of the coastal area being investigated (Saurashtra Region) is given below in **Table 2.3**.



Table 2.3 : Stratigraphic sequence of rocks of Saurashtra region

Age	Formation	Lithology
Holocene	Recent	Wind-blown sand, Fluvial-marine deposits.
Sub-recent to Pleistocene	Porbandar Beds	Miliolitic limestone, Marl Calcareous shale, etc.
Pleistocene to Pliocene, Dwarka Beds, Cherty limestone, Clay, Silt.	Pleistocene to Pliocene, Dwarka Beds, Cherty limestone, Clay, Silt.	Pleistocene to Pliocene, Dwarka Beds, Cherty limestone, Clay, Silt.
Pliocene to Miocene	Gaj Beds	Variegated clay Marl Impure limestone, etc.
Eocene	Supratrappean	Impure limestone, Calcareous sandstone, Lateritic rock.
Eocene to Cretaceous,	Deccan Trap and Intertrappean	Basaltic rock with minor Intertrappean clay.

2.4.2 Rocks vis-a-vis local geological setting

Various rock units, which occupy most of the area of *Amreli district* in general and study site in particular are described in short in the following paragraphs.

Deccan Traps : This rock type occupy most of the area in the *Amreli district* and include volcanic rocks of igneous origin. Entire *deccan traps* in the region show shearing and multi-directional fracturing. Rock types principally found include *basalt, trachyte, diorite, rhyolite* etc. The higher altitude topography generally contain the compact massive flows which is hard and tough whereas comparatively soft rock units / types of such igneous formations occupies the valley portion and plains. Rocks of lower altitude areas are weathered naturally.

- Gaj Beds : Gaj beds are marine sediments comprising of yellow colored marly limestone with clays. They occur as isolated outcrops at the margin of *deccan traps* towards coasts and as small mounds in the alluvium.
- Miliolitic Limestone : All along the coast there are thick cross-laminated beds of Miliolitic limestone of *Pleistocene* age which are composed of crushed shells of miliolina. A few outcrops of this are found away from the coast in the interior also.
- Recent Deposits : The coastal areas of *Amreli district* is still undergoing natural geological alterations and as such occurrences of recent deposit is quite obvious. The youngest deposits in the district are represented by various types of soils, alluvium, sand, mud deposits (fluvio-marine), grits and conglomerates, The major agents of weathering like wind, sea water, temperature variations etc. are playing important roles in the formation of these recent deposits.

On studying the regional geology it can be said that the '*deccan trap - basalt*' of Cretaceous to Eocene age is the oldest formation occurring in the study area. In stratigraphic succession, the *Deccan Traps* are overlain by tertiary '*Gaj Beds*'



which in turn is overlain by miliolitic limestone of Miocene-Pliocene age. In small patches, miliolitic limestone is overlain by recent alluvial formations. The limestone of this area is miliolitic limestone, which follows general strike of N40°E - S40°W and dips gently at 5° - 6° towards the east direction. Minor vertical and inclined joints are present and can be observed all along the mine faces.

Local geology of the area : Stratigraphic sequence of the mine lease area consist of (a) Wind blown sand and (b) Miliolitic limestone intermixed with Marl construe.

- a) Windblown Sand :The younger most geological formation in the mine lease is *windblown sand* constituted of the overburden with an average thickness varying from 0.5m to 4.0m. The thickness of overburden is comparatively more towards Kovaya and Vandh village while the thickness decreases towards village Babarkot which is on higher ground.
- b) Miliolitic limestone :Just below the windblown sand, miliolitic limestone occurs as compact limestone & marl of varying thickness which can be average out to 25m. With depth, there is general deterioration in the quality of limestone accompanied by soft, friable layers & lenses of marl. The limestone is buff, yellow or pinkish in colour, while the weathered surfaces show sooty to brownish appearance.

The main constituent of the limestone is the calcic shell fragments of Miliola and related organisms. The limestone deposit shows enrichment in calcium content at the upper layers, probably due to the leaching out of silica, calcium enrichment by capillary action and re-deposition in crevices. The limestone is generally compact, hard and bouldery in nature at many places.

2.5 LAND USE AND SOIL

Land use and land cover information is vital for any geo-hydrological studies as land is the housing media of water. Proper and optimum use of the land not only gives economic returns but also minimize ecological disturbances caused as a result of the industrial activity. *Remote Sensing* and *GIS technology* for mapping land use and land cover at Babarkot limestone mines of Narmada Cement Jafarabad Works, has been carried out recently. For the purpose of land use and soil description in this report the help of secondary data has been taken and this includes EIA report (ENMIN, 2004) and Land use-Land Cover reports (CSA, 2017). The source of information has been described appropriately and listed in the reference list.

In brief, land use and soil of the study area can be described as follows -



2.5.1 Land Use

'Land use' refers to the various ways in which the land is being utilized for different purposes by human beings. In contrary, 'land cover' refers to the *observed (bio)physical cover on the earth's surface i.e.* natural surroundings present in the area under study. Land use (LU) is characterized by the arrangements, activities and inputs people undertake in a certain land cover (LC) type to produce, change or maintain it. Definition of land use in this way establishes a direct link between land cover and the actions of people in their environment. Hence, land use (agricultural land, mining land, built-up land, fallow land etc) and land cover (various landforms, surface features and ecosystems e.g. grassland, barren land, vegetation, plantation, water body, mangroves details etc.) shall not be confused. Both of these words are meant to give an indicative assessment of the economic activity involved in any study area.

In the entire study region and as per census record of 2011 there are 20 villages within 10 km radius of mine lease. Mines office and NCJW colony is covered under Jafarabad Municipality for the purpose land use, population and household statistics as it falls under the administrative jurisdiction of Jafarabad (**Table 2.4**). Details of land use pattern are given in **Table 2.5 and 2.6** and **Fig. 2.5, Fig 2.6** for the mine lease area and area around.

Landuse / Landcover Map –10Km Radius

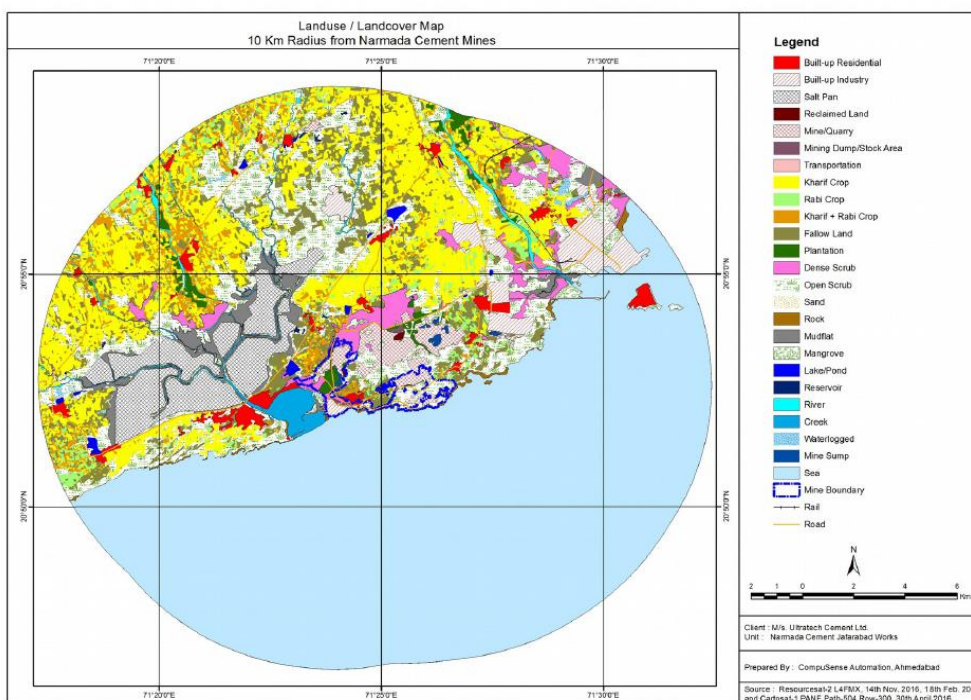


Fig. 2.5 : Land use pattern of NCJW study area

LU / LC Analysis : Based on the analysis of land use pattern of the core zone and buffer zone of the study area a land use analysis table is prepared and given



below. This table shows that in 500m radius area only, the land is utilised for mining. The land area in this zone is also reclaimed and the percentage of reclaimed land is highest in this zone compared to the core and buffer zone, meaning that land is put to the rehabilitation also.

Particulars	10 Km Buffer Zone	5Km Core Zone	Remarks
Mine/Quarry	638.59 Ha (1.34 %)	621.09 Ha (3.76%)	Core zone /buffer zone radius is considered from the centre of mine lease
Reclaimed Area	15.06 Ha (0.03%)	15.06 Ha (0.09 %)	
Mineral Stock area	13.74 Ha (0.03 %)	13.75 Ha (0.08%)	
Total	667.39 Ha (1.40%)	649.89 Ha (3.93 %)	

Other type of land uses in succession are - water bodies, agricultural land and waste land for 5Km and 10 Km radius of study area. As per the statistics of (CSA, 2017) in 500m zone wasteland is highest 599.80 Ha (33.89%) and water bodies share 21% of land area in 500m zone, which is the main mining area (CSA, 2017).

'Salt Pan' in the study area forms one major land use in the study region. The percentage area covered by *salt pans* is more in 5km radius area (7.89%) compared to the 10Km buffer zone (4.20%). This shows that salt pan activities are dominant in and around the study area (CSA, 2017).

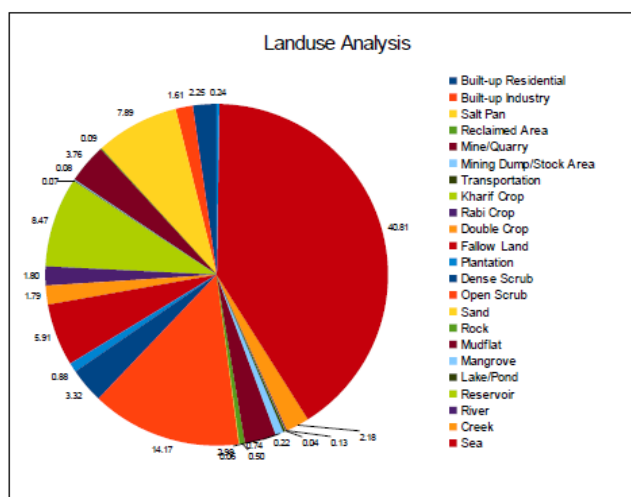


Fig. 2.6: Land use analysis for core zone (5 Km radius area) of NCJW mine

The change detection analysis of the land in study area indicated very negligible change (between the year 2013 and 2017) with respect to the land percentage and land area has been observed. All those land small areas (less than 0.2 Ha) are considered as “No Change” area. Hence, broadly and recently in 05 years period land use pattern has observed no changes and thus have no impact on land (CSA, 2017).



On one side of the study area, land is fully utilized by the sea (Arabian Sea / Gulf of Khambat - Gujarat Coast). As such, the land use is characterized with coastal features. *Sand dunes* of different sizes with associated sandy tract also forms a part of land use pattern in the study region. Coast line near NCJW study area, which is made of cliff and rocks has observed no changes between the year 2014 and 2017 (CSA, 2017).

Table 2.4 : List of villages in core zone and buffer zone with their population

Name of Village	Core Zone (CZ) / Buffer Zone (BZ)	Distance from Mine (Km)	Approximate number of Household	Total Population	Administrative Division
Babarkot	CZ	0.3	820	4624	Jafarabad
Mines Office	CZ	0.0	--	(included in J'bd municipality data)	Jafarabad
NCJW Colony	BZ	4.5	330 (as per UltraTech record)	1975 (included in J'bad municipality)	Jafarabad
Jafarabad (municipality)	BZ	4.0	5443	27167	Jafarabad
Bhakodar	BZ	2.0	261	1583	Jafarabad
Varahswarup	BZ	2.0	193	1193	Jafarabad
Vandh	BZ	3.4	363	2046	Jafarabad
Vadhera	BZ	5.5	750	4442	Jafarabad
Mitiyala	BZ	1.5	415	2385	Jafarabad
Lunsapur	BZ	6.0	316	1888	Jafarabad
Mithapur	BZ	6.2	201	1174	Jafarabad
Kadiyali	BZ	6.4	496	2982	Jafarabad
Lothpur	BZ	7.0	502	2878	Jafarabad
Uchaiya	BZ	9.7	194	914	Rajula
Rampara -1	BZ	7.5	62	342	Rajula
Kovaya	BZ	6.0	959	4061	Rajula
Dharanu Nes	BZ	8.5	74	363	Rajula
Balanivav	BZ	5.6	41	253	Jafarabad
Bhatvadar	BZ	5.7	67	401	Jafarabad
Dholadri	BZ	6.5	175	1050	Jafarabad
Kagvadar	BZ	5.8	174	985	Jafarabad
Nageshri	BZ	6.3	1045	5468	Jafarabad

Note : Core zone = mine lease area (MLA) ; Buffer zone= MLA boundary up to 10km radius;
Population shown in table is as per Census of 2011.



Table 2.5 : Land use / Land cover statistics for Buffer Zone / 10 Km radius

Land Use/Land Cover Statistics within 10 Km. Buffer – Narmada Cement Mines Babarkot			
CLASSIFICATION			
LEVEL – I	LEVEL – II	% Area	Area (Ha)
Built-up	Residentia	1.47	701.15
	Industrial Area	2.15	1022.98
	Transportation	0.04	19.81
	Salt Pan	4.20	1999.20
	Sub-total	7.87	3743.15
Agriculture Land	Kharif	13.89	6605.76
	Rabi	1.96	933.78
	Double Crop	3.07	1458.83
	Fallow land	5.86	2785.92
	Plantation	0.72	344.64
	Sub-total	25.51	12128.93
Wastelands	Dense Scrub	2.20	1046.29
	Open Scrub	11.02	5240.90
	Sub-total	13.22	6287.19
Wet and	Sand	0.05	21.65
	Rock	0.24	115.46
	Mudflat	1.55	736.37
	Mangrove	0.49	234.71
	Sub-total	2.33	1108.20
Water bodies	River	0.51	240.96
	Creek	0.83	393.08
	Lake/Pond	0.24	113.31
	Reservoir	0.04	17.40
	Mine Sump	0.08	40.32
	Water logged	0.13	63.42
	Sea	47.83	22741.26
	Sub-total	49.66	23609.76
Others	Mine/Quarry	1.34	638.59
	Reclaimed Area	0.03	15.06
	Mining Dump/Stock Area	0.03	13.74
	Sub-total	1.40	667.39
	Total	100	47544.61



Table 2.6 : Land use / Land cover statistics for core zone/ 5 Km radius

Land Use/Land Cover Statistics within 5 Km. Buffer – Narmada Cement Mines Babarkot			
CLASSIFICATION			
LEVEL – I	LEVEL – II	% Area	Area (Ha)
Built-up	Residential	2.25	371.31
	Industrial Area	1.61	266.04
	Transportation	0.07	11.18
	Salt Pan	7.89	1303.12
	Sub-total	11.81	1951.66
Agriculture Land	Kharif	8.47	1398.58
	Rabi	1.80	297.14
	Double Crop	1.79	296.28
	Fallow land	5.91	976.91
	Plantation	0.88	144.87
	Sub-total	18.85	3113.77
Wastelands	Dense Scrub	3.32	549.16
	Open Scrub	14.17	2340.48
	Sub-total	17.49	2889.64
Wetland	Sand	0.06	9.68
	Rock	0.50	83.01
	Mudflat	2.99	493.33
	Mangrove	0.74	121.97
	Sub-total	4.29	707.99
Water bodies	River	0.13	20.73
	Creek	2.18	360.27
	Lake/Pond	0.22	36.76
	Reservoir	0.04	7.24
	Mine Sump	0.24	40.32
	Waterlogged	0.00	0.00
	Sea	40.81	6742.12
	Sub-total	43.63	7207.44
Others	Mine/Quarry	3.76	621.09
	Reclaimed Area	0.09	15.06
	Mining Dump/ Stock Area	0.08	13.75
	Sub-total	3.93	649.89
	Total	100.00	16520.39

From geological and geo-hydrological angle land areas covered with *Alluvial Plains* have excellent ground water prospects whereas the valley fills, pediplain and milolitic limestone ridges have good groundwater prospects (**Fig . 2.7**).

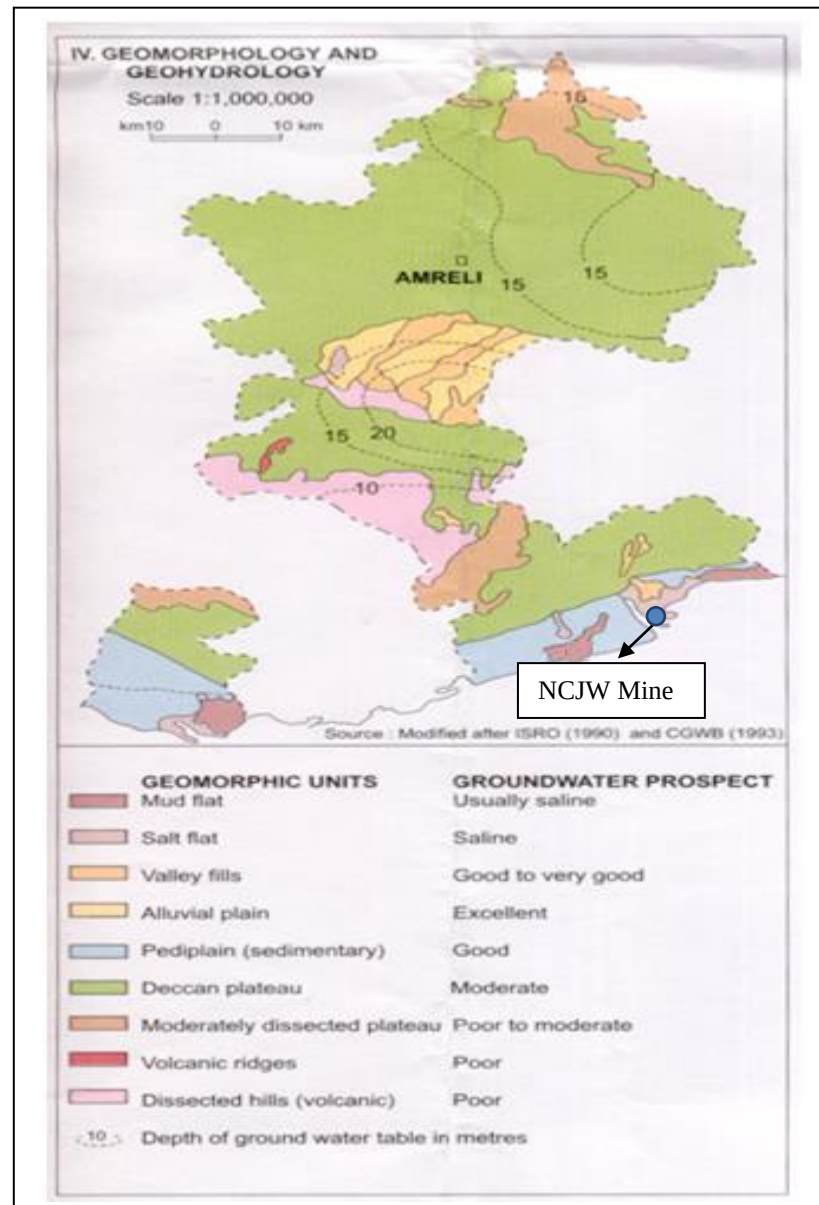


Fig. 2.7: Geomorphology and geo hydrology of Amreli district, Gujarat
(Source : GSI, 2002)

2.5.2 Soils

The soil in the area is classified as 'coastal alluvium' and formed by deposition process. It is a product of rock weathering from higher elevation and deposition along the low-lying coastal areas. Such alluvial coastal soils are generally young in formation and have weak profiles.



No soil sampling or analysis is done in and around the study area. Based on the secondary data (from different authentic sources) the description is provided here. **Table 2.7** gives soil quality details of the area around limestone mining. It is analyzed and assessed that the soil colour is medium black while coastal area is covered with alluvial soils. The soil is rich in Ca, Mg, Fe and Na content and has texture from silty-loamy to silty- clay-loamy. Due to its texture it can retain moisture. The coastal alluvium has sandy texture.

Table 2.7 : Soil quality of the study area

S. No.	Parameter (Unit)	Kovaya Village	Varahswarup Village	Bhakodar Village	Rampara Village
1.	pH	7.75	7.80	7.70	8.20
2.	Porosity (%)	52.60	51.40	49.10	55.50
3.	Conductivity (milli mhos)	6.50	0.44	23.00	6.20
4.	Ca	6.40	3.20	14.40	2.80
5.	Mg	4.80	4.00	29.20	6.40
6.	Fe (ppm)	3.75	1.25	2.50	35.00
7.	Na	23.75	2.00	68.50	23.25
8.	N	0.06	0.09	0.05	0.03
9.	P	ND	ND	ND	ND
10.	K	0.75	0.25	2.0	2.25
11.	Nitrates as NO_3	0.08	0.10	0.02	0.01
12.	Sulphates	3.25	0.58	2.66	2.75
13.	Chlorides	30.68	0.34	164.40	30.10
14.	Phosphates	ND	ND	ND	ND

Source : ENMIN, 2004 ; All values in m equivalent / 100g unless stated

Poor content of N, P, K in soil makes the soil not good for agriculture and plant growth. Due to this mine lease area and area around it, is generally devoid of large trees. At places some trees and thorny bushes of local varieties have been observed in the area. Probably, seawater inflicts the soil quality. A thin soil cover ranging in thickness from few centimetres to 1m only overlies the limestone deposit. In general, the study region has mostly loamy clayey, mixed calcareous and monto-morillonitic soil.

2.6 HYDRO-METEOROLOGY

Hydro-meteorology and its details are essential for any hydrological studies to establish the various controlling factors, as they govern the occurrence and movement of surface as well as groundwater in the study area or a region. Rainfall, climate (relative humidity, wind speed and its direction) and



temperatures are the key parameters from this viewpoint. These are described in short in the paragraphs below.

2.6.1 Rainfall

The study area receives rainfall from S-W Monsoon. Rainfall statistics as recorded at Jafarabad Taluka HQ for last 20 years starting from 1996 to 2015 has been given in **Table 2.8**. Rainy seasons starts in the month of June (first /second week of June) and continues up to middle of September. Rains are received in the monsoon months of the year. February to May is the dry season and monsoonal rain is generally heavier compared to rain in other parts of Gujarat.

Table 2.8 : Rainfall statistics of the study area

(Source: UltraTech Cement Limited, NCJW, Gujarat)

Year	Total Rainfall (in mm)	Year	Total Rainfall (in mm)
1996	767.0	2006	760.0
1997	551.5	2007	876
1998	829.0	2008	519
1999	254.7	2009	740
2000	324.0	2010	849
2001	536.0	2011	567
2002	1157.8	2012	272
2003	1316.2 (MAX.)	2013	765
2004	1072.0	2014	563
2005	726.0	2015	913
Average annual rainfall =	717.91 mm or say 718 mm (71.8 cm)		
Recent	<i>Annual rainfall in 2016 = 970mm (as per www.gujaratweather.com)</i>		

Another data sets (secondary) of average rainfall of the study area is available from GSDMA, Gujarat and according to them the average rainfall recorded for the Jafarabad area is 636 mm (Period : 1986 to 2015).

Considering all available data (mentioned above), the average rainfall of Jafarabad area is worked out as **775 mm** $[(718 + 663 + 970) / 3 = 775 \text{ mm}]$. Therefore, for this particular study and for the purpose of discussion and analysis the same figure of 775 mm has been used.



2.6.2 Climate

The climate of the study area is hot semi-arid (NBSS&LUP - Agro eco region - 5) and hence characterized by hot and wet summers and dry winters. Since the area is located adjacent to *Arabian Sea* it is characterized with coastal climate. The rains are moderate and the predominant wind direction is from West and S-W (May to September) while in the post-monsoon and winter it is from N-E to S-W. In April to June the sky remains clear and moderately clouded during July to September. Mean cloudiness is usually >06 Oktas and marked with higher concentration in evening compared to the morning.

Winters are pleasant with minimum temperature reaching up to 10°C while the summer temperature goes up to 40°C - 42°C (mean). The average annual temperature of the area lies in the range of 26°C (minimum) & 33°C (maximum). Relative humidity varies from 48% to 90% during different period in a year. During the monsoon season relative humidity is more than 80% whereas January – February records 50% or less humidity. Due to the close proximity of sea the diurnal variation in relative humidity remains nearly constant throughout the year. The average monthly wind speed is 15.3 Km / hour. Mean annual wind speed is highest in the summer months (May-June) and lowest in December. To get an idea of the meteorological conditions 2015 data as recoded at Bhavnagar observatory can be looked at **(Table 2.9)**.

Table 2.9 : Meteorological data of Bhavnagar for the year 2015

Month	Daily Temperature (Mean)		Relative Humidity (in %)		Wind Speed (Mean, Km/hr)	Mean Cloudiness (Oktas)	
	Maximum	Minimum	8.30 hrs	5.30 hrs		8.30 hrs	5.30 hrs
Jan	27.6	12.9	44	29	8.4	1.2	1.4
Feb	30.3	14.9	44	21	8.6	1.1	1.2
Mar	34.7	19.6	39	22	9.8	1.0	1.3
Apr	37.6	23.9	44	27	11.3	1.2	1.4
May	39.6	26.0	54	37	13.9	1.4	1.4
Jun	37.6	27.1	65	47	15.3	4.3	4.6
Jul	33.2	26.0	54	37	14.7	6.4	6.8
Aug	32.3	24.8	77	64	12.5	6.4	6.7
Sept	33.2	24.2	74	63	10.0	4.6	5.4
Oct	34.2	22.5	60	34	7.7	2.0	4.3
Nov	31.6	18.0	50	31	6.8	1.5	1.7
Dec	28.6	14.2	45	34	7.7	1.3	1.5
Mean (Annual)	33.4	21.0	56	39	10.5	2.7	3.1

Source : Gujarat state metrological observatory, Bhavnagar

Analysis w.r.to climate: The mine lease area has poor vegetal cover and not having any indications of good vegetation in the surrounding areas also. Only 'babool' and 'subaool' trees are visible characterizing that the area records less



precipitation but close to the normal average rainfall of the state. Thus, the climate of the area can be characterized as 'dry' in general.

Since the annual precipitation range varies from 500 mm to 1000 mm, which covers nearly 30% to 40% of the annual evapotranspiration losses. Hence, gross annual water deficit may be observed and area may record drought conditions occasionally. As such the area is located near coast, salinity and seasonal inundation by seawater in the coastal region may be observed. Salinity hazards in the irrigated agriculture areas are the constraints of the study area.



CHAPTER – 3

WATER QUALITY & GEOPHYSICAL INVESTIGATIONS

The ensuing study is aimed towards determination of seawater intrusion. *Water quality analysis, geophysical field survey* (Electrical Resistivity Tomography or ERT) and *groundwater modelling* has formed the basis for deriving investigations results. In the paragraphs below and in subsequent chapters these are explained one by one in detail. It may be noted that the area of investigation, forms a part of Gujarat Coast of India and assumes significance from industrial development view point.

3.1 WATER QUALITY

Total Dissolved Solid (TDS) - A water quality parameter, is an important parameter for assessment of the magnitude of dissolved solids in the normal fresh water / ground water. In case of coastal aquifers, TDS values of ground water gives an idea of the quantum of salt (i.e. dissolved solids) likely to be present in the water (TDS values of sea water are generally very high).

A network of observation wells is set up in the study area. The wells are all dug wells (**Table 3.1**). The pre-monsoon and post-monsoon samplings were carried out in May, 2017 and November, 2016 respectively. Sea water samples from the Arabian sea is also collected to know the concentration of salt present (**Table 3.2**). Based on the actual scenario as observed in the field **Table 3.3** is prepared for network of observation wells to establish the ground water status in the study area during monitoring period. Together with the quality and depth an analysis of the ground water scenario for the NCJW mining area is discussed in this report. Standard procedure of sample collection and its laboratory analysis has been followed. The samples are analysed for all the major ions by following standard methods (APHA, 1998).

The results for WQ analysis for pre-monsoon and post-monsoon sampling are presented in **Table 3.4**. The concentration level of Chloride (Cl), Sodium (Na) and Total Dissolved Solids (TDS) is presented in maps form for the pre-monsoon and post-monsoon seasons (**Fig. 3.1 to 3.3**). The study area contour map alongwith the ground water flow direction is depicted in **Fig 3.4**. A close examination of Table 3.4 indicates that TDS values >3000 mg/L are noticed in samples namely NCJW-GW1, NCJW-GW5, NCJW-GW15, NCJW-GW16., NCJW-GW21 and NCJW-GW22. The TDS contours (**Figure 3.3**) indicate very



high concentration in the lease area and area all around the lease. High values of Sodium (Na) are recorded in both pre-monsoon (from 795 mg/L to 1205 mg/L) and post monsoon (from 704 mg/L to 1026 mg/L) samples (**Figure 3.2**). In addition, all such samples have Chloride (Cl) concentration lies in the range of 99 mg/L to ≥ 2012 mg/L for pre-monsoon season and 80 mg/L to ≥ 1518 mg/L for post-monsoon season. The dilution of chloride concentration between pre & post-monsoon is also observed in the water quality analysis, which shows the normal natural phenomenon is occurring in the studied coastal region. Such high TDS values and higher Na & Ca content can be attributed to possible seawater intrusion in the study area. The high concentration of these are due to or on account of infiltration from the sea high tides, which intrude the mainland area nearby in the immediate vicinity of coast. *Dhatarwadi River and Raidi River*, which terminates into the Arabian sea and forming watershed boundaries on this coastal area, also gets influenced by the sea tides forming the salty backwater and encroaching the ground water in the immediate vicinity of coast.

Table 3.1: Observation wells of NCJW study area

Location (Name of Village)	Dug well ID for description	Type of water	Latitude	Longitude	Remarks
Babarkot	NCJW GW	Ground Water	N 20° 52'22.0"	E 71° 24'58.1"	
Mines Office	NCJW GW	Ground Water	N 20° 52'22.49"	E 71° 24'34.6"	
NCJW Colony	NCJW GW		N 20° 51'56.1"	E 71° 21'20.3"	
Jafarabad (municipality)	NCJW GW	Ground Water/ Surface Water	N 20° 52'4.2"	E 71° 21'30.8"	Both hand pump water and pipe line supply water are in common use.
Bhakodar	NCJW GW	Ground Water	N 20° 53'45.4"	E 71° 27'11.00"	
Varahswarup	NCJW GW	Ground Water	N 20° 53'00.4"	E 71° 26'39.5"	Temple Well
Vand	NCJW HPW	Ground Water	N 20° 54'23.9"	E 71° 24'35.0"	Hand Pump
Kagvadar	NCJW GW	Ground Water	N 20° 58'23.0"	E 71° 23'31.9"	
Nageshri	NCJW GW	Ground Water	N 20° 55'46.4"	E 71° 20'22.6"	
Vadhera	NCJW GW	Ground Water	N 20° 51'04.7"	E 71° 18'23.6"	
Mitiyala	NCJW GW	Ground Water	N 20° 53'46.7"	E 71° 23'24.1"	
Lunsapur	NCJW GW	Ground Water	N 20° 55'47.6"	E 71° 24'50.4"	
Mithapur	NCJW GW	Ground Water	N 20° 55'34.7"	E 71° 20'56.1"	
Kadiyali	NCJW GW	Ground Water	N 20° 51'58.3"	E 71° 17'49.4"	
Lothpur	NCJW GW	Ground Water	N 20° 57'16.1"	E 71° 26'02.7"	
Uchaiya	NCJW GW	Ground Water	N 20° 57'22.8"	E 71° 27'46.0"	



Rampara -1	NCJW GW	Ground Water	N 20° 56'04.7"	E 71° 27'45.6"	
Kovaya	NCJW GW	Ground Water	N 20° 54'18.4"	E 71° 27'18.9"	
Dharanu Nes	NCJW GW	Ground Water	N 20° 57'56.8"	E 71° 26'54.4"	
Balanivav	NCJW HPW	Ground Water	N 20° 57'12.5"	E 71° 21'42.4"	Hand Pump
Bhatvadar	NCJW GW	Ground Water	N 20° 57'45.9"	E 71° 22'31.2"	
Dholadri	NCJW GW	Ground Water	N 20° 54'25"	E 71° 18'37.7"	
Narmada Cement Plant (Babarkot)	NCJW	Arabian Sea	N 20° 52'05.9"	E 71° 24'40.2"	SEA WATER (Babarkot)
Dhatarwadi	NCJW RW	Surface Water	N 20° 56'15.6"	E 71° 27'46.5"	River water
Raidi	NCJW RW	Surface Water	N 20° 56'53.4"	E 71° 19'50.9"	River water

Table 3.2 : Surface Water, Sea Water and Other water type details in the study area for post-monsoon (2016) and pre-monsoon season (2017)

Sample Code	Source	Latitude	Longitude	RL (m)	MP (m)	Post-monsoon - 2016			Premonsoon-2017		
						DWL	GWL	GWL	DWL	GWL	GWL
NCJW – SW 01	Narmada sample from pipe line near Kanderiya (River water)	N 20°51'44.1"	E 71°19'54.5"	04	- TDS Values = 172.2 mg/L to 212.1 mg/L - Hardness =76 mg/L - Chloride : Bicarbonate ratio <0.047731 <i>Please see Table 3.4 (S. No. - 28)</i>						
NCJW-SW 02	Raidi river (River water)	N 20°56'53.4"	E 71°19'50.9"	21	Please see Table 3.4 (S. No. 25)						
NCJW – Sea water	Sea water (Near Babarkot)	N 20°52'05.9"	E 71°24'40.2"	03	TDS Values = 32,000 mg/L						
NCJW – Pipeline (GW-24)	Pipeline water in mines office premises	N 20°52'31.4"	E 71°23'56.7"	17	Please see Table 3.4 (Point No 27)						
NCJW – MPW GW-25	Mine pit water (East block pit, Babarkot)	N 20°52'41.7"	E 71°25'19.8"	2	1.80	NA	NA	NA	2.82	1.02	- 0.98

When ratio of chloride vs bicarbonate is calculated it was found that at number of place >01 value is noticed (**Table 3.4**) which is an indication of the presence of intrusion in the study area. The confirmation about the presence of intrusion has also been done on the basis of *cations - anions analysis*. Various parametric values are as given in the water quality analysis table (**Table 3.4**).

On observing TDS plot of **Fig. 3.3** it is found that TDS concentration in post-monsoon season is higher compared to the pre-monsoon season which is reverse of the normal trend. As per the ground water chemistry and recharge mechanism taking place in the NCJW aquifer observance of such trend is possible. As per the ground water recharge mechanism taking place underground, when the dry limestone strata (unsaturated unconfined aquifer) is



drenched (in monsoon) more leaching of calcium takes place and TDS values are increased. This particularly happens at deeper level and when ground water of shallow depth mixes with ground water of deeper levels TDS even in post monsoon season is found more. If TDS is higher, the sodium and chloride content of ground water should also be higher, the ground water chemistry principles says. The same case is observed in NCJW site study. TDS of NCJW aquifer's ground water is since mixed with sea water (coastal area) further increased TDS values are possible. This is the reason, why CIMFR generated TDS values (**Fig. 3.3**) have shown this trend (primary data).

In brief, wherever salinity ingress is present the TDS values are generally higher compared to the prescribed limit in both pre and post monsoon season. **Fig 3.3 (a & b) and** TDS data / values of **Table 5.4** clearly shows this. Such data also indicates that a correlation between the ground water recharge and management. At the NCM pit, existing recharge mechanism, through stored water in unused / abandoned pit is playing positive role (**Annexure - II**)

As an attempt to further study the possible seawater intrusion in the study area, geophysical investigations have been carried out at selected locations. The locations were selected on the basis of available field logistics, approachability and presence/absence of overhead power lines.

3.2 GEOPHYSICAL INVESTIGATIONS

The primary purpose of the geophysical investigation is to study the variations of properties namely, density, resistivity, magnetic susceptibility and acoustic velocity in the near sub-surface strata and correlate it with the geological or anthropological stresses at the site.

Among the geophysical methods, the resistivity method is generally employed in the field oriented studies. As the present investigation is to be focused on possible seawater intrusion [where the conductivity of the seawater ($3-10 \text{ mho-m}^{-1}$) has significant contrast with respect to fresh water aquifer ($0.0125-0.2 \text{ mho-m}^{-1}$)], resistivity method (ERT) is found as a useful tool. In the present study area, the study objective is focussed to examine whether the resistivity images had any signatures of seawater intrusion or not ?



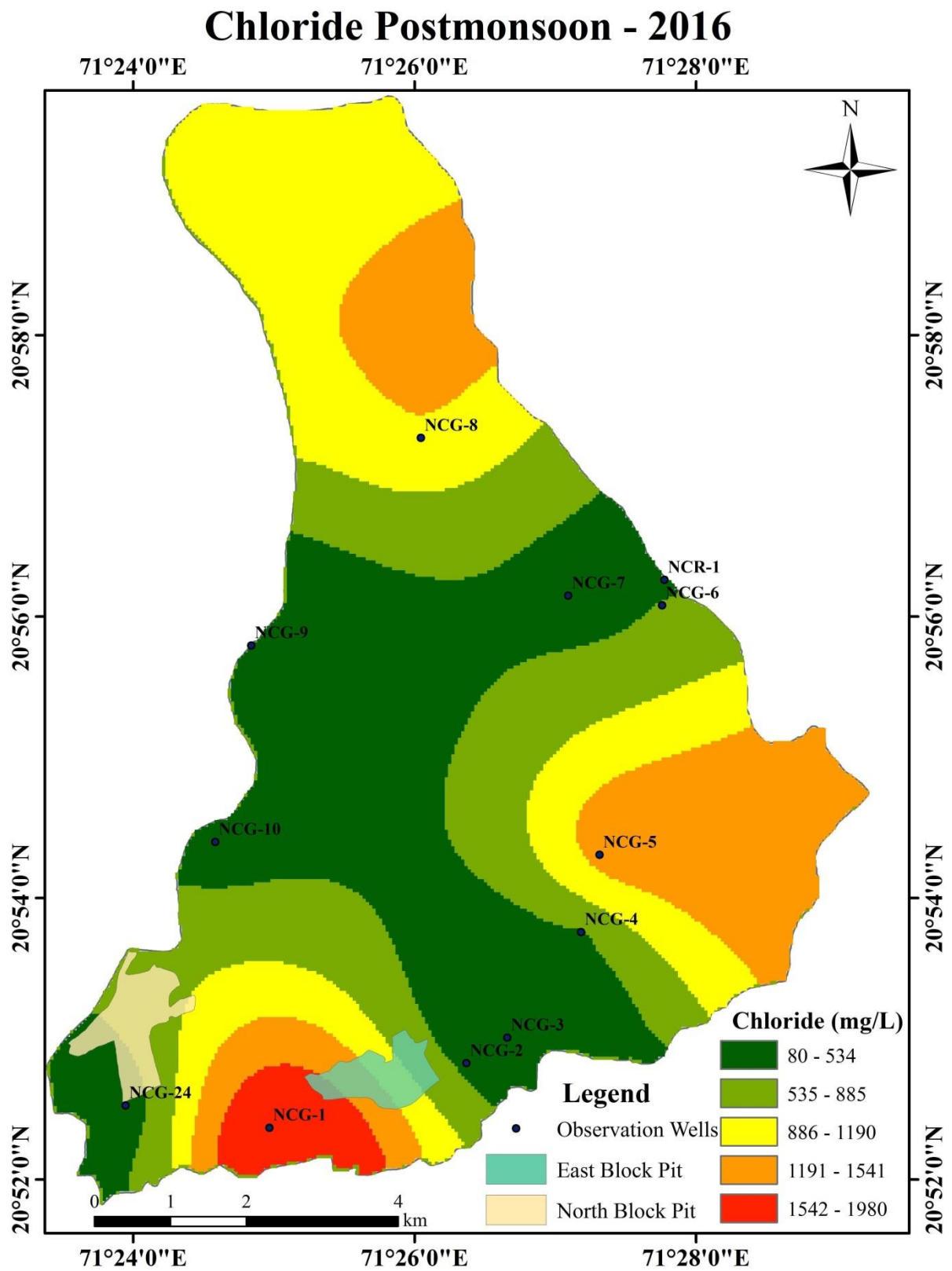


Fig. 3.1(a) : Chloride concentration in groundwater of NCJW study area (Post-monsoon, 2016)

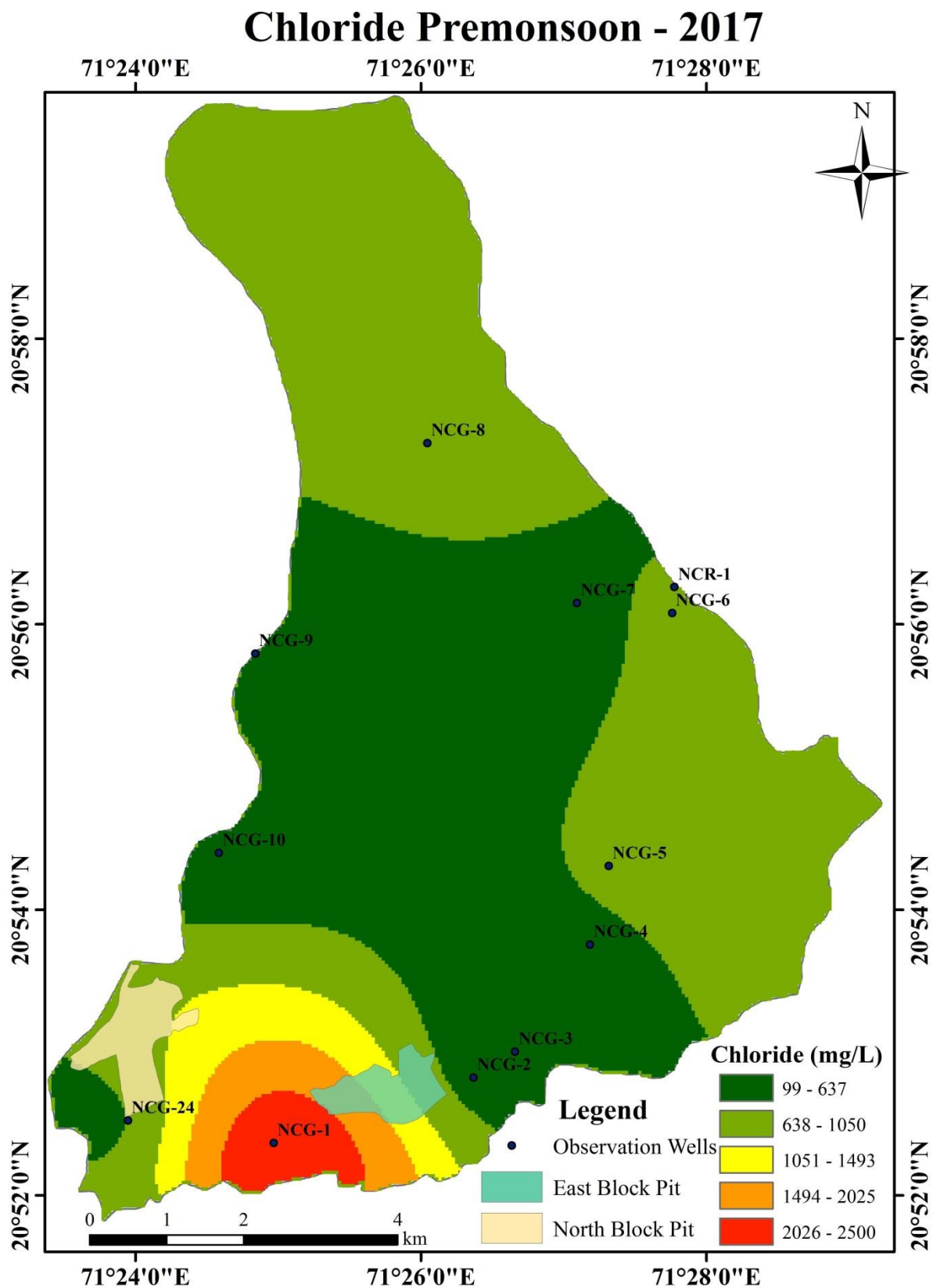


Fig. 3.1(b): Chloride concentration in groundwater of NCJW study area (Pre-monsoon, 2017)

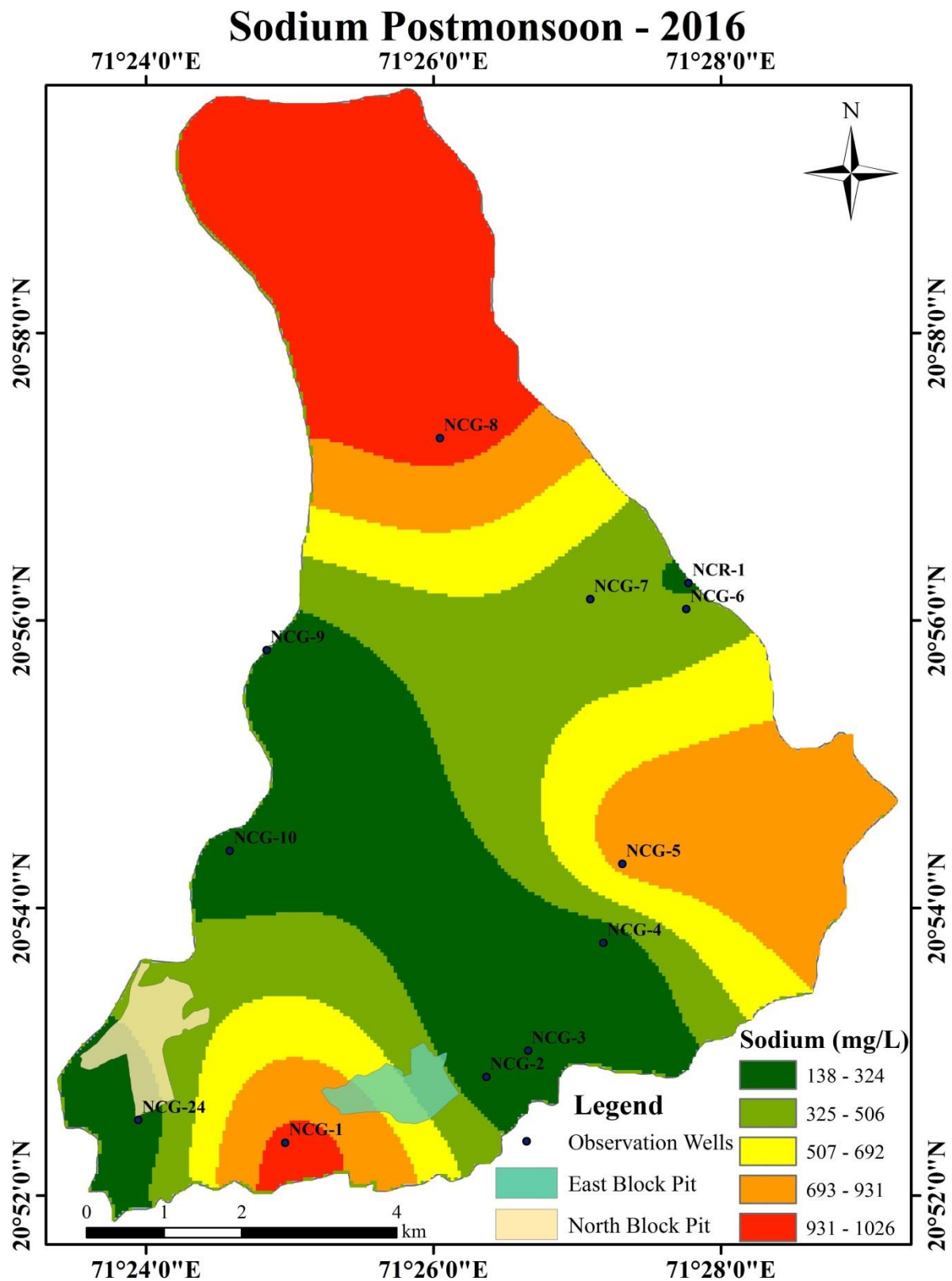


Fig. 3.2(a): Sodium concentration in groundwater of NCJW study area (Post-monsoon, 2016)



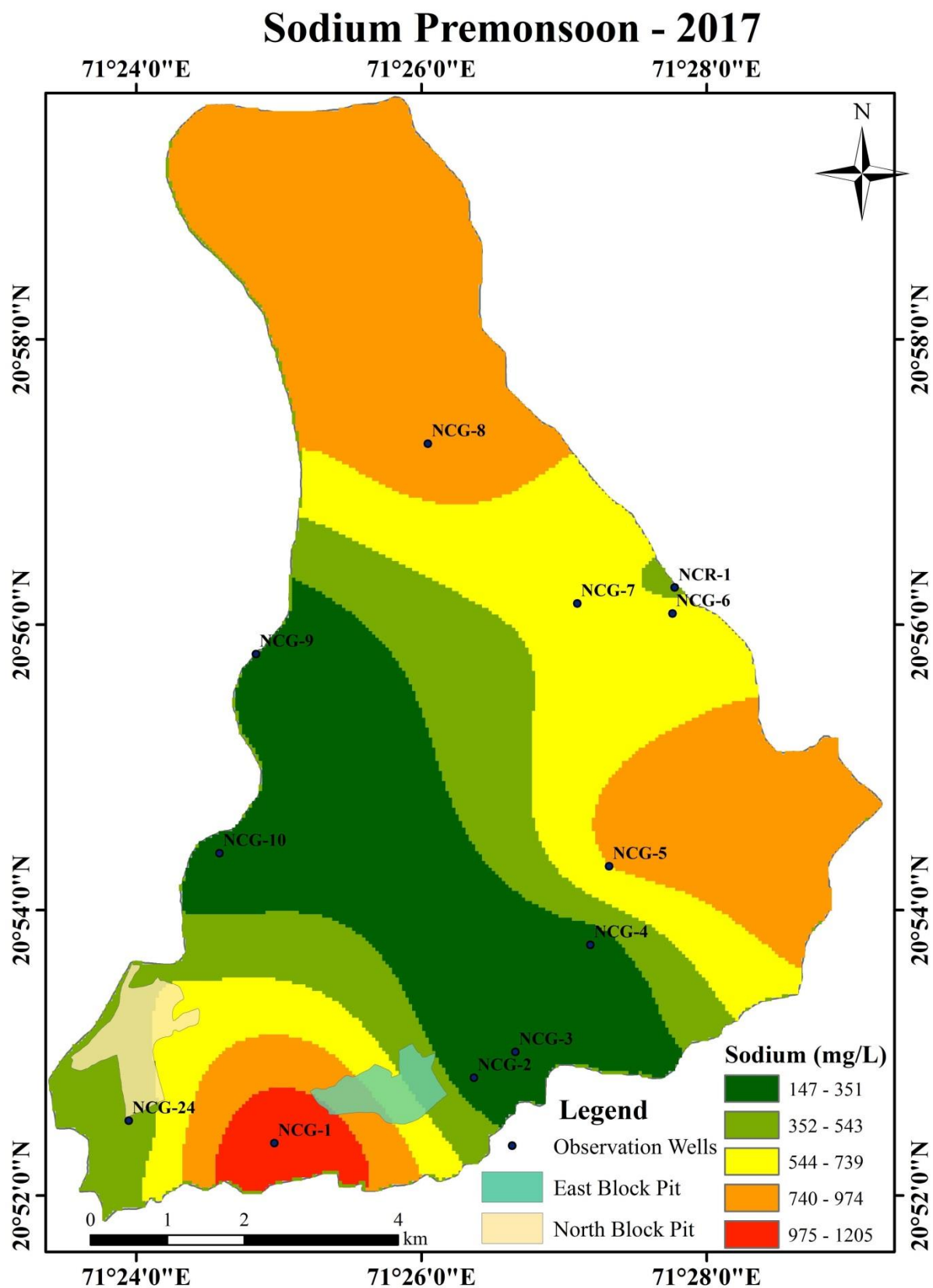


Fig. 3.2(b): Sodium concentration in groundwater of NCJW study area (Pre-monsoon, 2017)

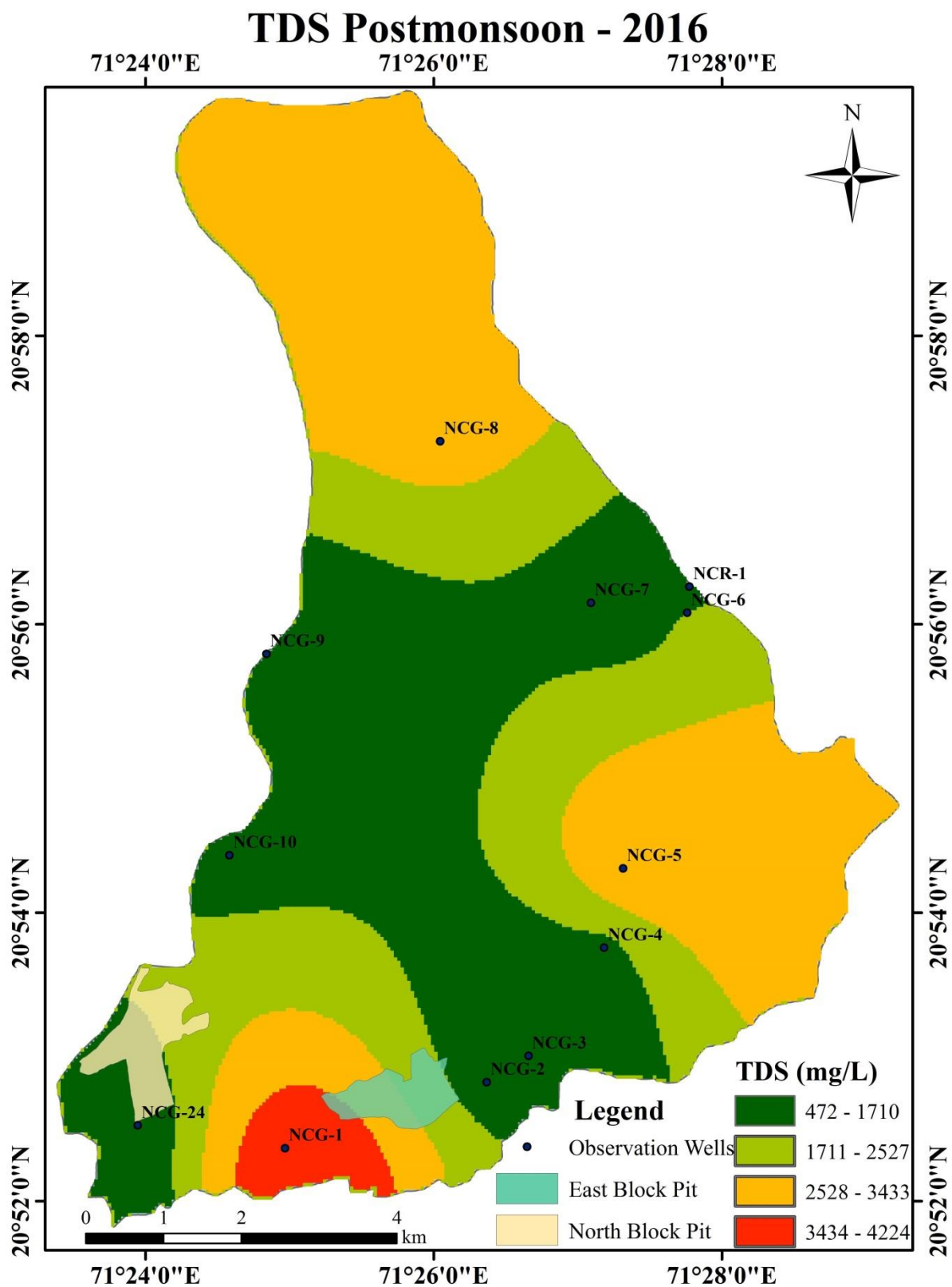


Fig. 3.3(a) : TDS concentration in groundwater of NCJW study area (Post-monsoon, 2016)



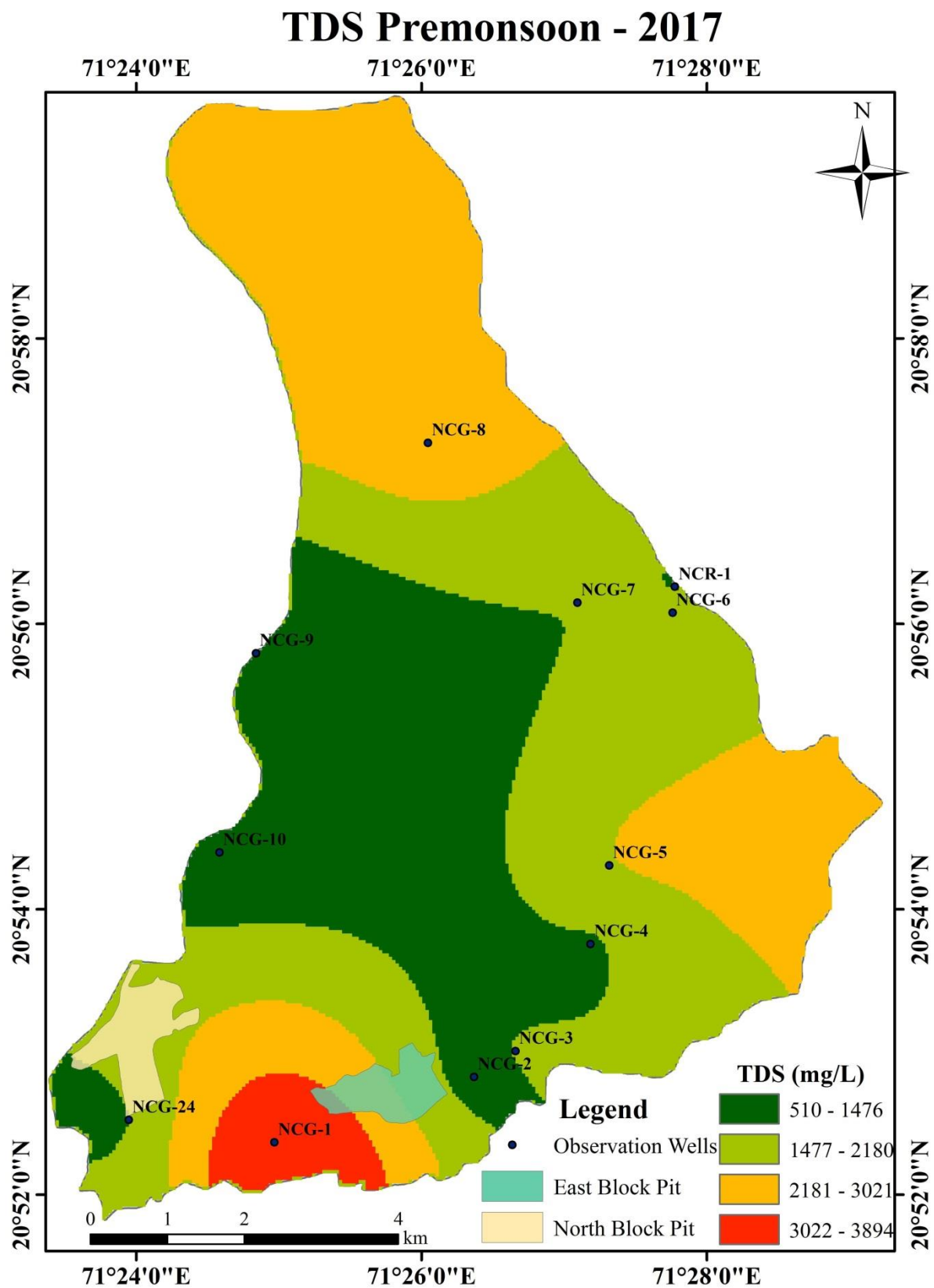


Fig. 3.3(b): TDS concentration in groundwater of NCJW study area (Pre-monsoon, 2017)

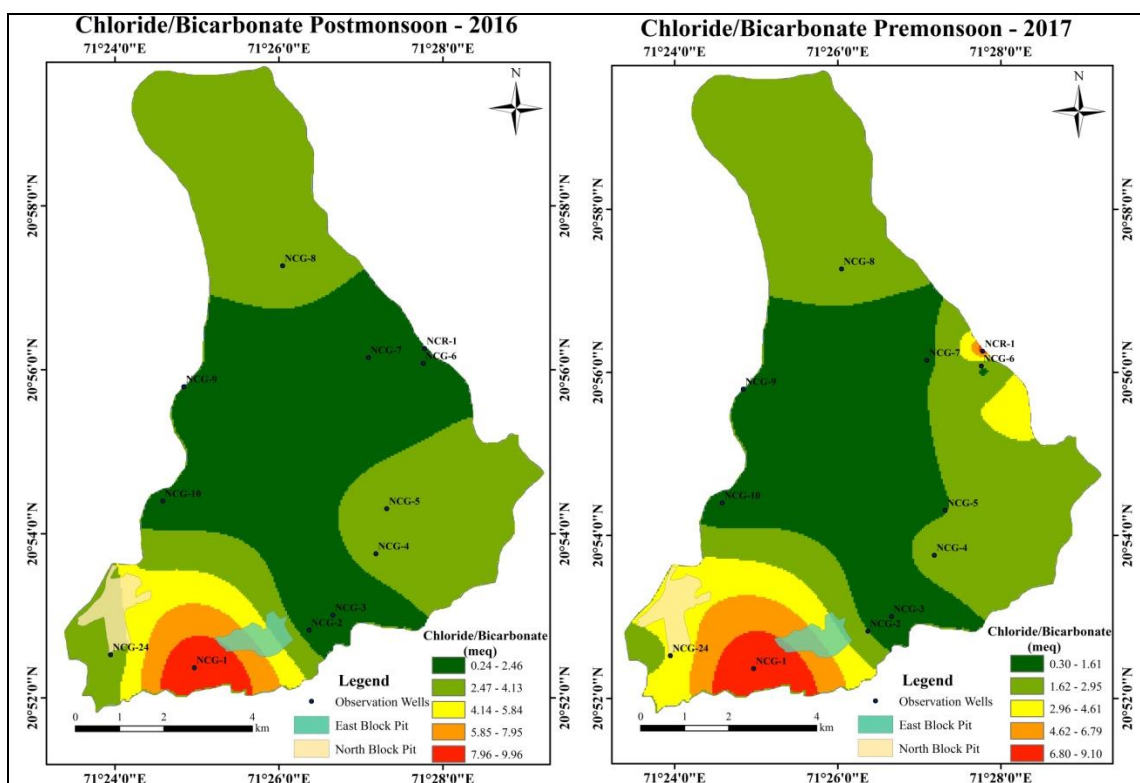


Fig. 3.4 : Map showing chloride : bicarbonate ratio in ground water of NCJW study area

3.2.1 Electrical Resistivity Tomography (ERT)

This is also termed as 'geophysical tomography' or 'geophysical imaging' and used in the present study to examine the signatures of seawater intrusion in NCJW study area.

The electrical resistivity method involves the measurement of the apparent resistivity of the sub-surface (soil and rock) as a function of depth or position. From these measurements, the true resistivity of the sub-surface can be estimated. The resistivity in the sub-surface is a complicated function of porosity, permeability, ionic content of pore fluids and clay mineralization. The electrical resistivity surveys have been used since the 1920s for hydro-geological, mining and geotechnical investigations. The most common electrical method used in hydro-geologic and environmental investigations is Electrical Resistivity Tomography (ERT).

Theory : The basic principle involved in the electrical resistivity surveys is Ohm's law i.e, $V=IR$, current is injected into the Earth through a pair of current electrodes C1 and C2, and the potential difference is measured

between a pair of potential electrodes P1 and P2 (**Fig. 3.5**). The potential variations may be changed due to size, shape and conducting capacity of the material in the subsurface and from the quantities of potential differences

and the current applied the apparent resistivity (ρ_a) value is calculated.

$$\rho_a = K \frac{V}{I} \dots \dots \dots (1)$$

Where K is the geometric factor, which depends on the arrangement of the four electrodes.

The resistivity value calculated by Eq. (1) is not a true resistivity of the sub-surface, but an apparent value, which is governed by the aggregate effect of the sub-surface. The apparent resistivity and the true resistivity are linked by a Physico-mathematic operator. The true resistivity can be extracted from the apparent resistivity values through an inversion program on a computer. We have used Res 2D software for inversion due to its capability of high degree calculation.

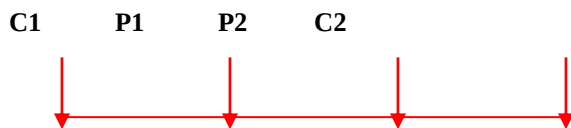


Fig. 3.5: A conventional four electrode array to measure the sub-surface resistivity

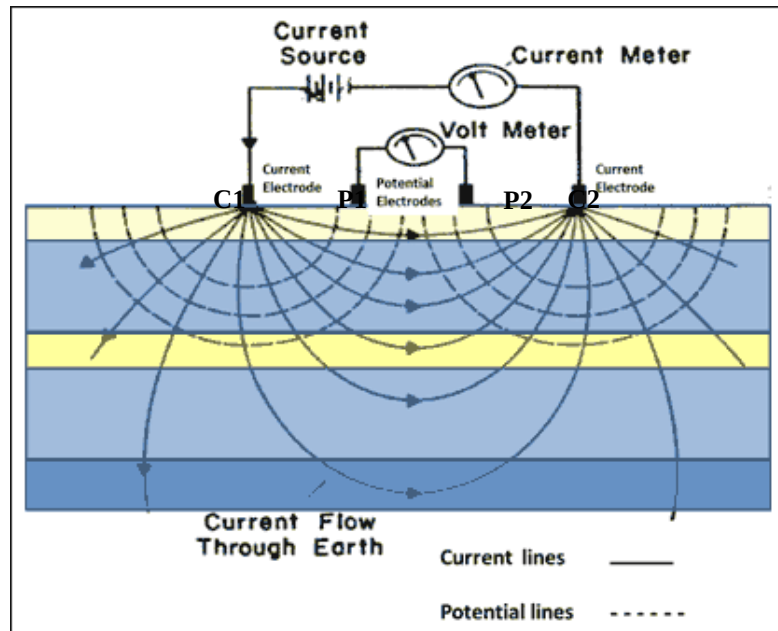


Fig. 3.6: Basic principle of electrical resistivity method

3.2.2 Traditional resistivity surveys

The resistivity method (**Fig. 3.6**) has its origin in the 1920s due to the pioneering effort of the Schlumberger brothers. Till the 1980s, traditional surveys were employed for quantitative interpretation. The traditional surveys are mainly of two types.

- a) *Resistivity Sounding*: In this method, the center of the electrode array remains fixed but the spacing between the electrodes is changed in steps to obtain information from the deeper sections of the sub-surface. The key assumption of the resistivity sounding is that the resistivity property varies only in the Z-directions (vertically downwards) and does not change in the horizontal directions.
- b) *Resistivity Profiling*: In this case, the spacing between the individual electrodes is kept fixed and the entire array is moved along a straight line. This gives information about lateral changes in the sub-surface resistivity but it cannot detect vertical changes in the resistivity. The interpretation of data from profiling surveys is mainly qualitative.

In many engineering and environmental studies, the sub-surface geology is very complex where the resistivity can change rapidly over small distances. One dimensional (1-D) resistivity surveys were common till the early 1990s due to the fact that proper field equipment were not available for intensive 2-D & 3-D surveys. However, with advancements in the domain of geophysical instrumentation, multi-electrode resistivity systems and fast computer softwares are made available to researchers to address 2-D and 3-D surveys.

Resistivity Tomography: This is a fast and efficient method of getting the resistivity image of the sub-surface using multi-electrode cable, which has number of electrode switches. This survey is employed to acquire 2-D or 3-D resistivity variation in the sub-surface. The switches are connected to electrode stakes and activated in succession for injecting electric current into the earth. Accordingly, each electrode is activated and potential is measured at other electrodes. The ratio of the measured potential (V) and the injected current (I) is the required resistance value. This resistance value is then multiplied by a Geometric factor (K), which is a function of the disposition of



the current and potential electrodes to give the *apparent resistivity*. During the resistivity survey, a series of *apparent resistivity* values are obtained, which is used to build up a pseudo-section (**Fig. 3.7**).

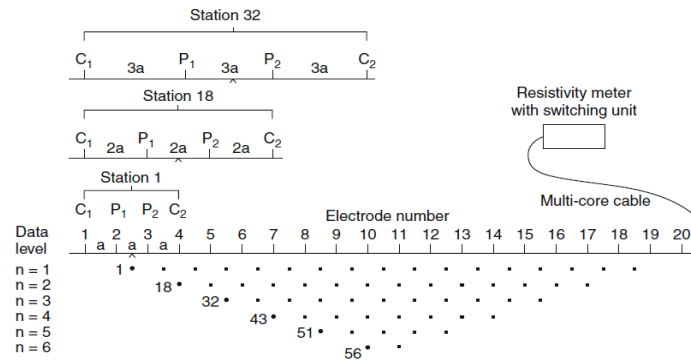


Fig. 3.7: Schematic diagram of multi electrode system for 2-D electrical survey (pseudo-section)

Finally, the measured apparent resistivity values are inverted to produce the resistivity image of the sub-surface. This resistivity image can be linked to the geological settings of the surveyed area. This also provides useful information pertaining to the changes, which may have occurred in the study area. The changes can be related to geogenic factors like seawater intrusion and anthropogenic factors like withdrawal of groundwater, presence of leachate generated from dumping of industrial and municipal waste, variations in soil salinity due to disposal of wastewater etc.

In this study *resistivity imaging* has been adopted for data acquisition.

For this purpose, the 4 channel system known as *Terameter LS* (Manufactured by M/s ABEM Bv, Sweden) is used in the present study (**Fig. 3.8**). The key features of the LS imaging system are *integrated roll-along function* & *automatic electrode contact test* which gives full control of data acquisition process and storage of data. It has powerful transmitter with 2500 mA maximum current transmission and 250 W output power which gives higher quality data. High quality receiver with Input Voltage Range + / - 600 V and Input Impedance 200 M-Ohm provides sensitivity which enable high resolution data recording.

The resistivity images were acquired with the help of Schlumberger electrode arrangements (Telford et al, 1976). The measured data were inverted using the Res 2-D software (Loke, 2004). The inverted data were finally examined for signatures of SWI. For analysis of electric properties of non-conducting rock matrix filled with fluid, an empirical relationship *Archie's Law* have been taken in to consideration. Archie's law gives basic understanding of brine saturation and resistivity of rock.

$$C_t = \frac{1}{a} C_w \phi^m S_w^n$$

Where, ϕ denotes the porosity, C_t the electrical conductivity of the fluid saturated rock, C_w represents the electrical conductivity of the brine. S_w is the brine saturation, m is the cementation exponent of the rock, n is the saturation exponent (usually close to 2) and a is the tortuosity factor.

From this relationship, obtained resistivity is categorized on the basis of sea water saturation within limestone matrix. As per the Archie's Law, in such cases where limestone host rock completely saturated with the sea water it exhibits very low resistivity normally saying 0.3 ohm-m.



Fig. 3.8: Four channel TERAMETER LS system
(Manufactured by M/s ABEM Bv, Sweden)

Different researchers have attempted the study of seawater intrusion by geophysical method (Ebrahim et al, 1997, Jones et al, 1999, Wilson et al, 2006). The non-uniqueness nature of geophysical data together with the use of *multi-electrode resistivity imaging method* makes the data amenable to qualitative interpretation. The more challenging part of the interpretation is the

attempt to link the low-resistivity zones with possible seawater intrusion. As the pore fluid, which can be a mixture of fresh water and seawater with varying proportion, is embedded in the pores of the host rocks, which will have different resistivity corresponding to the mineral composition, an investigator's interpretation may vary from person to person. However, attempts to correlate with the earlier studies can explain the intrusion phenomena aptly and the background resistivity picture can be made clear. In this study area, the limestone forms the host rock whereas studies attempted earlier had sand and gravel as the host medium.

3.2.3 Site for resistivity imaging survey

Resistivity imaging survey has been carried out at different locations in the study area (**Fig 3.9 & Fig. 3.10**). The sites are selected in such a way that whole area, particularly mining and ancillary activities are fully covered. Such representative locations (or profiles) are selected near the seacoast, mining pits as well as areas close to the backwaters of the Arabian Sea (**Table. 3.5**). The profile length varied from 160m to 400m. The objective of the survey was to examine whether the resistivity image had any signatures of seawater intrusion.



Fig. 3.9 : A field study picture of resistivity imaging survey at NCJW study area

The applied criteria for site selection was that the area should be free from electrical and magnetic currents.

The resistivity results provide a clear view of the thickness of the weathered regolith and of the distribution of the various lithological units. Using a combination of apparent resistivity of formations and inferred depth of weathering, it is possible to characterize the various lithology on the geophysical profiles. As limestone is the principal host rock in the study area and the seawater and freshwater are embedded in the pores, the interpretation is done on the basis that the very low-resistivity images could be attributed to the seawater intrusions. For interpretation, it was decided to divide the total range of resistivity into few bands and present the profile images.

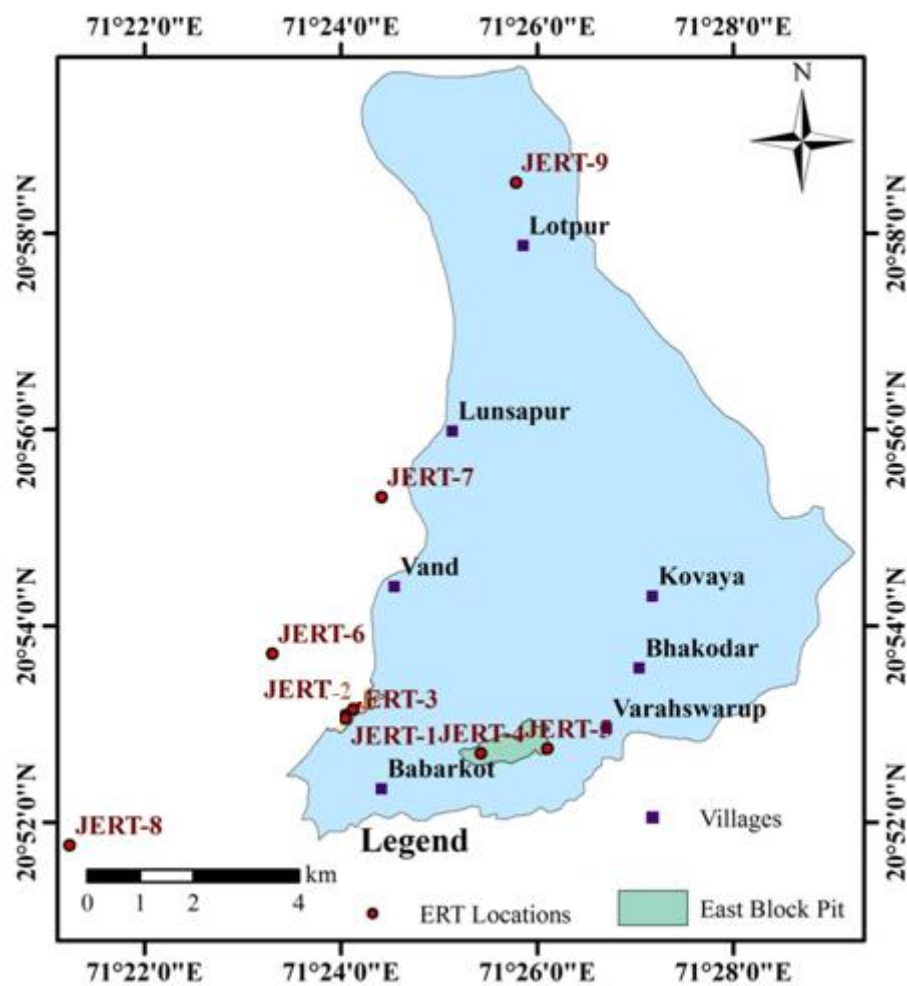


Fig. 3.10 : ERT locations in the study area

Table 3.5 : ERT locations with MRL

JERT S.Nos.	Latitude	Longitude	MRL (m)	Location
1	N 20° 53'05.3"	E 71° 24'03.1"	6.24 m	Within North block mine pit
2	N 20° 53'09.1"	E 71° 24'07.7"	7.32 m	Within North block mine pit
3	N 20° 53'03.1"	E 71° 24'02.9"	8.01 m	Within North block mine pit
4	N 20° 52'42.1"	E 71° 25'25.6"	2.09 m	Within East block mine pit
5	N 20° 52'44.9"	E 71° 26'06.3"	17.96 m	Adjacent to East block mine pit
6	N 20° 53'43.0"	E 71° 23'18.2"	28.00 m	Mitiyala village
7	N 20° 55'18.7"	E 71° 24'24.9"	21.00 m	Lunsapur village
8	N 20° 51'45.9"	E 71° 21'14.3"	10.17 m	NCJW colony ground
9	N 20° 58'30.9"	E 71° 25'47.1"	24.00 m	Vand village

3.3 ANALYSIS OF RESISTIVITY SURVEY

Taking into account, the theoretical principle involved in sea water intrusion and depending on the local conditions, the range of resistivity is separated into 04 (four) different zones as mentioned below :

- Very low : 0-3 ohm-m
- Low : 3- 45 ohm-m
- Intermediate : 45-250 ohm-m
- High : > 250 ohm-m

The zone characterized by very *low*-resistivity values (0-3 ohm-m) is interpreted as the zone of seawater intrusion. The zones characterized by *low* and *intermediate* values can also have mixture of fresh water as well as seawater in the pores. Hence, the presence of seawater intrusion cannot be ruled out in such zone also. As seawater has very low resistivity i.e. 0.3 ohm-m and it will be trapped inside the limestone aquifer, it is decided to treat the very low resistivity zone in the range (0 - 3 ohm-m) as the *confirmed zone* affected by seawater intrusion. The high resistivity may be present in limestone and host rocks present in the study area as water can conveniently flow through rock pores because of secondary porosity present in it. On the basis of resistivity survey in different zones following findings or inferences has been emerged. All depth values expressed in this section are the BGL values i.e. depth from the ground surface on which the resistivity profiles are taken and



observations recorded. 'Resistivity Bands' shown in color in Fig. 3.11 to Fig. 3.19 (for JERT1 to JERT9) has differing values as generated by the instrument. Hence, care should be taken in understanding and interpretation of the inverted resistivity sections of the site where profiling is done.

The resistivity profile JERT-1 has been carried out inside the North block mine

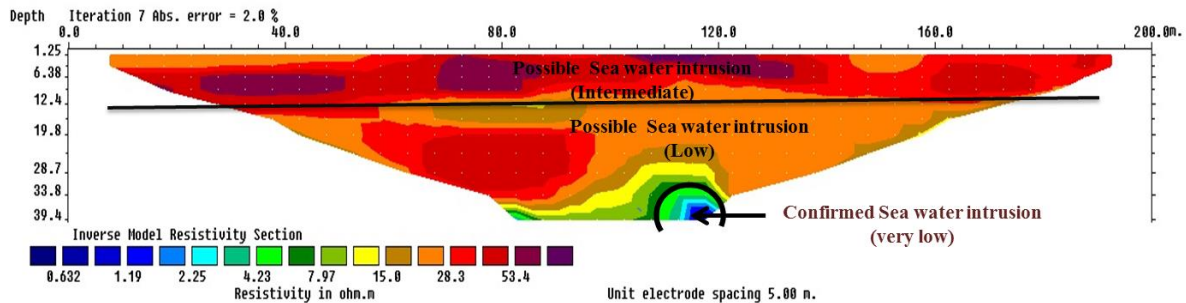


Fig. 3.11: Interpreted ERT location (JERT-1)

The resistivity profile JERT-2 (Fig 3.12) has been carried out inside the same North block mine pit but at other location (PI see lat-long from Table 3.5). Inverted resistivity section indicated that the soil is covered in the top 6-8m, whereas saturated limestone extend from 8m to up to 39m. Patch of very low resistivity zone is present at 34 m depth approximately.

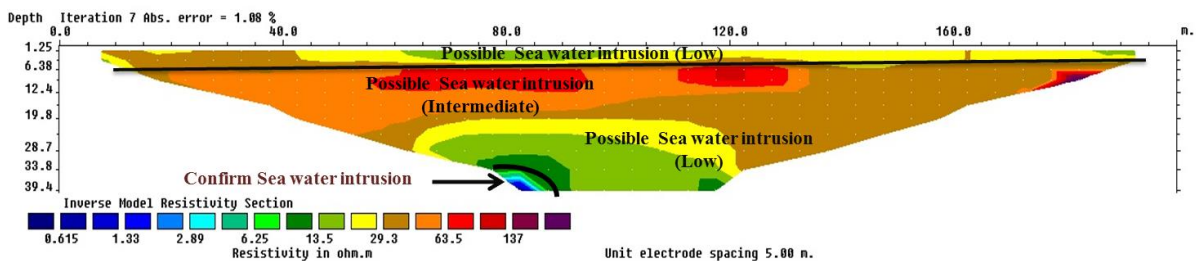


Fig. 3.12 : Interpreted ERT location (JERT-2)

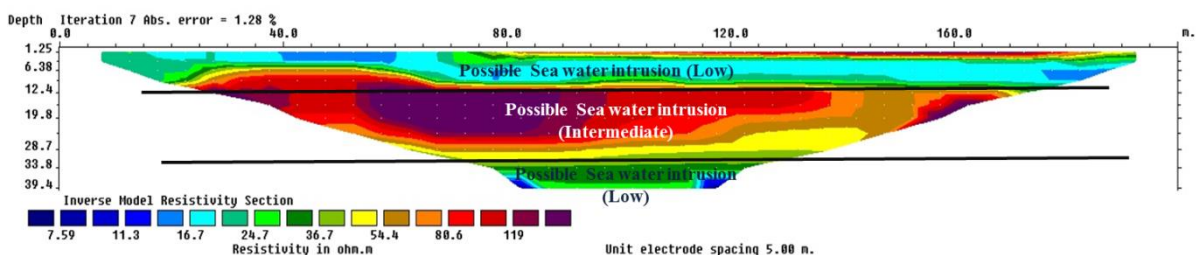


Fig. 3.13: Interpreted ERT location (JERT - 3)

The profile JERT- 3 (**Fig.3.13**) of the North block mining pit also recorded the low resistivity zone of approximately (≤ 20 Ohm-m) and is extended at 10m depth from surface. The intermediate resistivity zone (50 to 125 ohm-m) extends from 10m to 33.8 m depth and it is followed by low resistivity of 7 ohm-m to 50 ohm-m. In this profile, very low resistivity zones (0-3 Ohm-m) are not prominently present upto the depth of 39.4 m.

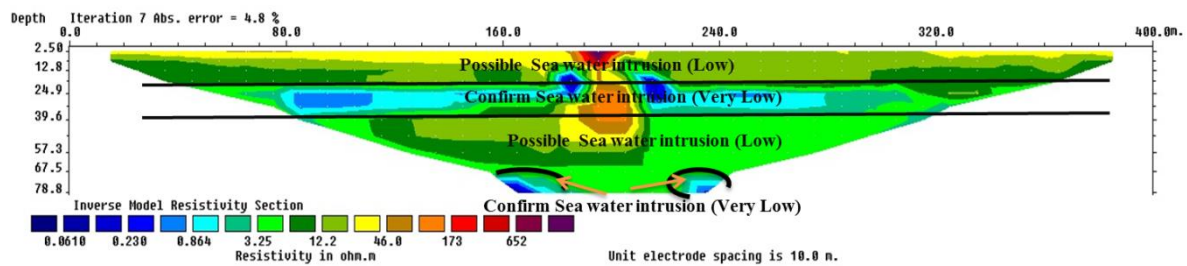


Fig. 3.14: Interpreted ERT location (JERT - 4)

The ERT profile No. 04 has been carried out inside the East block mine pit (JERT- 4). The interpreted section shows that most of the region is marked by Low resistivity 3-50 ohm-m though there are patches of very low resistivity zone (< 3 ohm-m). The profile is showing shallow aquifer which can be attributed to the supremacy of sea water bounded between approximately 24m - 39m (**Fig. 3.14**).

The resistivity profile JERT- 5 (**Fig. 3.15**) has been carried out at adjacent field to East block mine pit. It's topographical elevation is high compared with other ERT profiles conducted within the mining pits. In inverted electrical model, top

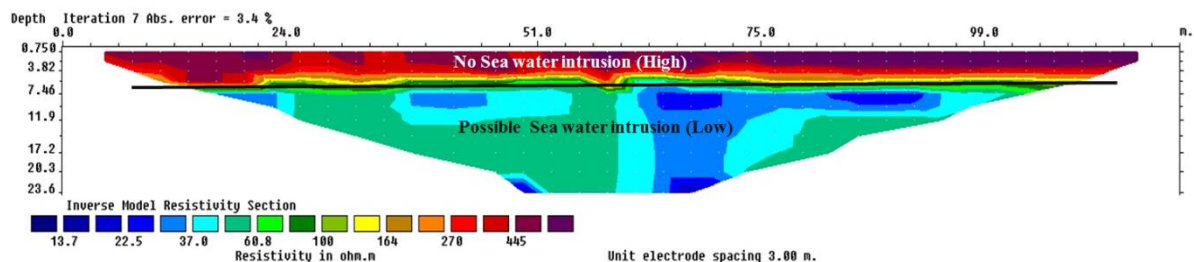


Fig. 3.15: Interpreted ERT location (JERT - 5)

geo-electric layer with high resistivity (< 250) is associated with soil and dry limestone upto depth of nearly 8 m and is associated with low resistivity zone.

Very low resistivity in which we are concern is absent upto a depth of 23.6 m in this site. The recorded resistivity is 13.7 ohm-m in this profile.

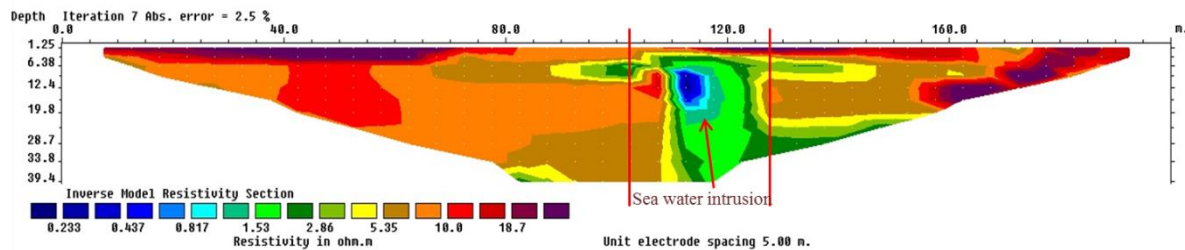


Fig. 3.16: Interpreted ERT location (JERT - 6)

The ERT profile JERT- 6 (**Fig.3.16**) has been carried out at *Mitiyala village*. From interpreted resistivity section, it is assessed that the entire profile comes under *low resistivity zone*. This profile shows heterogeneous resistivities and this heterogeneity is interpreted as fracture media / rock with salt water fresh water mixing in the ground water. The reasons of less magnitude of resistivity at village Mitiyala, are when analysed it was found that the sea backwater (Jafarabad Creek) and its spread area is present all around the village and thus its proximity is the principal reason for SWI. Other villages namely *Lunsapur and Vand*, lying in the buffer zone of mine, have also observed similar trend. All these BZ locations are vulnerable from SWI angle and ingress is present at the depth of more than 20m MRL.

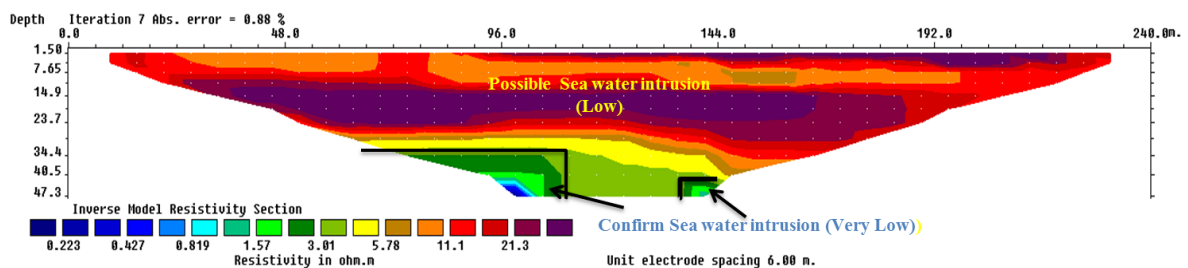


Fig. 3.17: Interpreted ERT location (JERT-7)

The ERT profile JERT-7 (**Fig 3.17**) has been carried out at *Lunsapur village* away from the coast. The interpreted section shows low resistivity zone up to all the depth 47.3 m of profile. Patch of low resistivity zone is identified at the depth of 34 m.

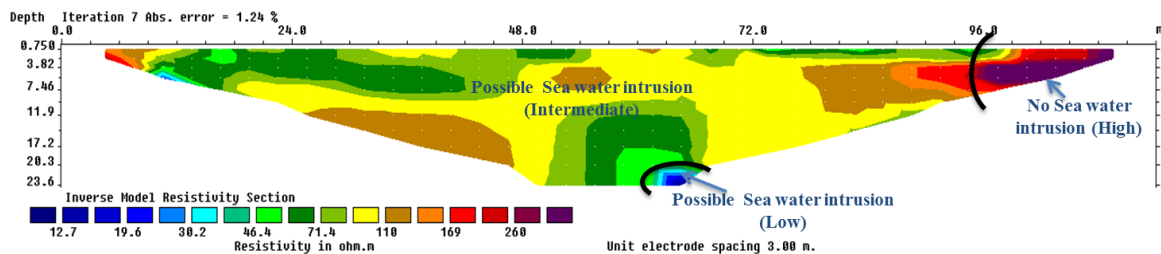


Fig. 3.18: Interpreted ERT location (JERT- 8)

From the interpreted ERT profile JERT- 8 (**Fig.3.18**) very low resistivity zone is not seen in the entire profile. Most of the resistivity of the profile lies within high resistivity zone. Low resistivity zone can be found at the depth of 20.3 m.

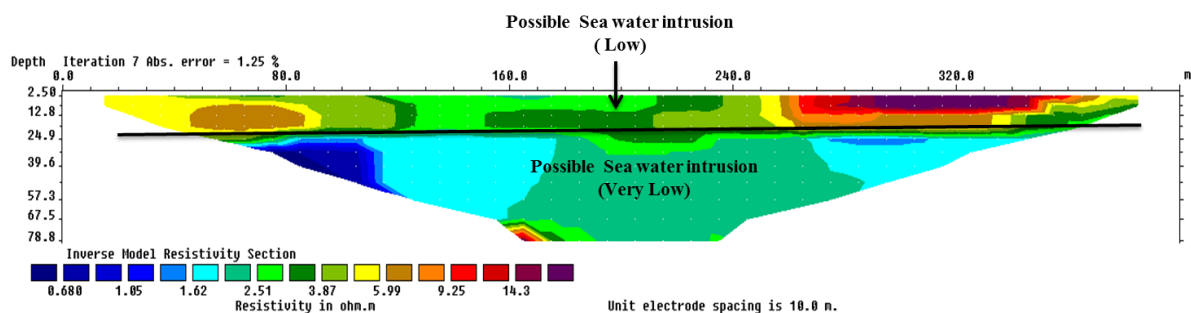


Fig. 3.19 : Interpreted ERT location (JERT-9)

The resistivity profile JERT-9 (Fig.3.19) has been carried out at Vand village. Most of the interpreted parts of the profile shows intrusion affected site. In the top layer, resistivity is relatively high up to 25 m depth and after that depth, very lower resistivity (0-3 Ohm-m) patch is observed. Thus, Vand village is a vulnerable site from possible presence of sea water at a depth range ranging from 48 m (MRL + BGL = 24+24m = 48 m) and below. The *resistivity survey results* (**Table 3.6**) can be summarized as follows -

- Inverted resistivity sections indicates that very low resistivity zones may be associated with salinity ingress and is found at varying depth from 3m to 78.8m.
- At NCJW colony ground (JERT8) SWI is not present. The site can be categorized as 'safe'.



- In North block and East block Mine pit though low resistivity has been found (Table 3.6) but at depth and except at JERT3. All 05 profile locations where resistivity values concerning with SWI is determined, are in safe zone. Here, word, '**safe**' means SWI at this location **is kept contained** and hence safe from excavation angle. In the same sense the word 'vulnerable' has been used i.e. strong possibility of salinity ingress.

Table 3.6 : Summarized results of resistivity survey at different ERT locations

Profile No.	Total imaging Depth (m)	Sea Water Intrusion Depth (m)		Inference Drawn (Safe/vulnerable)
		Confirm (Very Low)	Possible (Low & Intermediate)	
JERT 1	39.4	33 -39.4	39.4	Safe
JERT 2	39.4	34 - 39.4	39.4	Safe
JERT 3	39.4	-Not Present -	39.4	Safe
JERT 4	78.8	24 - 39	78.8	Safe
JERT 5	23.6	-Not Present -	07-23.6	Safe
JERT 6	39.4	03-39.4	03-39.4	Vulnerable
JERT 7	47.3	40	47.3	Safe
JERT 8	23.6	-Not Present -	23.6	Safe
JERT 9	78.8	24 -78.8	24	Vulnerable

Note : All values are BGL (below ground level) values unless stated. For MRL please refer table 3.5.

- ERT conducted within the north and east mine pit area namely JERT1 JERT2, JERT3, JERT4 and JERT5 has sea water intrusion signatures at depth of approximately 33 m (MRL = 6.24m), 34 m (MRL =7.32m), No sign (MRL =8.01m), 24.0m (MRL =2.09m) and No sign (MRL = 7.96m), respectively. In the case of JERT3 mine pit area is marked with low-resistivity zone but not marked with very-low resistivity zone. On analysing JERT 3 (mine pit area) one can confirm prominence of sea water up to the depth of 39 m but still there is the possibility of sea water intrusion zone present below 39 m. Due to geophysical limitations and the rock/soil layers existing in field, the information below 39.4 m could not be obtained at these profiles. At some profile locations viz. JERT4, JERT7 and JERT9 more imaging depth is achieved.

While analysing about *Mitiyala village (at 28m MRL)*, *Lunasapur village (at 21 m MRL)* and *Vand village (at 24m MRL)*, it is observed that ERT conducted shows SWI zone at various depths. The village Mitiyala, lying in



the BZ, has presence of SWI [at the depth of 28m (MRL) + 12.4m (from Fig. 3.16 of JERT 06) = 40.4m from BGL) and its reason can be attributed to the proximity of sea backwater and its spread area is all around the village.

Identified *sea water zone* of the Mitiyala village is associated with fracture and this is identified at site at a depth of 40.4 m MRL (JERT-6). Similarly, at *Lunasapur village* (JERT 7), salinity ingress is present below 60m (21m MRL + 39m ERT depth from BGL) as marked by small blue patch of low resistivity where fresh water and salty sea water is mixed.

3.4 CONCLUSIONS DRAWN FROM RESISTIVITY SURVEY

In continuation of the *summarized resistivity survey results* mentioned in the paragraph above following major inferences can be drawn -

- ❖ The resistivity imaging studies clearly indicated very low resistivity anomalies (0 to 3 ohm-m) in certain profiles. The distribution of this low resistivity anomaly is not simple and it is distributed in a complex form. It exhibits a diffused form.
- ❖ Limestone and host rock when mixed with sea water, it exhibits very low resistivity. The resistivity of *limestone with fresh water* varies from 30 Ohm-m to 60 Ohm-m approximately and it gets reduced to 03 Ohm-m. The factors responsible for reduction in these values are - the type of limestone (solubility) in which it is stored and saturation percentage of freshwater-sea water mixture. Because fresh water is less dense than saltwater 'density dependent ground water flow conditions' are marked.
- ❖ The water sampling indicates high values of TDS, Chloride and Sodium in the observation wells in the study area. The high values of chloride and TDS can be on account of intrusion of seawater.
- ❖ The 'intrusion zone' lies at a depth of >24 m bgl (**Table 3.6, column 3**), hence limestone mining from (+) 4m MRL to (-) 8 m MRL is possible. It may be noted that ground water of the study area is already brackish and mining operation can be done in open pit form, without any adverse impact. However, it is desirable that to a depth of (-) 4m MRL to (-) 8 m MRL precautions shall be exercised (Pl read section 5.7.1 also).



- ❖ The ensuing geophysical investigation and assessment has reconfirmed the presence of sea water intrusion in the study area which is cross verified from the CIMFR field study (salty taste of dug well's water).
- ❖ If deeper excavation is allowed, the status quo of the water quality can be easily maintained by proper management of ground water in the study area.



Table.3.3 : Ground water details in observation wells of established network in the study area for post-monsoon (Nov, 2016) and Pre-monsoon (May, 2017)

Sample Code	Source	Latitude	Longitude	RL (m)	MP - meter	Post-monsoon - 2016			Pre-monsoon - 2017			Location Details
						DWL-meter	GWL - (bgl-m)	GWL- (amsl-m)	DWL-meter	GWL - (bgl-m)	GWL- (amsl-m)	
NCJW-GW-1	DW	N 20°52'22.0"	E 71°24'58.1"	24	0.33	21.36	21.03	2.97	20.61	20.28	3.72	Babarkot
NCJW-GW-2	DW	N 20°52'49.5"	E 71°26'22.1"	23	1.70 (+)	15.46	17.16	5.84	18.49	20.19	2.81	Varaswaroop
NCJW-GW-3	DW	N 20°53'00.4"	E 71°26'39.5"	24	1.20	18.94	17.74	6.26	19.21	18.01	5.99	Varaswaroop
NCJW-GW-4	DW	N 20°53'45.4"	E 71°27'11.00"	22	0.91	11.11	10.20	11.80	14.90	13.99	8.01	Bakodar
NCJW-GW-5	DW	N 20°54'18.4"	E 71°27'18.9"	12	0.20	0.55	0.35	11.65	3.60	3.40	8.60	Kovaya
NCJW- SW-1	River sample	N 20°56'15.6"	E 71°27'46.5"	06	-	-	-	-	-	-	-	Rampara
NCJW-GW-6	DW	N 20°56'04.7"	E 71°27'45.6"	13	0.10	3.48	3.38	9.62	4.60	4.50	8.50	Rampara
NCJW-GW-7	DW	N 20°56'08.9"	E 71°27'05.5"	09	0.00	1.61	1.61	7.39	3.10	3.10	5.90	Rampara
NCJW-GW-8	DW	N 20°57'16.1"	E 71°26'02.7"	18	0.00	2.42	2.42	15.58	5.10	5.10	12.90	Lothpur
NCJW-GW-9	DW	N 20°55'47.6"	E 71°24'50.4"	14	0.00	0.85	0.85	13.15	1.00	1.00	13.00	Lunsapur
NCJW-GW-10	BW	N 20°54'23.9"	E 71°24'35.0"	28	-	-	-	-	-	-	-	Vand
NCJW-GW-11	DW	N 20°53'55.5"	E 71°23'27.0"	23	1.40	8.95	7.55	15.45	dry	-	-	Mitiyala
NCJW-GW-11A	DW	N 20°53'46.7"	E 71°23'24.1"	22	0.90	-	-	-	12.50	11.60	10.40	Mitiyala
NCJW-GW-12	DW	N 20°51'04.7"	E 71°18'23.6"	10	0.00	3.07	3.07	6.93	8.22	8.22	1.78	Vadhera
NCJW-GW-13	DW	N 20°51'58.3"	E 71°17'49.4"	16	0.50	4.88	4.38	11.62	10.10	9.60	6.40	Kadiyari
NCJW-GW-13A	DW	N 20°52'13.1"	E 71°17'48.5"	10	0.60	-	-	-	5.40	4.80	5.20	Kadiyari
NCJW-GW-14	DW	N 20°54'25"	E 71°18'37.7"	09	0.90	3.55	2.65	6.35	7.30	6.40	2.60	Dholadri
NCJW-GW-15	DW	N 20°52'4.2"	E 71°21'30.8"	17	0.90	4.80	3.90	13.10	5.80	4.90	12.10	Jafarabad – municipal well in public garden
NCJW-GW-16	DW	N 20°51'56.1"	E 71°21'20.3"	24	0.60	11.45	10.85	13.15				Jafarabad - UltraTech residential colony
NCJW-GW-17	DW	N 20°57'22.8"	E 71°27'46.0"	10	0.60	5.72	5.12	4.88	7.70	7.10	2.90	Uchaiya



Sample Code	Source	Latitude	Longitude	RL (m)	MP - meter	Post-monsoon - 2016			Pre-monsoon - 2017			Location Details
						DWL-meter	GWL - (bgl-m)	GWL- (amsl-m)	DWL-meter	GWL - (bgl-m)	GWL- (amsl-m)	
NCJW-GW-18	DW	N 20°57'56.8"	E 71°26'54.4"	24	0.70	10.81	10.11	13.89	15.60	14.90	9.10	Dharanu Nes
NCJW-GW-19	DW	N 20°58'23.0"	E 71°23'31.9"	31	0.87	12.03	11.16	19.84	21.90	21.03	9.97	Kagwadar
NCJW-GW-20	DW	N 20°57'45.9"	E 71°22'31.2"	20	0.00	5.94	5.94	14.06	11.40	11.40	8.60	Bhatvader
NCJW-GW-21	HP	N 20°57'12.5"	E 71°21'42.4"	24	-	-	-	-	-	-	-	Balanivav
NCJW-GW-22	DW	N 20°55'34.7"	E 71°20'56.1"	17	0.00	9.85	9.85	7.15	10.70	10.70	6.30	Mithapur
NCJW-GW-23	DW	N 20°55'46.4"	E 71°20'22.6"	22	0.70	10.78	10.08	11.92	15.80	15.10	6.90	Nageswari

AMSL: above mean sea level; BGL: below ground level; DWL: depth to water level; GWL: groundwater level; MP: measuring point; LHS: left hand side; RHS: right hand side



Table 3.4 : Water quality at NCJW mining area (including surrounding areas)

Narmada cement Jafarabad																									
Sr.no.	Sample Code	EC(µS/cm)	TDS(mg/l) By E.C.	TDS by calculation	calcium hardness (mg/l)	Magnesium hardness (mg/l)	Sodium (mg/l)	potassium (mg/l)	Total alkalinity (mg/l)		Bicarbona te millieq.	sulphate (mg/l)	chloride (mg/l)	Chloride millieq.	Ratio(Chl oride/Bic arbonates)	Nitrate (mg/l)	Total cations	Total anions	CATIONS ANIONS	% error	ph	turbidity	fluoride	phosphate	
1	NCJW-GW-1	7040	4224	3874.4	684	596	984	18	280		4.590164	136	1980	55.77465	12.15091	58	68.68	65.13	3.56	2.7	6.9	0	0.33	1.79	
2	NCJW-GW-2	2170	1302	1237.3	304	184	230	4	340		5.57377	29	440	12.39437	2.223695	28	19.81	20.22	-0.41	1.0	6.8	0.4	0.79	1	
3	NCJW-GW-3	2090	1254	1010.3	356	156	165	25	512		8.393443	16	100	2.816901	0.335607	12	18.00	13.53	4.47	14.2	7.3	27	0.5	1.5	
4	NCJW-GW-4	2490	1494	1479.2	496	316	177	25	232		3.803279	69	540	15.21127	3.999514	161	24.48	23.85	0.63	1.3	6.8	0	0.35	1.24	
5	NCJW-GW-5	5380	3228	3325.2	388	280	750	90	576		9.442623	378	1300	36.61972	3.87813	8	48.20	55.95	-7.75	7.4	7.2	0.6	0.23	4.24	
6	NCJW-SW-01	788	472.8	573.2	92	80	138	6	160		2.622951	28	180	5.070423	1.933099	5	9.57	8.91	0.66	3.6	7.6	15	0.23	0.63	
7	NCJW-GW-6	2840	1704	1749.6	112	316	415	15	448		7.344262	147	560	15.77465	2.147887	43	26.91	28.39	-1.48	2.7	7.5	0.2	0.56	1.48	
8	NCJW-GW-7	2370	1422	1541.2	68	144	420	5	496		8.131148	136	420	11.83099	1.45502	2	22.60	24.52	-1.92	4.1	7.6	0	4.2	0.5	
9	NCJW-GW-8	4940	2964	3317.8	124	396	1026	6	440		7.213115	511	1140	32.11268	4.451985	49	55.08	52.09	2.98	2.8	7.2	0.24	1.6	0.18	
10	NCJW-GW-9	1137	682.2	824.9	60	88	202	2.5	472		7.737705	21	80	2.253521	0.291239	2	11.79	12.11	-0.32	1.4	7.5	0.1	2.5	0.68	
11	NCJW-GW-10	2120	1272	1251.9	348	116	182	2.5	380		6.229508	59	340	9.577465	1.537435	121	17.22	20.30	-3.08	8.2	6.9	0.07	0.55	0.91	
12	NCJW-GW-11	1770	1062	1076.4	108	120	249	9	252		4.131148	99	360	10.14085	2.454728	35	15.59	17.75	-2.16	6.5	7.3	1.1	0.67	0.5	
13	NCJW-GW-12	2720	1632	1571.9	368	180	303	6	280		4.590164	57	720	20.28169	4.418511	15	24.23	27.28	-3.05	5.9	7	0.03	0.81	0.26	
14	NCJW-GW-13	2300	1380	1412.2	216	172	288	33	260		4.262295	120	580	16.33803	3.833153	3	21.08	24.02	-2.94	6.5	7.2	0.9	0.83	0.5	
15	NCJW-GW-14	1531	918.6	989.0	328	176	107	5	400		6.557377	77	220	6.197183	0.94507	6	14.80	15.83	-1.02	3.3	7.5	0.1	0.24	0.56	
16	NCJW-GW-15	7810	4686	4737.6	376	540	1140	76	472		7.737705	374	2320	65.35211	8.44593	74	69.70	83.63	-13.94	9.1	6.9	0.3	0.51	0.66	
17	NCJW-GW-16	10450	6270	5988.2	956	740	1251	36	332		5.442623	356	3400	95.77465	17.59715	51	89.03	110.58	-21.55	10.8	6.6	0.6	0.49	0.68	
18	NCJW-GW-17	1028	616.8	1571.9	112	128	135	7	384		6.295082	24	940	26.47887	4.206279	6	10.81	34.74	-23.93	52.5	7.5	2	0.39	2.43	
19	NCJW-GW-18	1792	1075.2	1273.5	96	132	321	3	660		10.81967	35	180	5.070423	0.46863	4	18.56	18.99	-0.43	1.1	7.4	0.3	3.2	1.37	
20	NCJW-GW-19	1486	891.6	957.8	36	232	234	2	476		7.803279	48	120	3.380282	0.433187	7	15.53	13.95	1.58	5.4	7.1	0.1	0.92	0.77	
21	NCJW-GW-20	3330	1998	2323.8	76	516	574	10	556		9.114754	116	640	18.02817	1.977911	272	36.93	35.86	1.07	1.5	7.2	15.7	1.1	0.51	
22	NCJW-GW-21	8010	4806	5220.0	516	204	1490	40	908		14.88525	415	1840	51.83099	3.482038	271	80.16	82.78	-2.61	1.6	7.2	0.6	0.72	0.72	
23	NCJW-GW-22	8110	4866	4920.5	412	1612	870	10	520		8.52459	474	2280	64.22535	7.534128	210	78.15	87.68	-9.54	5.7	7.2	2.5	0.52	0.47	
24	NCJW-GW-23	2350	1410	1387.8	172	284	322	4	416		6.819672	88	320	9.014085	1.321777	100	23.15	20.70	2.44	5.6	7.5	0.9	0.51	1.18	
25	NCJW-SW-02	811	486.6	517.0	140	148	65	2	200	152	2.491803	38	100	2.816901	1.130467	20	8.59	7.90	0.70	4.2	7.9	2.4	0.33	1.12	
27	NCJW-GW-24	1608	964.8	1003.1	240	128	225	6	168		2.754098	111	360	10.14085	3.682093	6	17.26	15.85	1.41	4.2	7.5	0.01	0.78	1.16	
28	NCJW Narmada r	287	172.2	212.1	76	48	21	2	120	72	1.180328	19	2	0.056338	0.047731	6	3.43	2.93	0.50	7.9	8.4	4.5	0.3	0.9	
				212.1								16	2	>01 value shows		2								0.23	
				5988.2								511	3400			272								4.2	



CHAPTER – 4

SEA WATER INTRUSION (SWI) & GROUND WATER : ANALYSIS & DISCUSSION

Coastal areas are in immediate hydraulic contact with the sea and these areas have been attracting human settlement all around the world. Industries, major seaports, tourist resorts, mines and several other man-made activities contributes significantly to the coastal water pollution / contamination. In coastal areas aquifers containing groundwater are vulnerable to contamination from two sides (a) firstly, from *salty sea water* and (b) secondly, large-scale abstraction of groundwater from landmass.

In coastal areas, hydro-geologic conditions may be represented by an *individual aquifer, confined aquifer, unconfined aquifer or island aquifer* and these are generally multi-layered aquifer systems. The possible reason of SWI in coastal aquifer may have either one or more combination of the following :

- i. Direct invasion of saltwater from the sea.
- ii. Presence of salt domes in geologic formations.
- iii. Invasion of saltwater from hidden ancient aquifers of past geologic times.
- iv. Concentrated salt water in tidal lagoons, aquaculture tanks, plains or other enclosures.
- v. Return flow from irrigation
- vi. Saline wastes from anthropogenic sources.

The coastal aquifer system has a sea front and there is a direct contact between continental freshwater and marine saltwater. Besides a slight difference in viscosity between the two fluids, there exists a density change that depends mainly on salinity differences. Under undisturbed natural conditions, a seaward hydraulic gradient exists in the aquifer with freshwater discharging into the sea. The heavier saltwater flow in from the sea and a wedge-shaped body of saltwater develops beneath the lighter freshwater, with the freshwater thickness decreasing from the wedge towards the sea. The freshwater/saltwater interface remains stationary under steady state condition with its shape and position determined by the freshwater head and gradient.

Inland changes in recharge or discharge modify the flow within the freshwater region, inducing a corresponding movement of the interface. A reduction in freshwater flow due to overdraft causes the interface to move inland and results in the *intrusion of saltwater* into the aquifer. Conversely, the interface retreats, following an increase in



freshwater flow. The extent of intrusion depends on many factors such as climatic conditions, aquifer boundaries, hydrological and structural properties of water transmitting media, seaward natural flow of freshwater, recharge and discharge from wells and tidal effects.

In this chapter, both theoretical aspects and practical results of SWI are covered in two parts (Part - I & Part - II). Described paragraphs had analyzed the SWI mechanism using mathematical modelling. This will make the reader to understand the mechanism of SWI and explains inter-granular movement of ground water and sea water in a coastal aquifer / coastal environment.

PART - I

4.1 SEA WATER INTRUSION (SWI)

The mechanism of sea water intrusion in coastal areas can be understood from the below described pages and it is essential that all those mine operators excavating minerals near the sea coast, must read the theoretical aspect of SWI.

4.1.1 Theoretical aspects of intrusion mechanism

Coastal aquifers, which border the sea are heavily urbanized these days and constitute an important source for water for the population living near coast. Lateral or depth-wise increase in the salinity of groundwater caused due to human interference with ground water regime, is termed as **“Salt water intrusion or Sea water Intrusion”**. The boundary between salt water and fresh water is termed as 'interface'. Thus, intrusion of saline water occurs where saline water displaces or mixes with freshwater in aquifer. The causative factor for this phenomenon are (a) due to excessive exploitation of ground water or (b) due to industrial operations (c) or both. It is noticed that nearly all coastal aquifers are susceptible to seawater intrusion problems.

Sea-water intrusion is basically a *density flow* and represents a special category of groundwater pollution. The interface moves towards a fresh water zone when a hydraulic gradient is established from the saline water zone to the fresh water zone. Such a situation arises when positive ground water development occurs or when high tide in sea are observed. When permeable formations outcrop in to the body of seawater and when there is landward hydraulic gradient, generally intrusion occurs. It is present in both deep coastal aquifers as well as in shallow coastal aquifers.



Ghyben-Herzberg principle explains the relationship between fresh water and saline water interface. According to this, the interface will occur at a depth h below the mean sea level (**Fig. 4.1**) and is given by –

$$(h_s + h_f) \gamma_f = h_s \gamma_s$$

where, $\gamma = \rho g$ and the pressure at the point of interface should be equal.

$$h_s = \gamma_f / \gamma_s - \gamma_f * h_f = \rho_f / \rho_s - \rho_f * h_f = 1 / G_s - 1 * h_f \dots\dots (1)$$

h_s = Depth below mean sea level where interface occurs and

h_f = Elevation of the ground water table above mean sea level

ρ_s & ρ_f = Density of fresh water and sea water respectively

Taking the specific gravity of fresh water as 1.0 and that of sea water as 1.025 ($=G_s$) from equation – 1

$$h_s = 40 \gamma_f \dots\dots\dots (2)$$

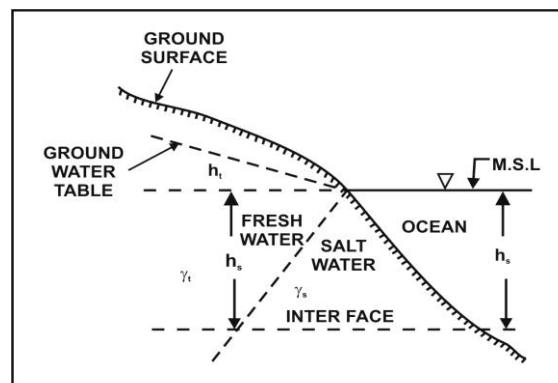


Fig. 4.1: Fresh water-salt water interface

It means that a rise or fall of ground water table (or Piezometer head) by 1 m will induce a fall or rise respectively of 40m in the underlying salt water level, even though the response may be greatly delayed. The net of flow lines and equipotential line shown in **Fig. 4.2** depicts the actual intrusion. Since the total pressure along an equipotential line is constant and the flow lines are sloping upward, the depth of interface given by *Ghyben –Herzberg* relation is less than the actual depth, but the difference is small for flat gradients.

The following situations arises in the context of salt water / sea water intrusion –

1. When salt water underlies freshwater in a homogenous and isotropic medium under water table condition.
2. When salt water underlies freshwater and two zones being separated by an impervious or semi-pervious layer.

3. When salt water overlies fresh water and two zones being separated by an impervious or semi-pervious layer
4. When fresh water laterally grades into saline water occurring under water table, confined or semi - confined conditions.
5. When fresh water aquifers alternate with salt water zones.

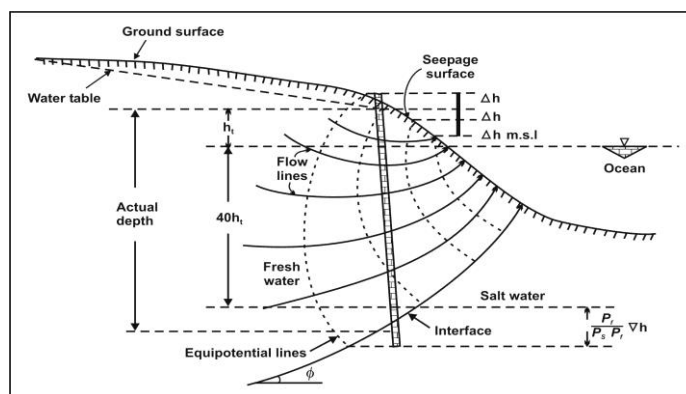


Fig. 4.2 : Sea water intrusion & interface as per Ghyben–Herzberg relation

4.1.2 Transport Mechanism

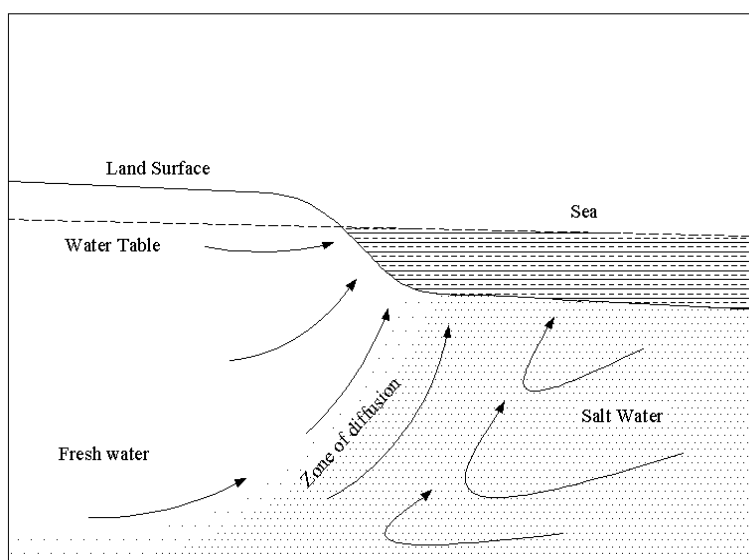
SWI is a natural process that occurs in virtually all coastal aquifers and constitutes of salt water flow, from sea towards inland freshwater aquifers. This behavior is caused by the fact that seawater has a higher density (because it carries more solutes) than freshwater. This higher density has the effect that the pressure beneath a column of saltwater is larger than that beneath a column of the same height of freshwater. If these columns were connected at the bottom, then the pressure difference would trigger a flow from the saltwater column to the freshwater column. This is precisely what happens in saltwater intrusion cases.

The flow of saltwater inland is limited to coastal areas only. Inland the freshwater column gets higher and the pressure at the bottom also gets higher. This compensates for the higher density of the saltwater column. Where this happens, saltwater intrusion stops. The higher water levels inland, have another effect : they trigger flow of freshwater seaward. This completes the picture at the sea-land boundary, we have in the high part of the aquifer outflow of freshwater and in the lower part, inflow of saltwater. The saltwater intrusion gets a sort of cone shape. When freshwater levels drop, the intrusion can proceed further inland until reaching the pumped well. Thereafter one may get salty water out of the pump which is not fit for drinking or irrigation.



Transport mechanism of water i.e. fresh water or saltwater transport is governed by *advection and hydrodynamic dispersion* in intrusion cases. In reality, due to hydrodynamic dispersion, the contact zone between freshwater and saltwater takes the form of a *transition zone* (or disperse interface), across which the salt concentration increases and hence water density records a higher value. This induces a cyclic flow of saltwater from the sea to the transition zone and finally backs to the sea (**Fig. 4.3**).

Fig. 4.3 : Zone of transition / diffusion in a coastal aquifer



In some instance the transition zone is thin, a few meters or less, but in other situations it can attain a thickness of more than 100 m especially in highly non-homogeneous formations e.g. limestone aquifer. In non-homogeneous highly permeable materials, with small freshwater flow, the top of the transition zone can reach the water table. Moreover, the thickness of transition zone is not constant, and may expand or contract in accordance with a succession of low and high tides and wet and dry periods.

Saltwater intrusion becomes an environmental hazard when excessive pumping of fresh water from coastal aquifer is done. This reduces the water pressure and intensifies the effect thereby drawing salt water into more and large new areas. To prevent this, extensive monitoring and assessment is needed.

PART - II

4.2 MATHEMATICAL MODELING FOR SEA WATER INTRUSION

In coastal aquifers, the investigation of groundwater flow at regional scale is complicated because the relatively minor spatial variation in groundwater density has a substantial effect on groundwater flow rates and patterns. Hence, an understanding of *variable-density groundwater flow* is important in saltwater intrusion studies, contaminated site remediation and fresh groundwater discharge into oceanic water bodies.

The first physical formulations of saltwater intrusion were made by *W. Baydon-Ghyben (1888, 1889)* and *A. Herzberg (1901)*, and called as 'The Ghyben-Herzberg formulation'. This formulation provided (derived) analytical solutions to approximate the intrusion behavior, which were based on a number of assumptions that do not hold good in all field cases. The Ghyben-Herzberg ratio states that for every foot of fresh water in an unconfined aquifer above sea level, there will be forty feet of fresh water in the aquifer below sea level. With dominance of computers in the current century, the higher computing power allowed the use of numerical methods (usually, FEM or FED method) that needs less assumptions and can be applied more judiciously to solve complex differential equations. Even now, some typical difficulties in modeling still arises.

4.2.1 Modelling Approaches

The mathematical analysis of the *variable-density* ground water flow for saltwater intrusion problem involves several simplifying assumptions depending upon whether the freshwater and saltwater are taken as *miscible* or *immiscible* fluids. There are two distinct approaches to model a coastal aquifer system.

- Sharp interface approach
- Miscible transport approach

The sharp interface approach, which assumes that freshwater being immiscible fluids are separated by an abrupt interface, is suitable when the width of transition zone is small relative to the thickness of the aquifer. For a thicker transition zone, the miscible transport approach is adopted, which accounts for the effects of hydrodynamic dispersion and represents the transition zone.

4.2.1.1 Miscible transport models

In miscible transport models, the problem of seawater intrusion is posed as that of a variable-density fluid flow accounting for the effects of dispersion. These models



require the simultaneous solution of the coupled groundwater flow and advective-dispersive equations. For a variable density fluid, the flow equation is (Bear, 1979)

$$\frac{\partial}{\partial x} \left(\frac{\kappa_x \gamma}{\mu} \frac{\partial p}{\partial x} \right) + \frac{\partial}{\partial y} \left(\frac{\kappa_y \gamma}{\mu} \frac{\partial p}{\partial y} \right) + \frac{\partial}{\partial z} \left[\frac{\kappa_z \gamma}{\mu} \left(\frac{\partial p}{\partial z} + \gamma \right) \right] + W \gamma^* = S_s \frac{\partial p}{\partial t} + \phi \frac{\partial \gamma}{\partial c} \frac{\partial c}{\partial t} \quad (1)$$

Where - p is the fluid pressure; κ_x , κ_y and κ_z are the intrinsic permeability in the x -, y - and z - directions, respectively; γ is the specific weight of fluid; S_s is the specific storage of porous medium; μ is the dynamic viscosity of fluid; γ^* is the specific weight of source or sink fluid, ϕ is porosity; c is solute concentration (defined as the mass of solute per unit volume of solvent); and W is the source/sink volume flux per unit volume of porous medium for positive inflow.

The last term on the right side of equation (1) represents the rate of change in specific weight due to a change in concentration over time. Since the contribution of this term compared to other terms is small, it is mostly neglected.

The solution of the governing differential equations, subject to appropriate boundary conditions, provides the spatial and temporal distribution of the salt concentration in the given domain for unknown values of pumpage and recharge. Due to the mathematical complexity of the miscible transport model the analytical solution to this problem are few.

Most of the numerical solutions for *miscible transport models* are based on the FEM (finite element) or FED (finite difference) method. However, the simultaneous solution of the coupled flow and transport equations is numerically difficult. The difficulty lies in the solution of transport equation, which comprises both the advective and dispersive components of transport. The advective component of transport dominates for most of the field problems. Solution of such an equation by conventional techniques viz., finite difference or finite elements is susceptible to numerical dispersion (Huyakorn and Pinder, 1983). Techniques aimed at minimizing numerical dispersion may require very small grid spacing and time steps, or may result in artificial oscillation.

An alternative technique, amongst others, to minimize the problem of numerical dispersion is the Method of Characteristics (Gardner et al., 1964). This technique minimizes numerical dispersion by delinking the advective and dispersive components of transport. The advective transport is simulated through a set of moving particles and the dispersive transport is simulated by finite difference or finite element.

Another important aspect while implementing the miscible transport approach is the formulation of boundary condition on the seaward side of a coastal aquifer. As mentioned earlier, due to the natural gradient, freshwater discharges to the sea along with the diluted saltwater. The extent of this outlet portion or window is



determined by trial and error before taking a simulation run (Huyakorn et al., 1987). However, since the window length is subject to an increase in the freshwater inflow and generally varies with time, it needs to be updated during the simulation itself in order to follow realistic changes in the flow field.

4.2.2 A miscible transport model of MODFLOW package : SEAWAT- 2000

A number of private and public domain computer codes are available which can be used to simulate variable-density groundwater flow, e.g., finite element based SUTRA code, and finite difference based HST3D, MOCDENSE and SEAWAT codes.

The USGS SEAWAT program (Guo and Langevin, 2002) simulates three-dimensional, variable-density, transient groundwater flow in porous media. The source code for SEAWAT-2000 was designed by combining MODFLOW and MT3DMS into a single program that solves the coupled flow and solute transport equations. MODFLOW was modified to solve the variable-density flow equation by reforming the matrix equations in terms of fluid mass rather than fluid volume and by including the appropriate density terms. Fluid density is assumed to be solely a function of the concentration of dissolved constituents under isothermal conditions. Spatial and temporal variation of salt concentration is simulated using routines from MT3DMS program.

The *miscible transport approach* should be adopted in areas where the transition zone is wide. When concentration gradients are low, the governing equations can be solved aurally on a basin-wide scale. However, when the flow is density dependent, the vertical dimension must be included. Because of computational constraints, studies based on this approach have been generally limited to two-dimensional vertical cross-sections. While simulating the movement of a narrow concentration front, some numerical instabilities and errors may occur, especially in areas where the transition zone approaches a sharp interface.

4.2.2.1 Description of Model in SEAWAT- 2000

(a) Spatial and temporal discretization : The model domain and finite difference grid are used to simulate groundwater flow within the NCJW coastal aquifer (**Fig. 4.4**). The model encompasses an area of about 72 km². Entire area is divided in 40 X 40 (Nos. of grid having each cell dimensions of 250 m X 375 m. The model was discretized vertically into 2 layers. The top elevation of layer 1 is spatially variable and corresponds with land surface elevation, based on a topographic map. The bottom of layer 1 is set at an elevation below the ground level (-) 20 m. The simulation period is considered as a one-stress period. The average hydrologic conditions for stress period are assumed to remain constant. Further temporal



discretization is introduced in the form of time steps within stress period. The length of the transport time step was assigned to start with 365 day and to be increased by a multiplier factor of 1.0.

(b) Assignment of values to aquifer parameters : The aquifer parameters taken as input parameters for NCJW study were Coefficient of Transmissivity (T) and Hydraulic conductivity (K) which is taken as 62.26 M²/day (0.00017m/s) and 15.11 m/day respectively. These were based on the authentic secondary data source namely CGWB, Gujarat or Gujarat Water Resources Development Corporation Ltd. (GWRDC, 2006).

(c) Boundary Conditions : Constant head and concentration were specified to the model cells along the coast. The specified constant concentration of TDS is 32,000 mg/L. The choice of this value of TDS was on the basis of the seawater sample collected in the field. The head for each cell was converted to freshwater head using the specified TDS concentration of 32,000 mg/L and the centre elevation of the cell. A reference density of 1,000 kg/m³ was used for freshwater and 1,025 kg/m³ for seawater. The coupled flow and transport model (SEAWAT) uses this reference value to calculate and adjust fluid densities relative to simulated concentrations of dissolved salts in the model.

The assigned boundary conditions taken are as detailed in **Table 4.1**. *Dhatarwadi river and Raidi river* are taken as watershed boundaries forming two boundary sides. Third one being the Arabian sea. *For the* modelling work, width of the river forming boundaries are assumed as 40 m and as per the ground elevation the model input values were given.

(d) Internal hydrologic stresses: Hydrologic stresses that are internal to the model domain are represented with internal boundary conditions. Internal hydrologic stresses include: recharge from rainfall, return flow, and municipal and agricultural withdrawals.

a) *Recharge*

The recharge rate in SEAWAT package is applied on the basis of annual average rainfall of the study region. For this model 775 mm is taken as annual rainfall and surface recharge is considered as 6% of the average rainfall. According to the long-term annual average of rainfall data of the study area, the average rate of recharge applied on the model was 47mm/year. This recharge rate is varied and future scenario is assessed. The general procedure for estimating recharge rate i.e. 6% was selected as per the rock type was limestone. The soil type, land use and evapo-transpiration rates were as per the standard norms applicable.



b) *Return flow*

Agriculture pumping within the area is of the order of 3.5 - 4.5 mcm/year in a given year approximately. A portion of this applied water infiltrates back into the aquifer. The quantities that infiltrate depend on methods of irrigation, crop types, soil types, and irrigation schedules. Hence, in the area 16% of the pumping at individual wells is recharged back to the aquifer.

c) *Municipal and agricultural well fields*

Table 4.2 given below gives an idea of the ground water consumption sources in the study region. though no fixed data is available but it is assumed that the area has medium order of abstraction rate (3.5 - 4.5 mcm / year). ; based on the rough estimation done on the available various data for the period between 1995 to 2016)

Summarizing above, the assigned model input parameter for SEAWAT - 2000 (**Table 4.1**) are taken and analysis is done. PCG (Pre-conditioned Conjugate-Gradient package) is selected as 'solver' for running the SEAWAT - 2000 model (to solve various finite difference equations). Solute (ground water) transport was designed to make use of the simple distribution that would result in adequate representation of the flow system. All parameter values were adjusted during the model calibration process until the model adequately reflected the observed water level distribution and interpreted flow patterns throughout the aquifer.

Table 4.1 : Model input details

• Modelled area (area covered in the watershed boundary) : 72 Sq. Km
• Grid dimensions : 40 X 40 (Nos.)
• Cell dimensions : 250 m X 375 m
• Simulation period : 20 Years and 05 Years
• Boundary Conditions : (a) Constant Head : 0 m on seaward side ; 20 m on landward side ; Linear (19 m to 1m) on left and right side boundary. (b) Constant Concentration : 32000mg/L on seaward side ; 0mg/L on all other sides (c) Initial Concentration : 32000mg/L on seaward side ; 0 mg/L on all other sides
Three watershed boundaries : Dhatarwadi River ; Raidi River & The Arabian sea
Width of the river forming boundaries are assumed as 40 m.
• Rate of pumping at pumping wells: (-) 60m ³ /day, (negative sign indicates extraction of ground water)
• Recharge Rate : 47mm/year i.e. 6% of annual average rainfall (775mm) of study region
• Coefficient of Transmissivity (T) : 62.26 M ² /day
• Hydraulic conductivity (K) : 0.00017m/s (15.11 m /day)



4.2.3 Calibration and model results for NCJW mining area

The numerical model is calibrated and tested against observed data. Time varying target condition (1995 to 2017) was selected for calibration purposes. Verification of the model is done based on the average water level in the year 2016 -17.

During calibration, measured and model-computed heads (water levels) are compared, and the difference is referred to as the residual. Average water levels of year 2016 -17 for 28 dug wells within the model domain were used as calibration targets. Within the model domain, observed water levels ranges from (+) 22 m to (-) 22 m above mean sea level (AMSL). The calculated residual mean error and absolute mean error are calculated (with a standard deviation error) for the simulation period of 05 years to next 20 year period. In general, the comparison of calculated and measured groundwater levels for studied year shows that they are compatible with each other for the assigned simulation period.

4.2.4 Simulation results for NCJW mining area

Groundwater withdrawal either from the dug wells or bore wells (for agricultural, / irrigational, industrial or domestic purposes) near the coast is the main cause of seawater intrusion which affects the mainland aquifer (**Table 4.2**). Excessive, less or controlled (limited) withdrawal of groundwater, decides the *intrusion plume* headway towards mainland.

Table 4.2 : Ground water consumption sources in the study region

S. No	Villages	Number of Water Sources				
		Bore Wells	Dug Wells	Total	With Electricity	Without Electricity
1	Babarkot	8	84	92	44	48
2	Kagvadar	0	82	82	36	46
3	Balanivav	3	61	64	29	35
4	Mitiyala	0	49	49	27	22
5	Kadiyali	0	38	38	19	19
6	Varahswaroop	0	47	47	31	16
7	Bhakodar	3	69	72	40	32
8	Vadhera	0	74	74	43	31
9	Rohisha	0	106	106	51	55
10	Balana	0	58	58	29	29
11	Bhatvadar	0	28	28	12	16
12	Vandh	0	31	31	18	13
Source : Verbal discussion with GWRDA, Bhavnagar						



In order to demonstrate the effect of future scenarios of groundwater pumpage on seawater intrusion, pumping scheme needs to be designed to use the calibrated model for calculations of future changes in water levels and salinity concentrations in a designated period of another 20 years. Thus, the '*predictive assessment*' based on the simulation results has been done for the study area. Simulation period of 05 years and 20 years is selected for the modelled area of 72 Km² and results are worked out. Based on this, it is arrived that decrease in groundwater withdrawal is a very important consideration to prevent (or keep contain) intrusion in future.

4.2.4.1 Results and Discussions

There are no major river within the core zone and the buffer zone of the mining lease area. '*Dhatarwadi River*' and '*Raidi River*', falling outside the buffer zone and in the immediate vicinity of mine lease area, acts as water divide and sea water intrusion is basically surrounded / spread in between these two boundaries. Arabian Sea is on the third side. In pre-monsoon season both *Raidi* and *Dhatarwadi River* remain dry because dams are constructed on upstream of these water channels.

To know and assess the *present scenario* of salinity ingress help of **Fig. 4.7** can be taken. *Present scenario* of salinity ingress shows that the intrusion has extended at about 1.28 km inside the main land (as measured with GIS using computer). A cross-section of the operative pits at the column number 15 of model is drawn covering both north pit and east pit (**Fig. 4.6**). The column 15 is selected as it adequately covers both operative pits. As per the future planning of the NCGW, the SEAWAT model is calibrated for the various pit depth i.e. below ground level (0m RL) considering that SWI may be present in the study area due to sea proximity.

The 'Visual Modflow / SEWAT' model was run for two time periods (5 years and 20 years) to assess the extent of saltwater intrusion in future. **Fig. 4.8 and Fig. 4.9** shows the intrusion of salt water for 05 year and 20 year scenario. It is observed that after 5 years, the SWI will be extended inland to a distance of 1.29 km (**Fig. 4.8**). The salinity ingress / intrusion, from the sea shore into the mainland over 05 years period is just 0.01 Km (Observed value : Present SWI distance -future SWI distance = 1.29 Km - 1.28 km. The nearness to accuracy of modelling results can be assessed, from the *correlation coefficient* obtained (**Fig. 4.10**). As per the calibration graph of observed values Vs calculated values, the obtained correlation coefficient is of the order of 0.7 to 0.8 indicating a good simulation results (**Fig. 4.10**).

From these figures it is quite clear that salt water has intruded very slowly over the years. It also means that the water management measures at NCJW are playing positive role in SWI containment. Period of 20 years prediction, cross-section of pits



at different pit depth (Chapter 5) and SWI at more than 22 m depth in the ERT analysis clearly shows this.

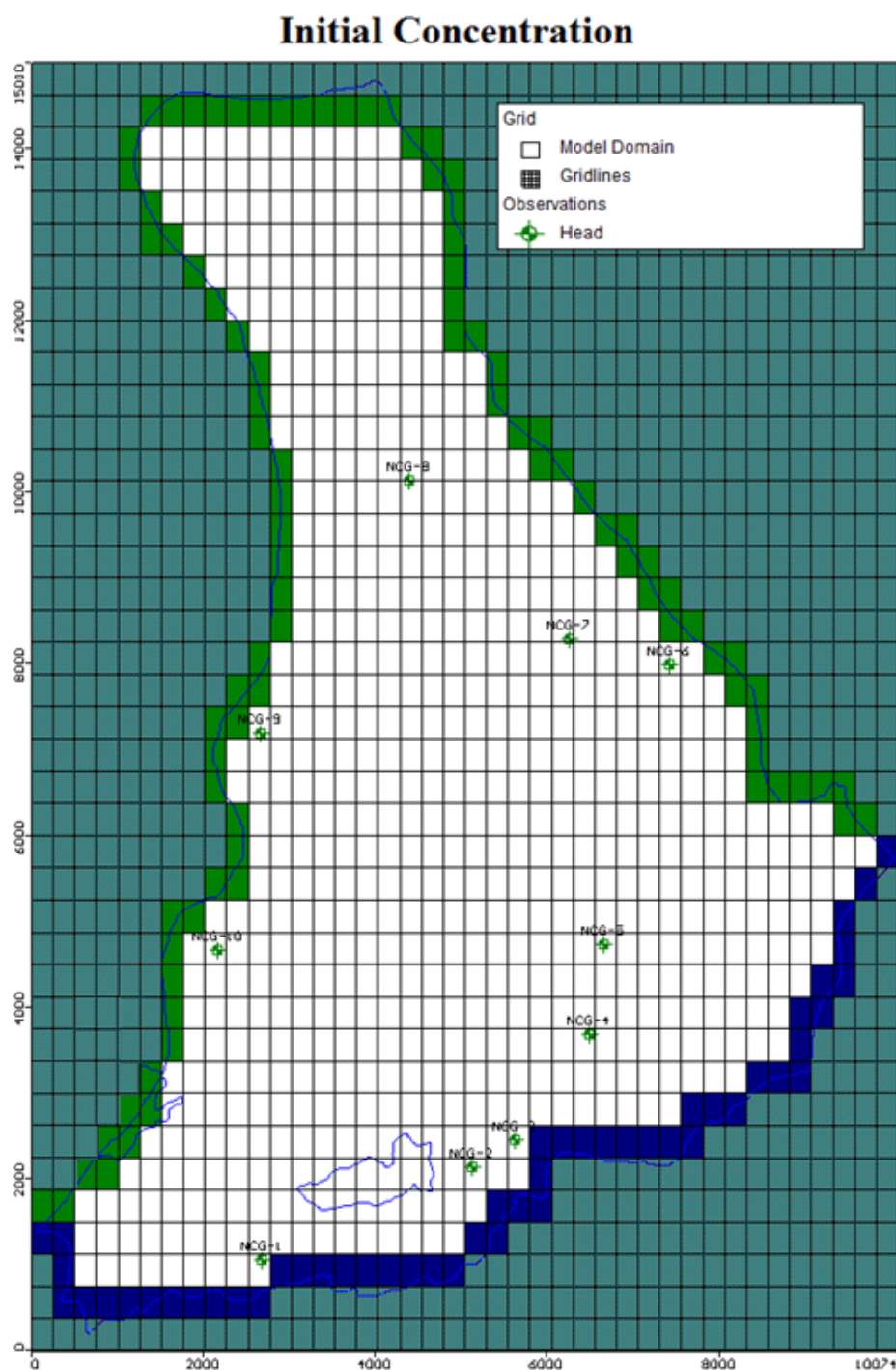


Fig. 4.4 : Initial concentration

The initial concentration input screen is used to define the existing conditions (background groundwater concentrations) of each chemical species being simulated.

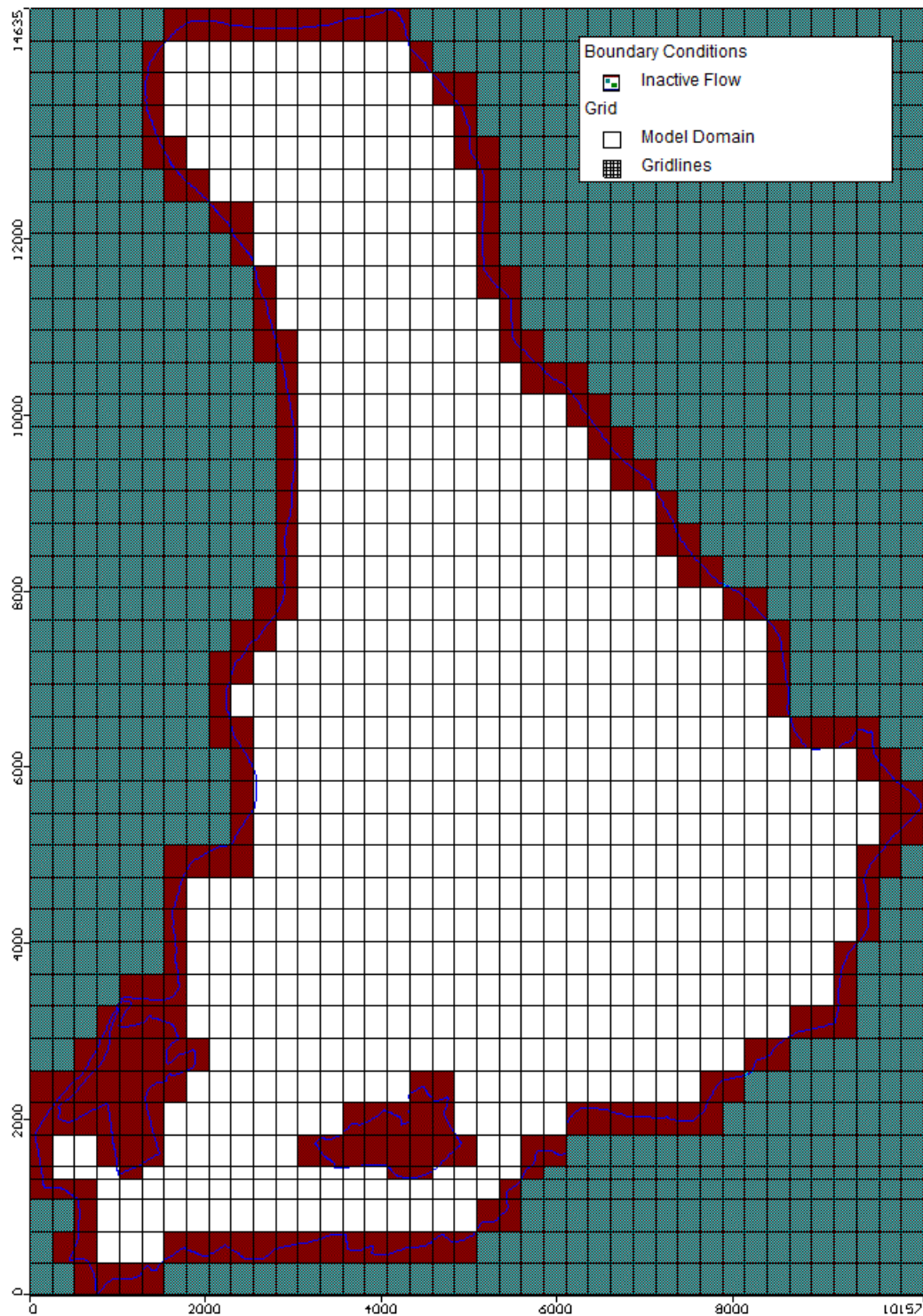


Fig. 4.5 (a): Constant head (Boundary Condition)

The constant head boundary condition is used to fix the head value in selected grid cells regardless of the system conditions in the surrounding grid cells, thus acting as an infinite source of water entering the system, or as an infinite sink for water leaving the system. Therefore, Constant Head boundary conditions can have a significant influence on the results of a simulation.

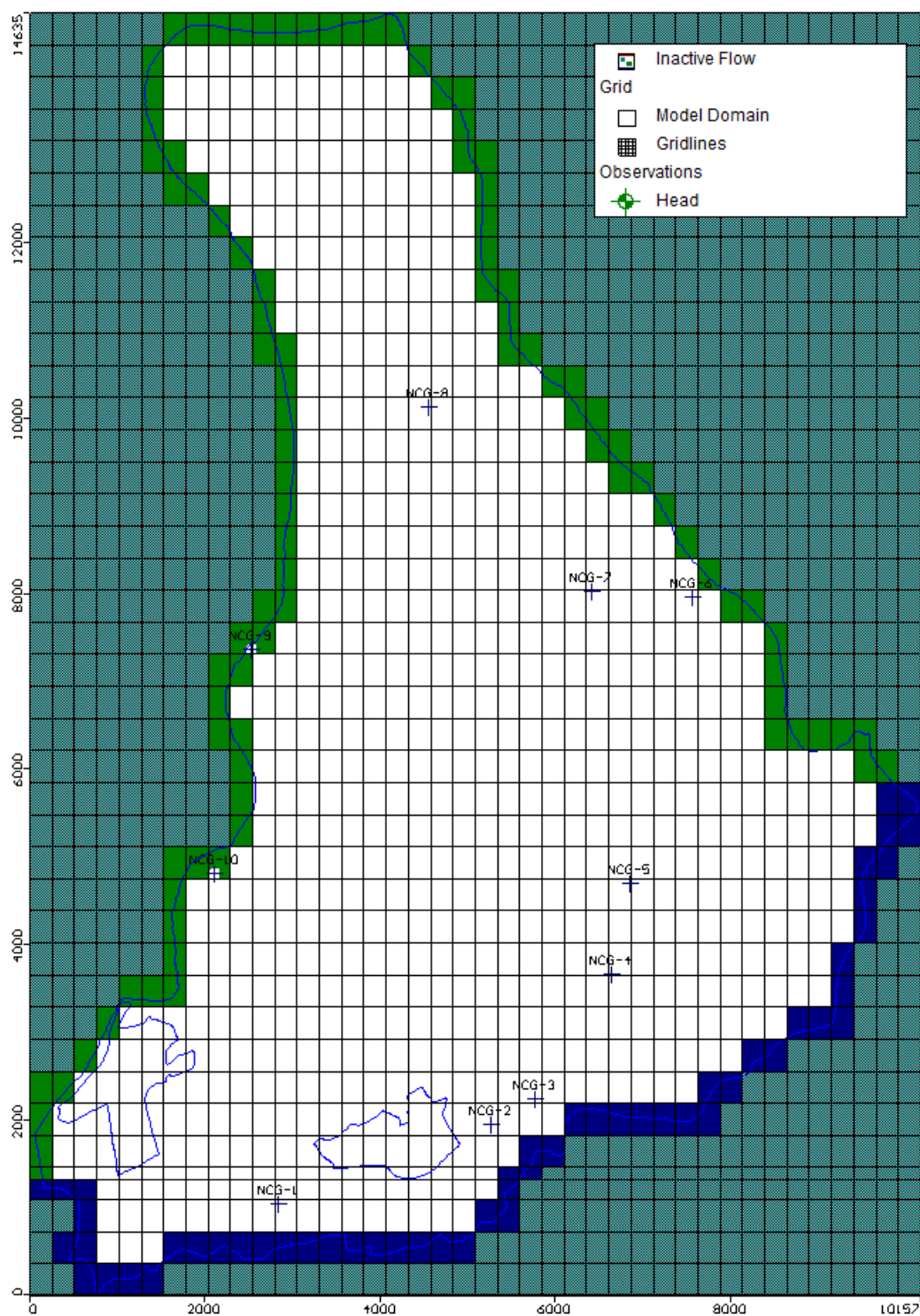
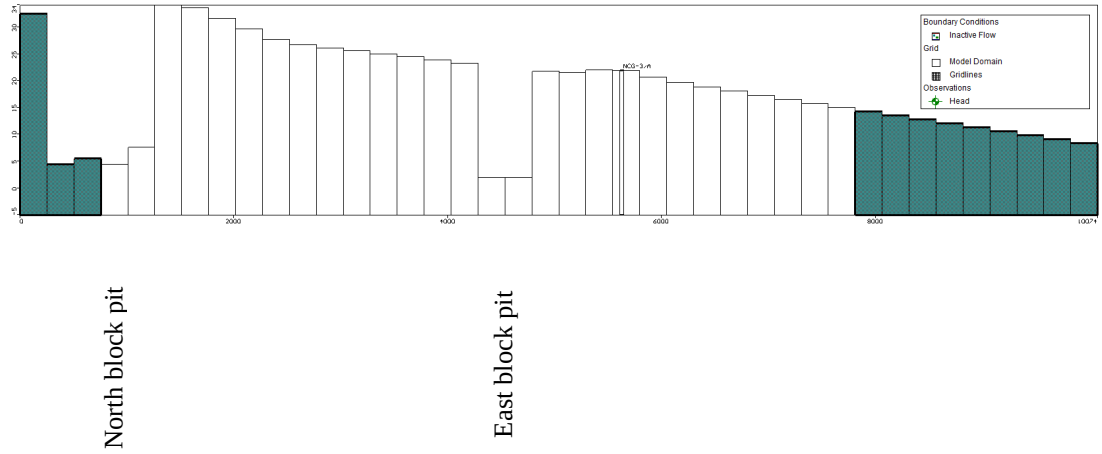


Fig. 4.5 (b): Constant concentration (Boundary Condition)

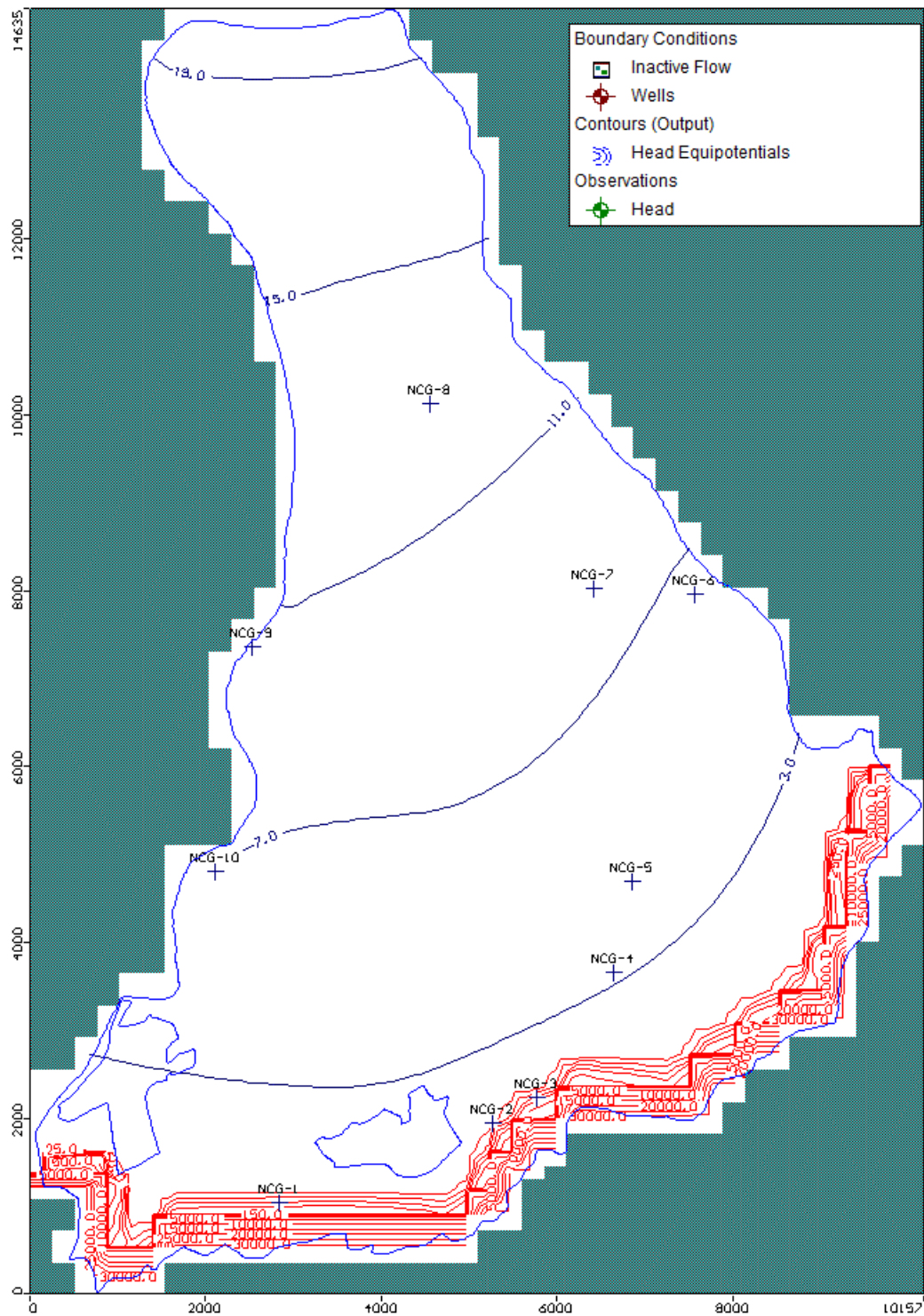
The constant concentration boundary condition acts as a salt water source providing solute mass to the model domain in the form of a known concentration.

Cross-section of Pits in the study area



 = Inactive flow (Cells forming modelling boundaries)

Fig. 4.6 : Cross-section at column 15 of the study area (North & East Pit)



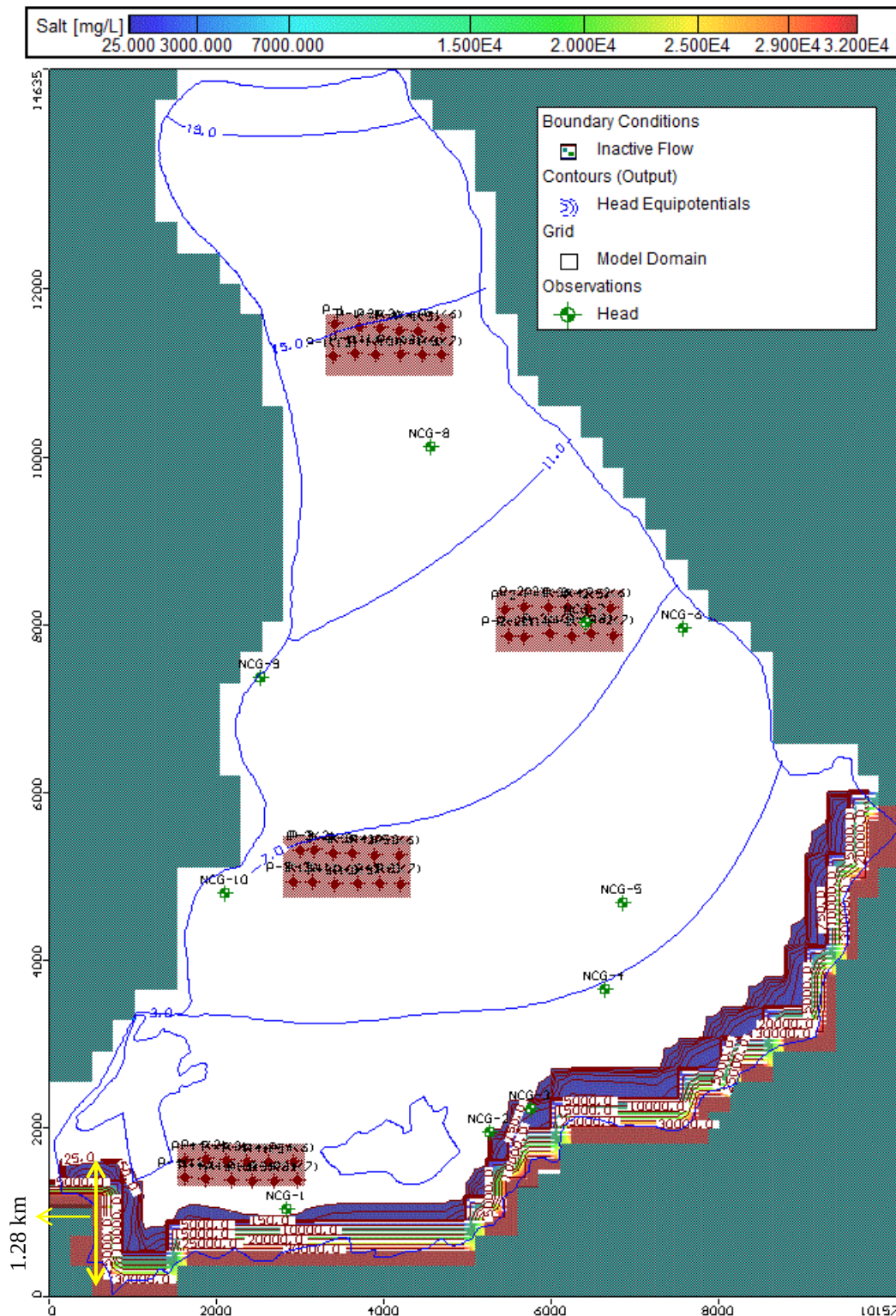


Fig. 4.8 : Results of 05 years simulation period (SEAWAT - 2000 output)

Distance between sea coast & line of intrusion = 1.29 Km at the pit depth of 0m

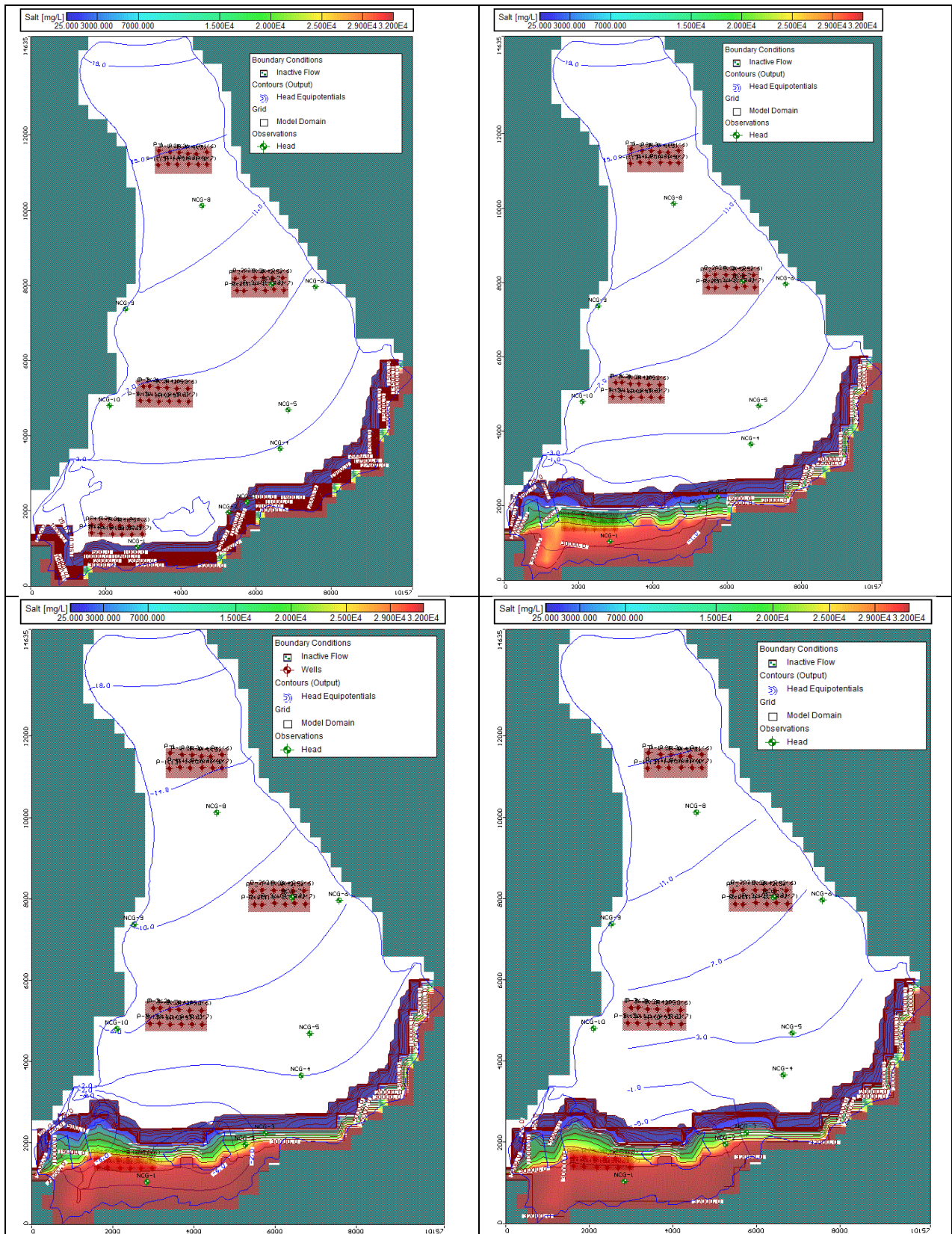


Fig. 4.9 : Results of 20 years simulation period (SEAWAT - 2000 output)
(Clockwise : 0m; - 4m; -8m and -12m depth)

A concentration of 32000 mg/L to 25mg/L (i.e. SWI from coast to land) has moved up to 1.28 Km ; 2.29 km ; 2.59 Km ; 2.65 Km for a simulation period of 20 years at the pit depth of 0m ; (-) 4m ; (-8)m and (-12)m respectively



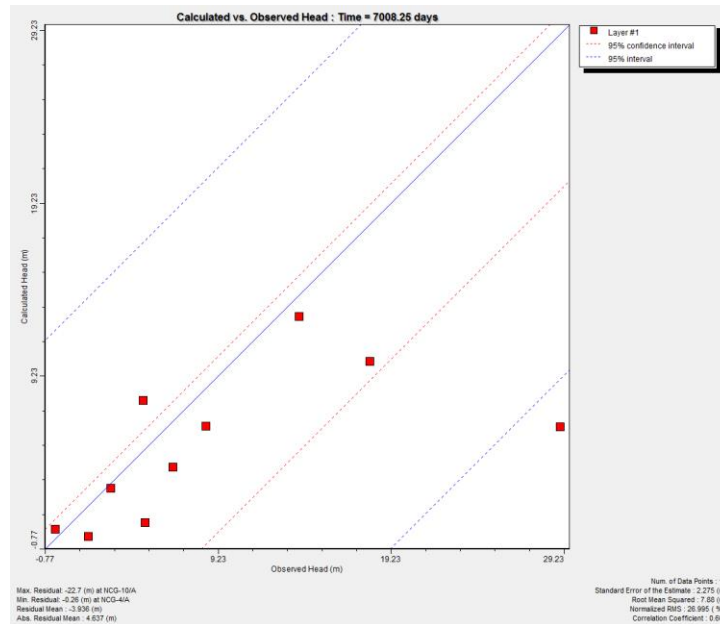


Fig. 4.10: Calibration graph for assigned simulation period (20 years) as obtained output of SEAWAT - 2000

4.3 ANALYSIS & DISCUSSIONS

The basic purposes of this study are to examine 'sea water intrusions' in a coastal aquifer system, which is located in and around a mining area from where the excavation of mineral is being done. The proximity of sea and its dynamic head (high tide) together with pumping makes saline water to intrude in to the main land (**Fig. 4.11**). Thus, seawater acts as the most common pollutant of coastal aquifers. It can be affirmed that seawater can be prevented from intruding by maintaining a head of fresh water above the sea water level which requires special management techniques as described in Chapter 06 of this report.

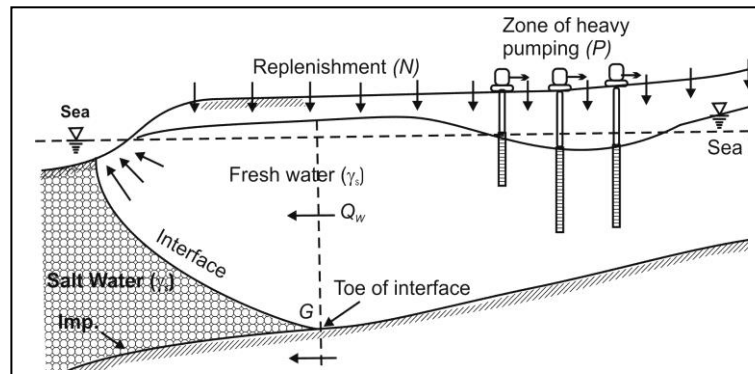


Fig. 4.11 : A typical cross section of a coastal aquifers with pumping (Bear, 1979)

Having understood the basic mechanism of seawater intrusion theoretically as well as practically through NCJW case record, following important interpretation can be given and inference drawn -

1. Naturally and in general all coastal aquifers are marked with SWI irrespective of the ground water exploitation in nearby areas. In general, in coastal aquifers a hydraulic gradient exists towards the sea. Owing to the difference in sea-water / fresh water density in an aquifer formation, a zone of contact is formed between the lighter fresh water flowing to the sea and the heavier underlying it. Similar condition has been observed in the NCJW mine area also.
2. Hydro-geochemical data and its analysis helps in estimating the type and concentration of salts. In NCJW study also similar approach have been adopted and results derived.
3. 'Seawater intrusion', attributes to the aquifer stresses depending on the geological environment and movement of groundwater. The geological environment with respect to the NCJW study area consists of limestone and host rocks.
4. To interpret the processes that control the 'groundwater chemistry', the chemical compositions of groundwater and chemical aspects that determine the factors affecting the *groundwater (geo-hydrological aspects)* must be analyzed. This has been done in this report for the study area.
5. As a result of chemical and bio-chemical interaction between groundwater and geological materials through which it flows, a wide variety of organic/inorganic chemical constituents in various concentrations are dissolved in it. In this case record miliolitic limestone /marly limestone is the geologic media for ground water flow, which partly contributes to the increase in TDS concentration besides sea water.
6. When SWI is the only cause for the salinity of groundwater in an aquifer system, the groundwater does not only exhibit high total dissolved solids (TDS) but also shows high concentrations of most major cations and anions. Similar observation have been recorded for NCJW area too.



7. Often a coastal aquifer is divided into a number of sub-aquifers by impervious / semi-pervious layers. This assumption is taken care in the modelling exercise of this NCJW study.
8. Mining and other industrial activity including ground water withdrawal in and around is causing very-very slow movement of seawater intrusion from south to north direction as sea is on southern part of the study area. It is established that ground water extraction over long periods and to a large extent triggers the SWI . Since, groundwater often serves as drinking water in an area, necessary steps must be taken to avoid water quality deterioration for NCJW study area which makes use of ground water.



CHAPTER – 5

LIMESTONE MINING AND RELATED ASPECTS OF HYDROGEOLOGY

Limestone for cement manufacturing is a major non-metallic mineral of industrial category. In India it is extracted from surface mines only for all practical purposes. No underground mining of limestone exists in the country. In recent years considerable expansion of the limestone mining has been witnessed due to large demand of cement all over the India. Thus, surface mining of limestone is poised for sustained growth, particularly cement grade limestone, as a result of which, extraction of limestone in coastal areas have also been geared and even export oriented units (EOU) are set up.

5.1 LIMESTONE MINING AT NARMADA CEMENT MINE

NCM is an open cast mechanised limestone mine operational since 1979 and has the captive status. With a rated capacity of 2.3 MT per annum the mine provides ROM feed to its cement processing unit located nearby the mine (at about <500 m from village Babarkot). The mining of ore and overburden is being carried out at this mine in combination with conventional mining and surface miner. From crusher to plant, the conveyor belt transports the ROM. Total mine dispatch is consumed in cement plant and the target production is achieved conveniently with limited stock in storage yards. The selection of mining method has been done on the basis of areas available for mining i.e. areas with blasting constraints and areas without blasting constraints. Conventional unit operations of mining namely *drilling and blasting* are applied on hard portion of deposit for both rock and overburden removal. By deploying fleet of various equipments namely dumpers, shovels, drills, dozers, graders etc. the mine production is achieved. It is observed that the limestone is not very hard from excavation angle.

At NCM limestone excavation is being done closer to the surface in East Pit and North Pit also called as east /north block (**Fig. 5.2 & Fig. 5.3**). The horizontal spread of mine is large as the mine is shallow and ground water is not intercepted in the mining area. The limestone mining site of NCJW lies all along the Arabian Sea of Gujarat coastline. Mining lease area is surrounded by *Varaswarup, Bhakodar, Babarkot and Vand, village boundaries* (**Fig. 5.1**).



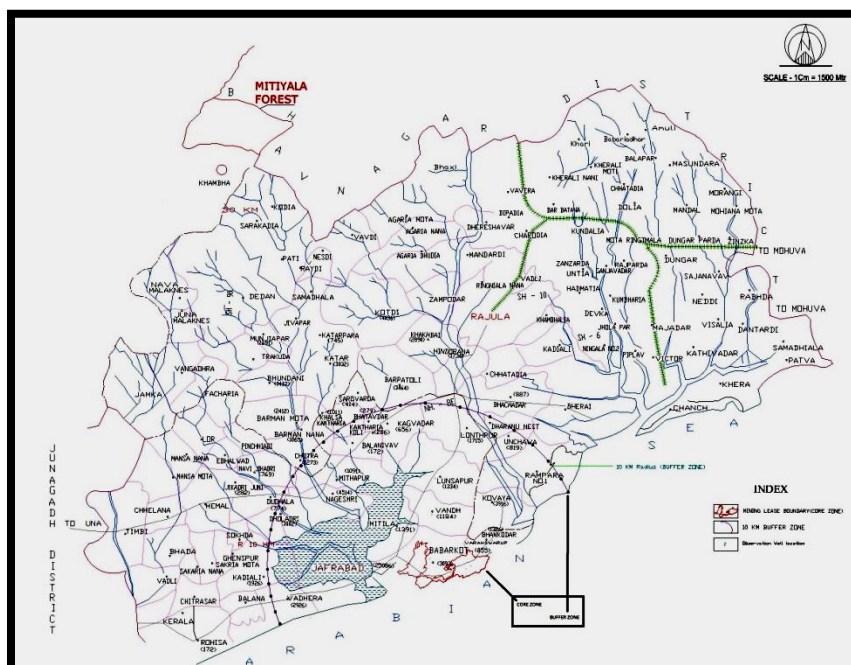


Fig. 5.1: Core Zone and Buffer Zone

The NCM mine is currently producing limestone (low grade and cement grade) for its captive use in cement manufacturing (**Table 5.1**) and achieved its rated capacity of production.

Table 5.1: ROM production at Narmada cement mine

S. No	Year (April - March)	Total ROM Production (Limestone of all grades)
1	2010-11	1860662
2	2011-12	1951286
3	2012-13	2020647
4	2013-14	1886526
5	2014-15	1962182
6	2015-16	1676020
7	2016-17	1538086

Salient particulars of mine from mining point of view are as given below –

- Mine Lease area – 565.94 ha (core zone + buffer zone; as on 2016)
- Lease Validity – 31/03/2030
- Mine Life – up to 2024 (i.e. 10 years from 2014)
- Total Mineable Reserves - 23.893 million tonnes (as on 01/04/2014)
- Active Mining Area (area of mining) – 261.9 ha (as on 01/04/2014)



- Area for Infrastructure - 90.03 ha
- Mining : Above 0m MRL
- General Strike of Limestone Deposit – N40°E S40°W
- Dip – 5° to 6° towards east
- Limestone Production – 2.3 million tonne/annum (average planned)
- Total limestone production /month (as on 2016-17) – 12,735 tonnes (15380086 /12)

5.2 SEA WATER INTRUSION Vs MINE PLANNING

A network of observation wells (mostly dug wells) were set up in the study area and the pre-monsoon and post-monsoon analysis as done for 2016-2017 shows that high TDS level, high sodium and high chloride content present in the aquifer water can be attributed to possible seawater intrusion in the study area. This possibility of SWI in the study area is further reconfirmed by geophysical investigations carried out at selected locations and as described in this report.

Considering the presence of SWI and present mining level at (+) 2m MRL, the planning for extraction of limestone at deeper depth can be done as reserve of limestone is available.

The aquifers present are mostly unconfined to semi-confined. The depth of water table varies from 14.37 m (AMSL) to 1.31m (AMSL) during pre-monsoon season of, 2017 and from 16.97m (AMSL) to 0.31m (AMSL) during post monsoon season of 2016. The ground water flow is towards the seacoast . The water table elevation (AMSL) at places indicates that there is negative head and the seawater is mixed with fresh aquifer water showing the salty properties of ground water all along the coastal dug wells. The east pit and north pit area /region has ground water flow towards sea (**Fig. 5.2 & Fig. 5.3**).

For the NCJW limestone mining area an interface line of SWI is drawn through ground water modelling. *This interface line is approximately extended to a distance of 1.28 Km inside the coast (Fig. 4.8 and Fig. 4.9).* For mine planning purpose this may be taken as a base. Mine management should utilize this inference for future mine planning of mine workings below ground water table.



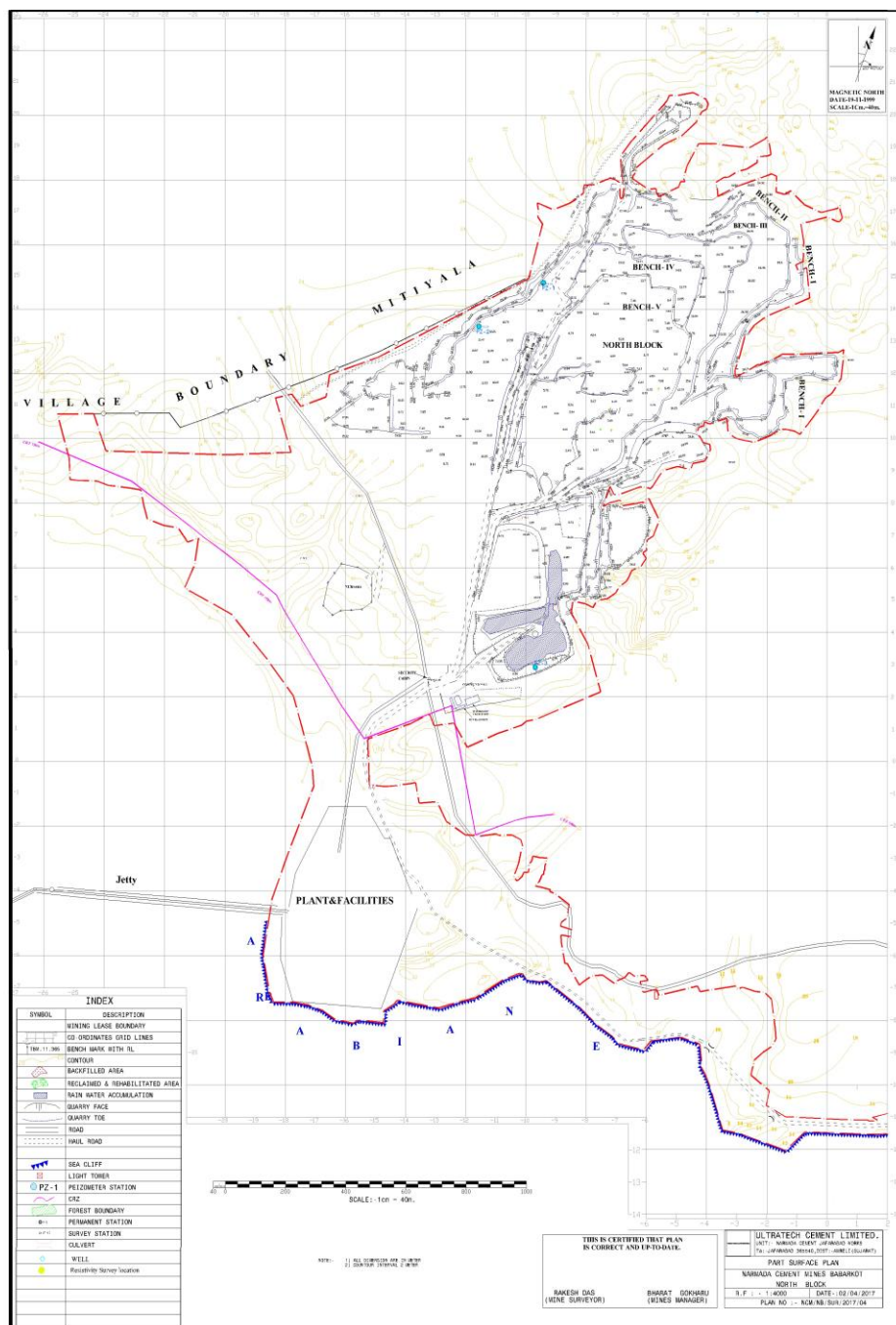


Fig.5.2 : North Block Map of NCJW Mining Area



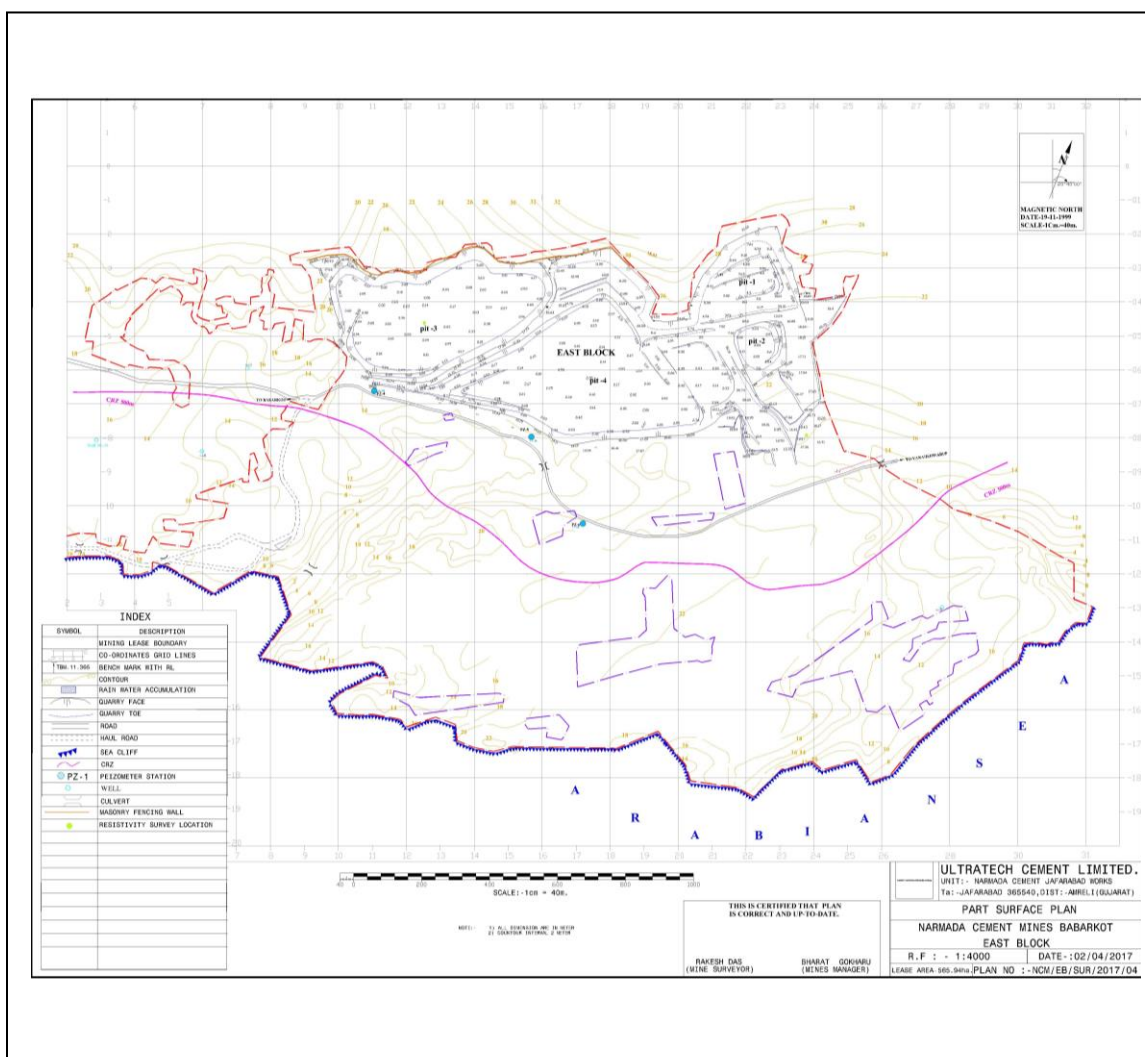


Fig.5.3 : East Block Map of NCJW mining Area

On the basis of field work, discussion and ground reality it is assessed that interface line / line of intrusion (arbitrary) should pass from 'Dholadhri' to 'Balanivav / Kagvadar' village area. This statement is written for two reasons, firstly the marked difference of sweetness of water present and secondly the presence of clay beds all around the Kagvadar / Bhatvadar village area.

Scientific planning of NCJW pits for eco-friendly mining (without resorting to conventional blasting method) can be done accordingly (Table 5.2). Other important aspects of water table depth, SWI interface distance must be kept in mind while making long-term and short-term plans for designing of pit and dewatering planning. The depth of intrusion as drawn from the resistivity survey

(Table 3.5) can be used for mine planning in future and mining below ground level can be planned.

Table 5.2 : Benches and working levels of Narmada cement mine

Parameters		North Block / Pit		East Block / Pit
Bench Height		6 m (Maximum)		--
Operating or working benches and its levels	Bench - I	<u>Bottom RLs</u> 32m	<u>Top RLs</u> 35 m	Pit No. 03 - abandoned RL = + 2m
	Bench - II	26m	30m	Pit No. 04 - operational RL = + 2 m
	Bench- III	20m	23m	
	Bench- IV	14m	18m	
	Bench- V	6 - 8m	--	
		Conventional Mining Operation		Surface Miner Operation

Further, it may be noted that the *limestone* from east block & north block of NCJW limestone mine is extractable by both conventional method and machine mining method but preference shall be given to cleaner mining options to achieve desired ROM production. This will help to promote 'Green Mining', a requirement to protect the scenic beauty of the sea and adjoining area.

5.3 LIMESTONE DEPOSIT AND AQUIFER SYSTEM

As said above, *miliolitic limestone* is the major water bearing formation in the study area and this limestone formation is being exploited at NCM.

Both low grade and miliolitic limestone is porous and non-homogenous in nature. The limestone formations has presence of secondary porosity and hence has good water holding capacity. The water holding capacity of such rock formations, particularly for water flow (as transmitting media) is greatly influenced or affected by the rock fractures present. Such fractures are either developed naturally or developed in the due course of mining activity. Therefore, water storage ponds in such type areas (or in the excavated pits resulted due to mining) are the desired features. On enquiring, it is inferred that in the past i.e. before the establishment of cement plant, the practice of water storage in the form of ponds (or man-made surface depression) was not practiced. With industrialization the awareness about ground water and importance of water preciousness among masses is



greatly realized. It is also noticed that a stagnant water storage structure on the approach road of mine (near the petrol pump) do exist which is filled with water during summer. This could be either sea water / or ground water but the aquifer recharge is taking place through such structure. Further, desalination unit installed by the UltraTech cement at Kovaya to meet out the water requirement of plant, colony and mines is praise worthy (**Annexure - I**). The mine management of NCJW's limestone mine has stored 6 -7 lakh m³ of rain water in their abandoned pits (resulted out of mineral excavation) for the industrial requirement (**Annexure - II**). This stored water have served dual purpose of recharge and water utilization during acute industrial need. Such storages are also immensely helpful in containment of 'seawater intrusion' by creating a hydraulic gradient towards sea i.e. away from the mining pits or main land. Accordingly, while doing ground water modeling (and also for future perspective planning of NCM mine) variable recharge rate and variable pit depths have been taken into consideration and results have been arrived at.

5.4 GEOHYDROLOGICAL ANALYSIS

All coastal areas are characterized with some peculiar features like *sea water intrusion* (SWI). Behavior of water table in the immediate vicinity of sea shore (a coastal area) is somewhat different compare to the mainland, where the topography controls the water table depth as well as pattern. The elevation (or RL) near the coast line is always more than the RL of sea level and impact of high tide line very near to the sea shore is particularly critical in respect of water movement in fractures and pores of rock media. Since NCJW study area lies very close to the sea shore the similar characteristics as that of coastal zone have been observed which are verified with this geological / hydrological study.

On observing the table given in **Fig 5.4** it is seen that the water level fluctuation (WLF) in and around the study area /region lies in the range of 0.15m to 9.87m BGL. The depth to water level varies from 1.0 m to 21.36 m (BGL) in the pre-monsoon period (May, 2017) and varies from 0.35 m to 20.26 m (BGL) in the post-monsoon period (November, 2016). Average flow of ground water is towards the seacoast.

As per the field study carried out for the NCJW mining pits exclusively, where actual limestone mining is going on, the static water level (SWL) and its range, for a yearlong study is summarized in Table 5.3 below -



Table 5.3 : Static water level and its range as recoded by CIMFR

Mining Blocks	Pre-monsoon, 2017	Post - monsoon, 2016
East Block and <i>surrounding areas</i>	1.31 m to 4.55 m	0.31m to 6.50m
North Block and <i>surrounding areas</i>	4.56 m to 14.37m	6.51m to 16.97m

Here, in the table given above word 'surrounding areas' includes villages namely *Babarkot, Varahswarup, Vand, Bhakodar and Kovaya* which are populated too. Higher TDS, sodium and chloride concentration in the dug well water of these villages have made the water 'salty' showing clear presence of intrusion in these areas.

Piezometer Data

For the purpose of water level determination in the NCJW area the Piezometer installed by the company. These observation points has depth range from 25 m to 34m and monitored in the past by GWRDCL, Gandhinagar. CIMFR have analyzed 2012 -2015 data of the installed piezometers for one particular location i.e. Babarkot. Since mining operation is located near Babarkot our point of concentration of this study is 'Babarkot Village'. NCJW plant and mine both are located in immediate proximity of this village. The trend of observation wells W1, W5 W7 W8 & W9 is presented in **Fig. 5.5**. In particular, water level fluctuation (WLF) of Piezometer shows variation from 0.1m to 2.7m (in 2012); 0.0 m to 1.1 m (in 2013); 0.3m to 2.9m (in 2014) and 0.3 m to 2.95m (in 2015) between pre and post monsoon season and graphical trend is almost flat. (Please see data table of Fig 5.5). It may be noted that some of the Piezometer were either filled up or abandoned also in the mining area. Summarizing, the static water level data in these four years (2012-15) it is observed that the SWL measurement ranges between 5.30 m to 25.50m. This data can be clubbed with 2016 field data, as obtained by CIMFR field study and also by the mine management of UltraTech and inference can be drawn.

In 2016, UltraTech recorded pre - monsoon season (May) and post-monsoon season (Nov) data for both water quality and water level fluctuation (**Table 5.4**) of



Table 5.4 : Piezometer ground water quality and water level fluctuation for mining pits of NCM (Pre-monsoon and Post-monsoon of 2016)

Location	PZM	RL	Total Depth (in m)	Hole bottom below MSL (in m)	May -2016 (pre-monsoon)					Nov. 2016 (post-monsoon)				
					SWL	TDS	pH	Na	Chloride	SWL	TDS	pH	Na	Chloride
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
NB	1	12.15	19.65	-7.50	12.3	600	7.7	34	64	--	--	--	--	--
NB	2	10.53	19.15	-8.62	11.3	1020	7.7	157	152	09.1	1040	8	151	144
NB	3	06.22	11.00	-4.78	06.4	340	8.1	13	56	04.4	430	7.9	18	112
EB	4	11.94	20.00	-8.06	12.9	1010	8.2	195	320	12.5	1120	7.6	205	222
EB	5	11.29	19.30	-8.01	13.4	1140	8.3	180	224	12.9	1190	7.6	154	240
EB	6	13.69	19.00	-5.31	14.8	940	8.2	85	128	14.4	980	7.4	80	112
Average	--	--	--	--	11.85	841.67	8.03	110.67	157.33	10.66	952.0	7.70	121.60	166.00

Data Source : Narmada cement mine, UltraTech-NCJW.
In this table NB refers to 'north block' and EB refers to 'East Block'.

the existing piezometers. In particular, 06 numbers of piezometers near north block (NB) and east block (EB) are analyzed for 2016 data. The depth of piezometers in NB is 11m to 19.5 m and in EB it is 19m to 20m.

In terms of water quality, TDS concentration of the order of 1000mg/L (approximately) is recorded in the piezometers near the mining pit with higher chloride and sodium content. pH of the ground water of mine area piezometers is slightly higher in EB (8.3) in pre-monsoon and declined in post-monsoon to 7.6 in post monsoon. The recorded SWL for north block is 6.4m to 12.3m and for east block it is 12.9m to 14.8 m.

Summarizing, it is inferred that the static water level (SWL) monitoring data over the years (2012-16) has a wide scatter and the field conditions being dynamic one can draw a range of values for both SWL and WLF as obtained by CIMFR field study and other involved agencies. Here, it may be noted that the water column height (or static water level) in the piezometer, which is nothing but a less diameter borehole, is significantly controlled by the *capillary action of water in the restricted depth & diameter borehole*. Another influencing factor namely *pressure of sea water tides on the coastal aquifer in immediate vicinity of the shore line* also affect the column height in the piezometers.

5.4.1 Water table in the study area

For this study, water table can be determined from (a) Piezometer data installed in the core zone (b) SWL of dugwells from field studies done by CIMFR and (c) from other secondary data sources (namely GWRDCL). To estimate the water



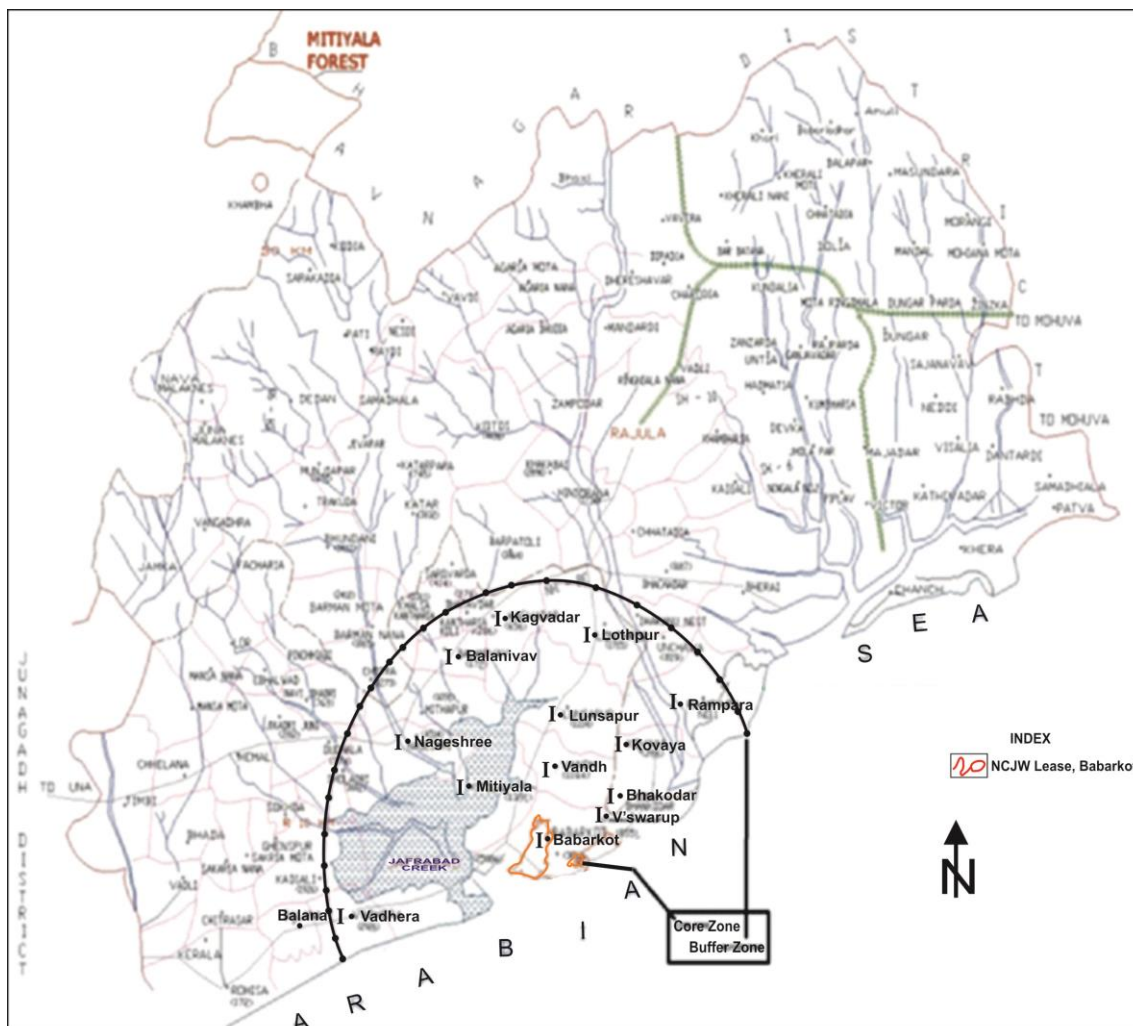
table in the study area an estimation has been done which is based on the data table given below.

STATIC WATER LEVELS IN DUGWELLS OF BABARKOT VILLAGE AS RECORDED BY DIFFERENT AGENCIES (all values are in meters)						
Piezometer data Year : 2012 -2015 /16			CIMFR data Year : 2016-2017		GWRDCL data Year : 2004-2005 (02 dugwells of equal total depth of 21.05m)	
Pre-monsoon (min-max)	Post-monsoon (min-max)	Winter (min-max)	Pre-monsoon	Post-monsoon	Pre-monsoon	Post-monsoon
12.50 to 21.10	12.10 to 20.60	12.40 to 20.70	20.26	21.36	19.71 & 17.40	19.10 & 16.60
Range of static water level = 12.10m (min) to 21.10 (max)						

Abridging all the above mentioned three data sources, it is estimated that the water table lies in the range of **14.00 m to 17.0 m** (approximately) in the core zone i.e. in the mine lease area and at Babarkot village where the NCJW operation is located.

Local water table in the piezometer (PZM) and observation wells (OW) also confirmed us that the depth of water table, may be in saturated zone or in unsaturated zone, has been identified below 14 m. On observing the mining pits in the field physically, no instances of *water table intersection* has been observed because the working pits has not gone below (+) 2m MRL.



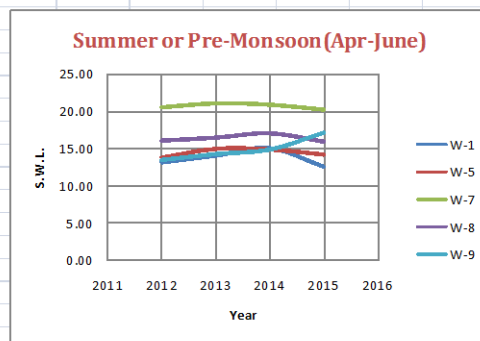


Name of Villages of Jafarabad administrative Division	Core Zone (CZ) / Buffer Zone (BZ)	Distance from Mine (Km)	Pre - Monsoon Water Level (in m)	Post - Monsoon Water Level (in m)	Water Level Fluctuation (in m)
Babarkot	CZ	3.0	21.36	20.26	1.1 m
Bhakodar	BZ	2.0	14.45	10.20	4.25 m
V'swarup	BZ	2.0	19.10	17.45	1.65 m
Vandh	BZ	3.4	Not Available	Not Available	Not Available
Vadhera	BZ	4.5	8.22	3.07	5.15 m
Mitiyala	BZ	5.0	11.60	7.55	4.05 m
Lunsapur	BZ	6.0	1.00	0.85	0.15 m
Lothpur	BZ	6.2	5.1	2.42	2.68 m
Kovaya	BZ	6.0	3.6	0.35	3.25 m
Balanivav	BZ	5.6	Not Available	Not Available	Not Available
Kagvadar	BZ	5.8	21.03	11.16	9.87 m
Nageshri	BZ	6.3	15.80	10.08	5.72 m
Range Values ----->			1.00 - 21.36 m	0.35 -20.26 m	0.15 -9.87m

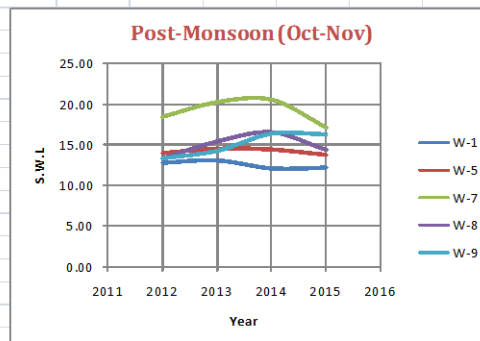
Fig. 5.4: Water level fluctuation between pre monsoon and post monsoon season at NCJW study area

Graphical Representation and trend of static water level of piezometric wells installed in NCJW - Ultra Tech Cement Ltd.
(Narmada Cement Jafrabad Works, Babarkot Mining Area, Village: Babarkot Taluka: Jafrabad Dist: Amreli, Gujarat)

Sr. No.	Village	Taluka	Well No.	Year			
				2012	2013	2014	2015
1	Babarkot	Jafrabad	W-1	13.10	14.00	15.00	12.50
2	Babarkot	Jafrabad	W-5	13.70	15.00	14.90	14.15
3	Babarkot	Jafrabad	W-7	20.50	21.10	20.90	20.15
4	Babarkot	Jafrabad	W-8	16.10	16.50	17.10	15.95
5	Babarkot	Jafrabad	W-9	13.50	14.30	14.90	17.20



Sr. No.	Village	Taluka	Well No.	Year			
				2012	2013	2014	2015
1	Babarkot	Jafrabad	W-1	12.80	13.10	12.10	12.20
2	Babarkot	Jafrabad	W-5	14.00	14.50	14.40	13.80
3	Babarkot	Jafrabad	W-7	18.50	20.30	20.60	17.20
4	Babarkot	Jafrabad	W-8	13.40	15.40	16.50	14.40
5	Babarkot	Jafrabad	W-9	13.40	14.30	16.40	16.30



Sr. No.	Village	Taluka	Well No.	Year		
				2014	2015	2016
1	Babarkot	Jafrabad	W-1	14.30	12.40	
2	Babarkot	Jafrabad	W-5	14.70	14.40	13.90
3	Babarkot	Jafrabad	W-7	20.70	20.40	17.10
4	Babarkot	Jafrabad	W-8	16.30	16.40	14.60
5	Babarkot	Jafrabad	W-9	14.10	17.10	16.50

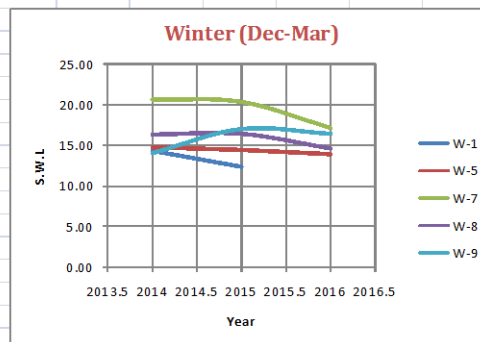


Fig. 5.5: Piezometer data and its trend for water level fluctuation between pre-monsoon and post-monsoon season at NCJW study area

5.5 GROUND WATER

In core zone 'miliolitic limestone' is the major ground water formation (aquifer) and in buffer zone fresh ground water is contained in 'The Deccan Traps'. The study area consist of miliolitic limestone of *Miocene to Pliocene* age and is a geologically younger formation. Below the miliolitic limestone, presence of clay has been observed (Kagvadar/Bhatvadar/Balanivav area) which causes restrictive movement of ground water flow at depth thereby developing deep saturated aquifers around the study area.

Detailed hydro-geological investigation were carried out in the study area by the state agencies namely Gujarat Water Resources Development Corporation Ltd. (GWRDC) covering entire area of *Rajula* and *Jafarabad* taluka of Amreli district. Based on the well inventories, pump tests, continuous monitoring round the year and secondary data and literature available the ground water scenario of local area as well as region is described. Similarly, CGWB has also revealed technical details of ground water and its use related data for the Jafarabad area.

Some ground water related pertinent points (based on secondary data) are as given below -

1. The aquifer parameters for NCJW area which can be taken as input parameters are – Coefficient of Transmissibility (T) = 62.26 M² / day; Permeability or Hydraulic conductivity (K) = 15.11 m /day; Specific Yield = 0.031 and Safe Distance = 123.71 m (GWRDC, 2006).
2. The mine area and Jafarabad region is covered under 'Safe category' as per CGWB analysis (CGWB, 2012) meaning that potential for future ground water development do exist in the area (**Fig. 5.6**). Overall ground water development in the region is around 64-65% and in specific mining area it is nearly 25-26% and total net draft of the study region is 3.0 million cubic meter / year.
3. Though, ground water consumption permission of 500 kilo liters per day (maximum limit permitted by CGWA) is obtained by UltraTech but actual consumption (annual draft) is less. At the Narmada cement factory industrial uses and domestic uses are in the ratio of 2:3. For the Narmada cement mine area, the details are as given in (**Table 5.4**).



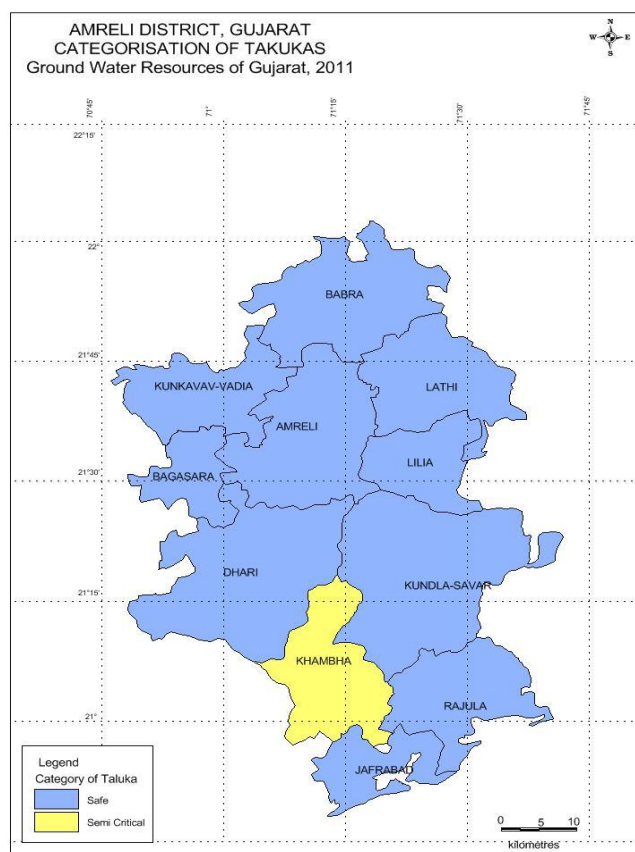


Fig. 5. 6 : Ground water development in the Amreli region of Gujarat (CGWB, 2012)

Table 5.5 : Water consumption at NCM in 2016-17

Month	Dust Suppression	Plantation	Drinking	Washing	Grand Total
Apr-16	2345	3606	214	16	6181
May-16	2230	3697	223	16	6166
Jun-16	1802	2961	223	16	5002
Jul-16	0	295	190	15	500
Aug-16	550	301	219	15	1085
Sep-16	895	496	155	15	1561
Oct-16	1552	1103	287	15	2957
Nov-16	2203	1935	188	14	4340
Dec-16	2413	2143	165	16	4737
Jan-17	1483	2247	170	15	3915
Feb-17	1170	2206	176	14	3566
Mar-17	1751	3024	221	13	5009
Avg.	1533	2001	203	15	3752
Total	18394	24014	2431	180	45019

Source: NCM, UltraTech Cement

- Ground water quality, based on the chemical analysis of 2016-17, indicate that higher total dissolved solids (TDS) concentration is observed. TDS values



are higher compared to the prescribed limit in both pre and post monsoon season. Sodium (Na), chloride (Cl⁻), carbonate (Co³) and bicarbonate (HCO³) concentration is also higher in the region which marks the presence of sea water intrusion.

5. Ground water flow direction of the NCJW study area is indicated in **Fig. 5.7** and flow is from north to south (NW - SE quadrant) converging towards the Arabian sea.
6. The tidal waves of Arabian sea off the Gujarat coast is one of the responsible factor for ground water quality change as the chemical parameters changes periodically.

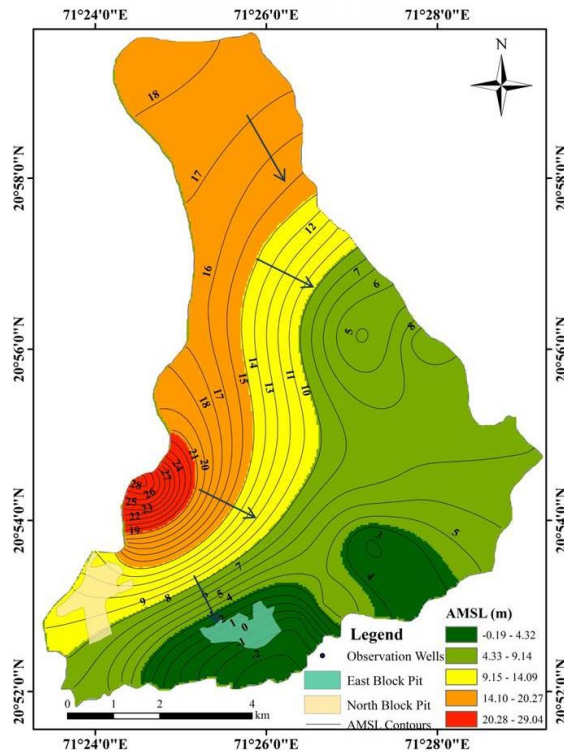


Fig. 5.7 : Ground water flow direction in the NCJW study area
(flow direction is from N to S towards sea ; NW - SE quadrant)

7. Annual **average** rainfall (775 mm /year) during the monsoon season improves the overall ground water quality as well as quantity in the study area. Since there are no major river in the buffer zone, this scenario does not prevail throughout the year. In respect of ground water and most part of the year the comfortable condition prevail.
8. 'Salt Pans' is an important industrial activity in the Jafarabad area and it is beyond doubt that these open fields of salty water contribute significantly to the ground water contamination & sea water intrusion that is already present



in the study area. Further, backwater of 'Jafarabad Creek' also adds / shares to the water salinity. One cannot separate the water pollution contribution of salt pan activity and mining activity. Hence, in brief it is obvious that water contamination and industrial activity of the region has to go hand in hand.

9. Ground water management measures must include, less ground water consumption and more ground water recharge measures into practice for the operative industrial units in view of the presence of SWI in the study area.

5.5.1 SWI : Constraints and assumptions of scientific investigations

The scientific investigations of SWI are based on the following assumption and constraints involving basic principles of ground water flow / movement in aquifer -

- The possible presence of *small scale heterogeneities are big unknown. This causes changes in the hydraulic properties of the aquifer too and* which are too small to be taken into account by the modelling exercise.
- The possible *presence of fissures, cracks and fractures in the aquifer (rocks)*, whose precise positions are unknown but which have great influence on the development of the SWI.
- A mixture of saltwater and freshwater is often under-saturated with respect to Ca (calcium), triggering dissolution of Ca in the mixing zone and changing hydraulic properties. Hence, it is assumed that the *change of hydraulic properties of ground water* occurs by the saltwater intrusion.
- SWI mechanism in real field situation is quite complex and dependent on the sea behaviour. Number of factors and parameters are unknown and significantly different from what one would expect. Therefore, assumption has to be made e.g. sea level fluctuations, high tide, climatic conditions etc. are often not in equilibrium but in SWI studies it is assumed that equilibrium exist (Soni and Pujari, 2012).
- Sea level rise and recharge rate etc. are expected to change with time. Its connection or interrelation with 'intrusion mechanism' is yet to be addressed scientifically.
- Aquifer dynamics tend to be pretty slow and it takes the intrusion cone a long time to adapt to changes in pumping schemes, rainfall, etc.



- Sea water intrusion and climate change are interrelated and this area is not researched at depth hence many queries remain unknown.

Thus, *intrusion mechanism* and *groundwater flow in the coastal area* is interrelated and complicated too because of the relatively minor spatial variation in *groundwater density (sea water Vs fresh water)*. An understanding of variable-density groundwater flow is therefore important in the intrusion studies. Fresh groundwater discharge from landmass (near coast) into the oceanic water body including '*contaminated site remediation*', has a substantial effect on groundwater flow rates and flow patterns as it has relation with pumping, which in turn is related with the building of hydraulic gradient built near the sea. The *cation exchange* process slows the advance of a saltwater intrusion and also slows the retreat of a saltwater intrusion.

5.6 EARLIER STUDIES AND ITS CO-RELATION

'Gujarat coast' is an important coast of India and plays significant role in the country's commercial as well as economical development because it houses number of important industrial units all along (including mines) and some are being added (solar energy industrial unit). Cement plants namely GCW , NCJW, Pipavav Port are some of them. In this section of study an attempt has been made to present the an abridged findings of earlier studies which are related with the NCJW study area has been described so that the reader can co-relates it with the present study. This will benefit to both company and reader. From excavation and exploitation point of view, two important research studies and its findings are covered, Following are the details -

(a) NIO, GOA research study and its findings (NIO, 1997)

About 58% of limestone reserves in the NCM mine lease area fall within 500 m from the shoreline and cannot be mined in accordance with the CRZ Notification promulgated by the Government of India in February 1991. Non-accessibility of mineral deposits within the CRZ has put the long-term expansion plans of NCCL into jeopardy. Hence, NCCL has applied to MOEF for exemption from the CRZ Notification and to permit the mining in the inland adjacent to the shoreline. To justify adequacy of 60 m buffer zone, information with respect to shore stability and prevailing marine environmental quality was required. At that time, the Narmada Cement Company Limited (NCCL) management, contracted NIO, Goa and undertook investigations along the coast of Jafarabad in 1996-97 with the



objectives of evaluating baseline marine environmental quality and establishing erosion trends along the sea cliffs. The assessments has concluded that -

- Sea tides at Jafarabad coast are *semi-diurnal type* and comparable with the predicted tides of Pipavav port located nearby.
- *The MHWS* and MHWN* for the Jafarabad Sea coast area were 3.78m and 2.68 m respectively.*

[means MEAN HIGHER HIGH WATER (MHHW) : A tidal datum that is the average of the highest high water height of each tidal day observed over a specific Metonic cycle (The National Tidal Datum Epoch). For shorter periods of observation, corrections are applied to eliminate known variations and reduce the result to the equivalent of a mean 19-year value ; MEAN HIGH-WATER SPRING (MHWS) The average high-water height at syzygy, recorded over a 19-year or computed equivalent period]*

- Sea currents attain speeds of over 100 cm/s with directions towards west-southwest during ebb and north-northeast during flood. The overall circulation is conducive to active long shore transport of the shore sediment.
- Sea cliffs are made up of well-supported rock with occasional discontinuities and a few fracture zones in the bedded sequence. Such cliffs are relatively stable to failures and toppling due to basal undercutting. Basal under cutting due to erosion of the marl layer appears to be the major cause of failure of these cliffs.
- Comparison of historical and modern day survey maps indicate that the Jafarabad shoreline is fairly stable and major changes have not occurred between 1894 and 1979.
- In the absence of substantial anthropogenic influences, the coastal water of Jafarabad has good water quality, healthy biological status and sediment free from contaminate.

Thus, it was made evident that shoreline is stable and environmentally safe. NIO report stated that in future, the NCM mine can meet out limestone requirement for the production of clinker at their Jafarabad factory, from their mine lease area which is located nearby the *Babarkot, Vararhswarup, Bhakodar, Jafarabad, Vadhera and Mitiyala villages*.

(b) CSIR - CMRI research study and its findings (CMRI, 2007)

In 2007, CSIR - CMRI (now CIMFR) had done sea water intrusion study for the Kovaya limestone mine of Gujarat cement works (GCW) situated on the same Gujarat coast in which Narmada cement limestone mine of NCJW is situated. The study was done for the future planning of the GCW mine. Simulation results



of modelling at the pit depth 0m, - 4m, - 8m and -12m indicated that the intrusion has not reached up to that pit depth.

Modelling study also indicated that as the depth of mining pits increases, the intrusion will extend up to the mining pit in next 10 years (for the pit depth 0m and - 4m) and 12 years (for the pit depth of - 8m and -12m) respectively. For this prediction and simulation, different ground water recharge were considered [as 500 mm/year (0m depth);750 mm/year(-4m depth);1000 mm/year(-8m depth) and 1250 mm/year(-12 m depth)] within the pit area.

It may be noted that at the time of study, the Kovaya mine pits (Pit -1 & Pit 2) were containing huge amount of storage water acting as the recharge pit. Due to the recharge through the mine pits itself the intrusion is kept contained and interface advance towards mainland is restricted. In brief, simulation results at different depth showed that as the depth of pit increases the recharge in the pit also increases, if the stagnant water is present in the pit. Due to increase in recharge the occurrence of intrusion (indicated in the form of 'dry cells' in modelling output) reduces.

These two research studies clearly indicates that the shoreline on which NCJW plant and mine is situated is stable and environmentally safe and excavation of minerals from the 'open **PIT** mine' can be done. As a whole, the mining operation upto a limited and restricted depth, even in CRZ, is feasible without any adverse effect on coastal environment.

5.7 IMPACT OF LIMESTONE MINING

Summarily, it can be inferred that the limestone mining at NCJW has impact on ground water quality, which is evident by high TDS content and water salinity of the area, but since '*current mining*' is being done above the water table such impact can be termed as 'marginal' and 'natural' which occurs in any coastal region. Considering the depth of SWI in the study area, "deepening of mine" may be done further upto a restricted depth, say (-) 04m to (-) 08 m MRL. **Fig. 5.8 (a) to Fig. 5.8 (d)** shows the cross-section of east block pit and north block pit at 0m; -4m ; - 8m and -12m depth (BGL) as derived from modelling. A concentration of 32000 mg/L to 25mg/L (i.e. SWI from coast to land) has moved up to 1.28 Km ; 2.29 km ; 2.59 Km ; 2.65 Km for a simulation period of 20 years at the pit depth of 0m ; (-) 4m ; (-8)m and (-12)m respectively (**Fig. 4.9**).



By creating a 'Safe Zone' and keeping restriction on the ground water abstraction, mining below the ground level will have *manageable impact* on the hydrological regime of Jafarabad area.

5.7.1 Precautions to be taken during mining

An alert and responsible mining with *best management practices* can evolve sustainable development of NCJW mining area. During mining the heavy pumping of water from the pit shall not be done as a precautionary measures. The discussion has clearly stated that the mining has not reached below the ground level hence no question arises for over-draft situation but it may arise in future. When such condition is observed less or no ground water exploitation shall be done.





Fig. 5.8 (a) : Cross-section of east block pit and north block pit at 0m depth

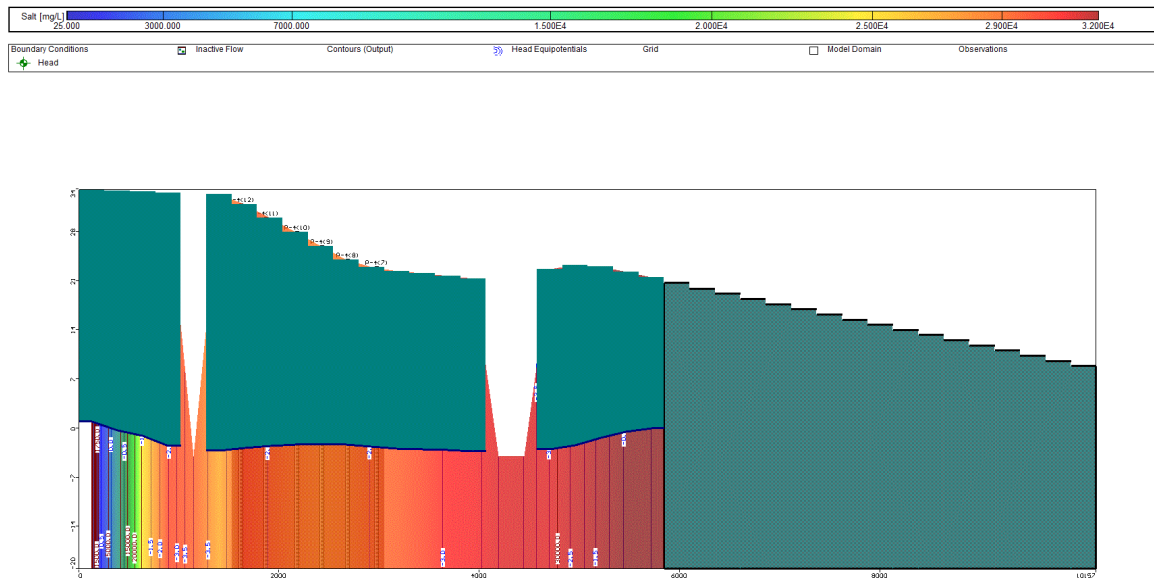


Fig. 5.8 (b): Cross-section of east block pit and north block pit at -4m depth



Fig. 5.8 (c): Cross-section of east block pit and north block pit at - 8m depth

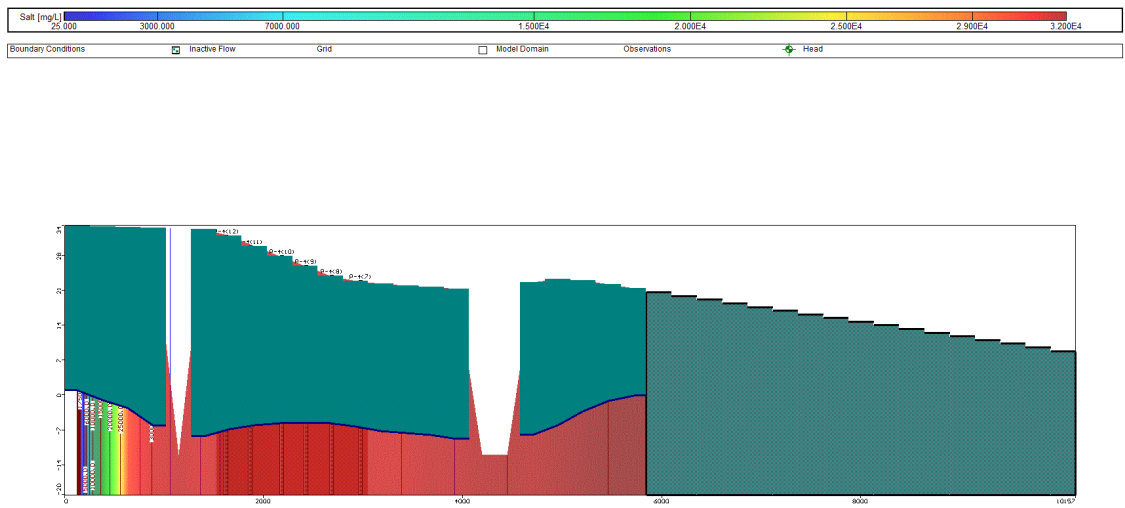


Fig. 5.8 (d): Cross-section of east block pit and north block pit at -12m depth

CHAPTER – 6

SURFACE WATER AND GROUND WATER MANAGEMENT

This study of the *Gujarat Coast*, where the mining area lies, has similar and almost identical characteristic as that of any coastal area worldwide. A review of surface water as well as ground water resources of the *Jafarabad coastal area* clearly indicated that water and its management is not a issue of serious concern.

India has long coastline and ever increasing population trend. Therefore, for the rational groundwater development effective and practical management strategy is essential. Important water structures and water conservation practices in any study area must be judiciously managed to meet the growing water needs. For a particular coastal region its site-specific features should be kept in mind for best and optimum results.

6.1 INTRODUCTION

The physiographic, geologic, topographic and climatic conditions have been taken care naturally by adequate drainage and scientific management of surface water. However, ground water management needs due attention. From the management point of view of ground water, the marshy and saline area, needs management to contain pollution. If required, water management can be done considering different elevation levels of the topography, i.e. below MSL or above MSL, vicinity or closeness of the industrial operation point or the mine lease area and special coastal features such as 'the Jafarabad Creek' in the present study.

The rock formations ranging in age from *Precambrian* to *Recent*, controlling the occurrence and movement of ground water are varied in compositions and structure. The drainage characteristics of the NCJW area is intimately related to the rocks on which the drainage is developed and the precipitation that occurs (less or more).

To prevent intrusion of the seawater into the main land limited groundwater withdrawal is the best possible solution. In the current study area the main water source is the surface water and not the ground water (for industrial purpose)



hence it is a good sign for the aquifer health from 'salinity plume advancement' point of view. Some salient points about water management are therefore briefly described below with a view that it will be noticed by the management of NCJW.

6.2 WATER MANAGEMENT

As evident from CSIR (CIMFR + NEERI) investigation that salinity ingress is taking place in the area and effective water management will pave the way to contain it. Therefore, followings management measures are of immense importance and therefore suggestive.

1. For the present case study augmentation of ground water recharge, through simple and economical means is beneficial in future. This can be implemented -
 - (a) By rain water harvesting in mining pits (direct artificial surface recharge).
 - (b) By creating recharge structure and creating head towards sea for containment of intrusion.
 - (c) By adopting scientific ground water management approach.(Please refer Annexure -II for implementation of these measures in and around NCM pit.)
2. Ground water utilization should be kept limited and its overuse should be avoided. In this context, it may be noted that spread or increase of salinity in coastal areas, is due to the excess draft hence controlling pumping pattern is a effective way of control of intrusion.
3. Effective surface water utilization is the best management practice (BMP) for optimum use of rainfed water resources. One related practice for the surface water is the "desalination of sea water" i.e. conversion of sea water to desalinated water for local miscellaneous uses as well as for permissible industrial applications. *UltraTech Cement Company* has adopted this practice at their Gujarat Cement Works (GCW) which is close to the NCJW. One "Seawater Desalination Plant" for production of 2040 m³/day distillate is functional also (**Annexure - I**). Thus, judicious management of surface water is the key for effective management.
4. Maintaining '**a fresh water ridge**' in the aquifer along the coast by surface spreading for unconfined aquifer (or by recharge wells for confined aquifers) is a method to control intrusion (Todd, 1974). .



5. Development of an '**extraction type sea water barrier**' (Fig. 6.1). This can be done by preparing a line of wells adjacent to the ocean and continuously pumping through the line wells will move both fresh water and sea water into the trough and keep the intrusion contained upto the created trough only.
6. Enhancing awareness about ground water conservation and management. of ground water. This can be done by **advocating training** and through rainwater conservation method also, considering water as valuable commodity for future generations.
7. Extension of sea water interface into mainland can also be restricted / averted by '**impermeable surface barriers**'. Construction of a barrier could be achieved using cost effective methods e.g. sheet piling, clay, emulsified asphalt, cement grout, bentonite, calcium acrylate or plastic. (Fig. 6.1).
8. To control SWI, **combination of injection-extraction barrier** can be adopted which is a combination of pumping in and out of the trough created near the sea (Fig. 6.1). This method is a costly method in which no of wells required are doubled (Todd, 1974).



Fig. 6.1: A barrier between sea and mining area for SWI management
(A 'fresh water ridge' by extraction of ground water through line of wells)

or construction of 'impermeable surface' can be maintained by such barrier)

9. It is made compulsory and essential to install 'Piezometer' in all the coastal aquifers permanently and monitoring be carried out for key parameters like water level, electrical conductivity of ground, sodium (Na), chloride (Cl) and bi-carbonate (HCO_3) content of ground water etc. A long-term monitoring plan of these parameters would be useful for better water management and evaluation.

The management measures and suggestions given above include new measures in addition to the conventional methods of water conservation. Their selection and implementation for a particular site will depend on the cost - economics involved because some of them are quite costly methods.

6.3 STATUARY COMPLIANCE

In many countries, there are restrictions posed by the government to install industries closer to the coastal areas e.g. In India such restrictions exist in the form of Coastal Regulation Zones (CRZ). Near coast, various categories of zones exists e.g. CRZ I,II,III etc. which have designated management norms (DTE, 2008 & 2010) and Coastal Zone Management (CZM) principles, which are adopted to manage such type areas. As per CRZ, the restricted distance for any economic activity is 500m from the sea coast. Sometimes, the statutory compliance of such restrictions is not evaluated technically and thereby mismatches with the field conditions occurs. Thus, evaluated technical results are not in consonance. This poses implementation difficulty hence, alongwith statutory compliance the technical issues should be addressed in such a way that the *law of the land* should be adhered to. It is noted that economic, social and political issues of coastal area management dominates over technical and environmental issues and adequate groundwater development is not given due consideration. This needs attention, adequately from water management view point.

Water is a valuable and constantly depleting (yet renewable) natural resource which require steps for its conservation too. By adopting water management tips as described above mining operation at NCJW will be more environmentally sustainable. Since, surface water and ground water management is an essential component of mine planning to keep the quarry bottom dry, real field data and experience of mine operator and investigator is extremely important. To



summarize, it can be said that proper management of water and proper drainage system, based on engineering judgment, can make the mining operation smooth and uninterrupted.

6.4 NCJW EFFORTS TOWARDS WATER MANAGEMENT

The farsighted efforts undertaken by the NCJW in its mining leases, plant and housing colony are praiseworthy and needs to be mentioned as these has started yielding results for a sustainable management of water (**Annexure - II**). As written earlier also such measures has a far reaching consequences in enhancing the water regime in the region in terms of both quantity and quality. Various sustainability measures which include conservation of rain water through rain water harvesting and roof top water harvesting system, restricting surface runoff to sea, artificial recharge, and mass scale plantation under reclamation and rehabilitation programme in moderating the water quality by diminishing the salinity of the ground water and making it suitable for domestic consumption (Annexure- - II). The TDS level of the water reduced remarkably from 2000 mg/L in year 2004 down to the range of 1200-1500 mg/L in current years. Water quality has improved in neighbourhood wells mainly due to rainwater storage / Water harvesting & ground water recharge in Mined out pits. Sweet water is available at shallow depth for a prolonged period of time whereas the situation was not so favourable before undertaking the sustainability measures by the Narmada Cements Ltd. The Industry is continuing its effort for the socio-economic upliftment of the inhabitants in years to come.



CHAPTER – 7

CONCLUSIONS AND RECOMMENDATIONS

Sea water or salt water intrusion (SWI) could be determined in two ways - (a) at regional scale (b) at local scale. In this study, SWI and its analysis has been done at local level for a mining area. Followings are the conclusion and recommendations of this Sea water intrusion (SWI) and the aquifer investigation of the Jafarabad area where NCJW mining area is located.

7.1 CONCLUSIONS

- 1) Based on the *Resistivity Survey, Water Quality Analysis and the Ground Water Modelling (SEAWAT-2000)* it is concluded that the sea water intrusion (SWI) or salinity ingress is extended in the study area. At *Narmada Cement's Open Cast Limestone Mine* it is present at depth more than the planned mining depth.

It is found that though there is progress of salinity ingress in this coastal region, which is a natural phenomenon occurring in any coastal environment globally but the progress is very steady. Probably the concerted efforts of the UltraTech Cement Ltd. and mine management through artificial recharge, water harvesting and sustainable water conservation measures adopted since the inception is the reason for this trend.

- 2) The groundwater quality analysis results of the study area have shown very high values of TDS, chloride (Cl) and sodium (Na), which may be linked to possible seawater intrusion (**Table 3.4**). TDS values of water more than 2000 mg/L is considered as *CONFIRMED* sea water intrusion. (*Arabian Sea* water is having TDS of the order of 32,000 mg/L) whereas TDS more than 1500 mg/L TDS value is eyed as *POSSIBLE* sea water intrusion in that locality. This possibility is confirmed through geophysical investigations (resistivity image profiling). The resistivity survey has indicated zones or patches of low resistivity (0-3 ohm-m) values at various locations in the study area (**Table 3.6**). These are present at varying depths as given in table below.



Profile No.	Total imaging Depth (m)	Sea Water Intrusion Depth (m)		Inference Drawn (Safe/vulnerable)
		Confirm (Very Low)	Possible (Low & Intermediate)	
JERT 1	39.4	33 -39.4	39.4	Safe
JERT 2	39.4	34 - 39.4	39.4	Safe
JERT 3	39.4	-Not Present -	39.4	Safe
JERT 4	78.8	24 - 39	78.8	Safe
JERT 5	23.6	-Not Present -	07-23.6	Safe
JERT 6	39.4	03-39.4	03-39.4	Vulnerable
JERT 7	47.3	40	47.3	Safe
JERT 8	23.6	-Not Present-	23.6	Safe
JERT 9	78.8	24 -78.8	24	Vulnerable

- 3) The ratio of Chloride : Bicarbonate of more than 01 value has been observed, which indicate the presence of sea water intrusion.
- 4) The shoreline on which NCJW plant and mine situated is stable and environmentally safe and excavation of minerals from the 'open **PIT** mine' can be done. As a whole, the mining operation up to a limited depth is feasible.
- 5) The extent of seawater intrusion in the study area (that includes lease area as well) has been judged and concluded on the basis of 'Ground water modelling' and 'Simulation results both at present and at future scenario'. The modelling results clearly indicated that salt water intrusion (**interface line**) has extended up to **1.28 - 1.29 Km (at 0m pit RL)** inside the coastline and towards mainland (**Fig. 4.7 & Fig. 4.8**).
- 6) NCJW mining pits will have vulnerability from the SWI now and in future also i.e. 2017 and beyond. The 'Visual Modflow / SEWAT-2000' model was run for two time periods (5 years and 20 years) to assess the salinity ingress into the mainland in coming years (**Fig. 4.8 & Fig. 4.9**).

From the 'predictive modelling', it is analyzed that the SWI from coast to land (salt concentration of 32000 mg/L to 25mg/L) will move up to 1.28 Km ; 2.29 km ; 2.59 Km ; 2.65 Km for a simulation period of 20 years at the pit depth of 0m ; (-) 4m ; (-8)m and (-12)m respectively (**Fig. 4.9**). Hence, it can be concluded that salinity ingress will occur when the mining depth is increased. Such plume movement to an increasing distance can be attributed to the enlargement of hydraulic gradient as per the fundamental laws of ground water movement.



- 7) It is estimated that the water table lies in the range of **14.00 m to 17.0 m** (approximately) in the core zone i.e. near the mine lease area and around the *Babarkot* village. Average depth of water table (DWT) in the dug wells of study area has recorded variations from place to place.
- 8) Water level fluctuations (WLF) in the study region lies in the range of 0.15m to 9.87m BGL (**Fig. 4.6**) The depth to water level varies from 1.0 m to 21.36 m (BGL) in the pre-monsoon period (May, 2017) and varies from 0.35 m to 20.26 m (BGL) in the post-monsoon period (November, 2016). Average flow of ground water is towards the seacoast.
- 9) It is concluded that mining in future (i.e. with deepening of mine further and expansion of mine production) can be done up to (-) 08 m MRL safely and conveniently because 'intrusion zone' lies at a depth of more than 20m - 22m below ground level (observation of ERT results). Cross-section of pits at different pit depth (Chapter 5) and ERT analysis of SWI (Chapter 3) clearly concludes that mining is feasible and safe.
- 10) 'Water management' measures at NCJW are playing positive role in SWI containment. With increase in depth of mine, mining will be safe from ground water pollution angle as SWI is a natural phenomenon and bound to occur in any coastal area. The simulation results and resistivity survey can be used to plan the mine in future whose details are described in various chapters of this technical document (Chapter 3, 4 & 5).
- 11) Geological condition of NCJW aquifer (miliolitic limestone) permits the transmission of ground water as it has presence of secondary porosity. Mixing of ground water and sea water is taking place in the study area causing brackishness of water.
- 12) It is concluded that 'Seawater - freshwater interface' can be kept controlled by augmenting water management measures such as less ground water draft and by maintaining adequate ground water recharge. Such measures are in place at NCJW and giving effective results also (**Annexure - II**)
- 13) The ground water draft should be maintained as low as possible to avoid or restrain the formation of hydraulic gradient towards mainland. Status quo of the 'safe ground water development zone' (**Fig. 5.6**), as per CGWB norms shall be maintained by the company.



CIMFR has concluded that 'pit mining' at Narmada cement for limestone extraction can be done easily. For continuing mining in a 'pit form' following important concluding points should be kept in mind as they are key as well as essential points for smooth mine operation.

- Dynamic nature of sea and location of mine in immediate proximity of shore line has a pivotal role in intrusion mechanism /SWI and salinity ingress is occurring in the study area as a natural phenomenon because of its location.
- Sea and *mining* both are the dynamic entities. Ground water flow mechanism in coastal aquifer and very near to the shore line differs greatly from the mainland whether it is a unconfined or semi-confined aquifer. The density-dependent ground water flow mechanism is affected by the high tide lines of sea.
- Narmada cement mine and its host rocks are limestone which is a sedimentary formation with adequate porosity for ground water flow. Such formations causes continuous dissolution of calcium in water causing higher TDS concentration of water throughout the year. Because of *continuous dissolution* taking place at both shallow and deep levels such formation's TDS levels of water are always high irrespective of the corrective measures.
- The consumption of ground water in the study area and in mine is not very high because of brackishness of ground water.

7.2 RECOMMENDATIONS

- ◆ In view of presence of SWI it is recommended that caution be exercised while continuing mining operation at depth below ground level. However, mining at restricted depth, up to the depth range of (-) 4m to (-) 8m RL, will be safe depending on the practical conditions encountered.
- ◆ Seawater should be prevented from intruding into the mainland as far as possible by adopting 'intrusion control measures' as described in this report. Sea water can also be contained naturally by maintaining a head of fresh water above the seawater.



- ◆ In the study area, both deep and shallow coastal aquifers should be protected. It is recommended to make use of scientific principle only for restricting ground water pollution.
- ◆ It is recommended that recharging of the aquifer must be done to the maximum possible extent. Two recommended recharge structures for the study area are either through '*mined out pits*' or through '*dug out depression area*' of topography as they can be made in the lease area or in the surroundings at a nominal expenditure. Surface water storage should be encouraged in NCJW premises.
- ◆ Piezometer, should be installed around the mining pits (i.e. near to operational East Pit and North Pit). Entire lease area shall be covered with such installations. Those old piezometers which are non-functional be made functional. Periodical monitoring of Total Dissolved Solid (TDS), Sodium and Chloride concentration in ground water is recommended for measurement in all season of the year.



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ANNEXURES



DESALINATION PLANT OF GCW

(Source: Kharkar, 2006)

The utilization of waste heat has been practiced in cement works for many years. However, the clinker cooler exhaust air is being used for the first time in India to generate steam for a “*Seawater Desalination Plant*”. The plant installed at the Gujarat Cement Works (GCW) contributes to the production of 2040 m³/day rated capacity of distillate. Hot exhaust air from the clinker cooler at about 270°C is cooled to about 170°C in a ‘Waste Heat Recovery Steam Generator (WHRSG)’. The WHRSG is an unfired boiler by using the waste heat from the exhaust air from clinker cooler ESP, instead of using an oil-fired package boiler. The plant is in operation from last one decade and contributes to the production of water in an area in which water is a precious commodity.

The process used in the 'Desalination Unit' is *multiple effect distillation under vacuum*. Energy in the form of live steam of WHRSG is supplied to the unit. The unit has four evaporators and one condenser. The seawater is sprayed in the evaporators outside the tubes of heat exchanger. The vapours generated in the first evaporator are forwarded to second stage. These vapours go to the next stage and the cycle continues. Part of low temperature saturated vapours from condenser zone recycled to cell-1 with live WHRSG steam through internal eject thermo compressor.

The 'desalination plant' requires 14 ton / hour steam at 7 bar gauge pressure. This steam requirement is fulfilled by using ‘WHRSG’, operated on cooler exhaust air. No fuel is required to be fired and hence no additional stacks will be required. The exhaust air from the unfired boiler will be let out through the existing cooler ESP stack.

The thermal design of the WHRSG are carried out in accordance with the process conditions. Tube selection, its thickness, the pitch, inclination and the erosion of the tubes and the flow direction of the gas through the WHRSG is taken into account scientifically. To minimize the deposit of dust on the tubes 'Soot blowers' are provided to remove dust particles from the heat transfer surfaces. Thus, this 'desalination plant' is an excellent example of the art of waste heat recovery from clinker cooler hot air and its re-utilisation.



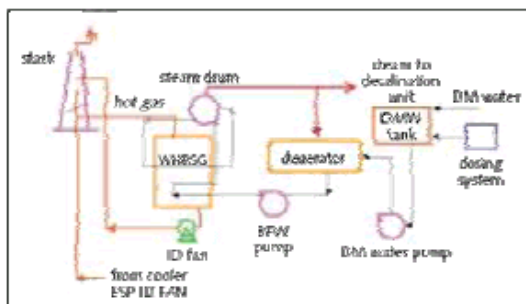


Fig. 1 Flow chart of WHRSG & Gas Path



Fig. 2 View of WHRSG after cooler ESP

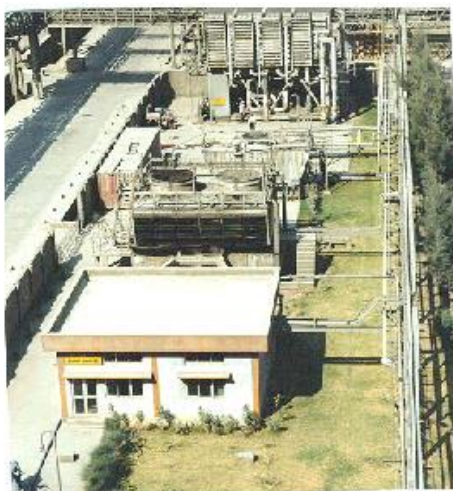


Fig. View of Seawater Desalination Plant

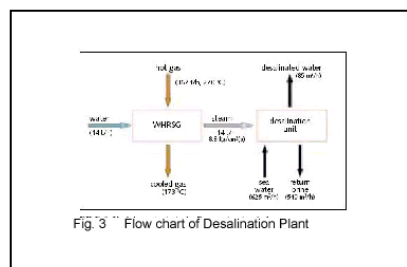


Fig. 3 Flow chart of Desalination Plant

Concentrated seawater is called as '*Brine*' and the production water (generated by the various stage condensation) is called *distillate*. The rejected seawater and brine (concentrated water after desalination) is pumped back to sea after cooling and processing. Desalination unit requires 600-700 M³/hrs raw seawater.

As per the design parameters of the desalination unit, the capacity of the unit is 2040 M³/Day (Type - 4 'T' MED) and it is made by M/s SIDEM, France. This plant had achieved 2421 m³ highest production in a day. However, the highest production of one month was recorded as 60,466 M³ approximately.



Sustainable Water Management & Conservation By Narmada Cements - Jafarabad Works (NCJW), UltraTech Cement Ltd

Jafarabad area in coastal belt of Saurashtra is a vulnerable tract in that it has a very low precipitation and salt laden saline winds of high velocity. Its proximity to sea, further aggravates the situation. In such areas, ecological considerations demand for the optimal conservation of water and a balanced pattern of utilization consistent with the long term requirements. Keeping this in mind, the *Narmada Cement* management in addition to the commercial interest has extended its all-out support for the socio-economic upliftment of the inhabitants of the region and has taken steps towards conservation and judicious use of fresh water (surface as well as underground).

The area is situated adjacent to the shore of Arabian Sea, in the semi-arid climatic condition, and is drought prone due to scanty average rainfall. There exist a wide demand and supply gap of fresh water for domestic consumption. Hence, need for ground water recharge is felt. Under this back drop, NCJW (UltraTech Cement Limited) has established scientific and systematic water management system to reduce the saline water ingress by improving the water balance aiming at reviving these local drinking water sources and to ensure sustainability. The main focus is on qualitative and quantitative sustainability of the local sources by the transfer of surface water through various interventions to sub-surface aquifers.

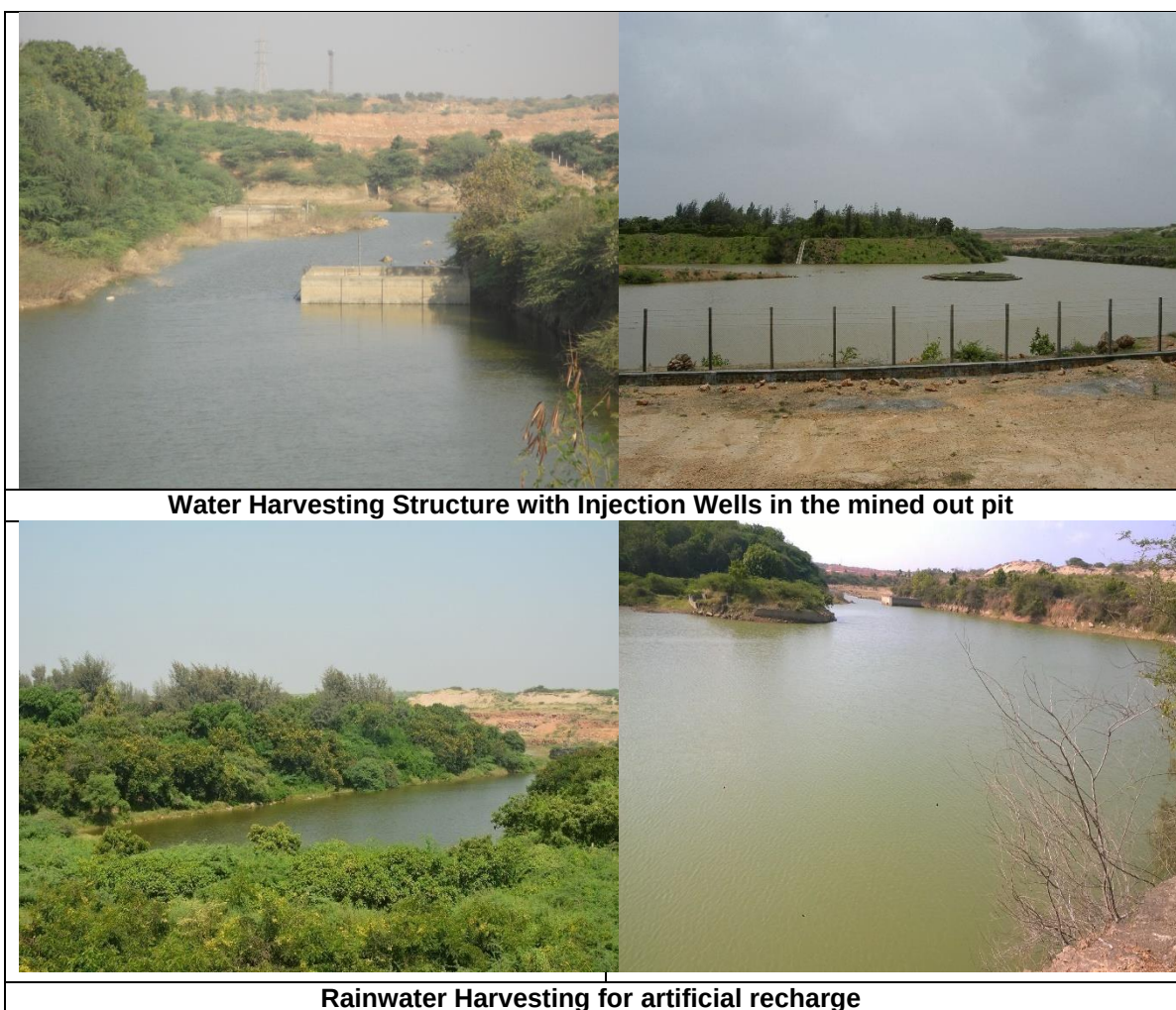
Water resources management is mainly through rain water harvesting, monitoring of ground water withdrawal and supply by incorporation of measurement devices in the plant and mines premises, data recording and optimising the water usages, ground water recharging through recharge wells and mined out pits. Water quality and quantity assessment is being carried at the various points by periodical sampling and analysis. By establishing Piezometer network in mines and surrounding area the ground water table fluctuation and quality is monitored. All possible measures are adopted to reduce salinity ingress and conservation of sweet water in this water scarce region.

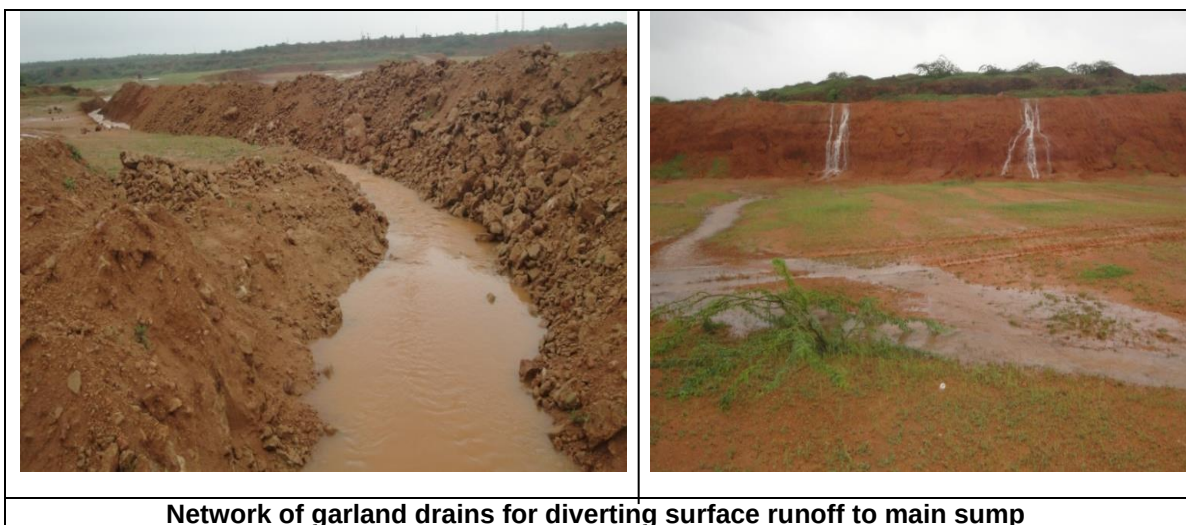
Water Harvesting

Rain Water Harvesting (RWH) is done in Mine Sump created in completely mined-out area of 6.50 ha. In North Block pit; having water holding capacity of 6.50 Lakhs m³ which holds water throughout the year, and in East Block pit of the lease mined out area hold the recharge water during the monsoon. A network of drains / garland drains, culverts and earthen check bunds have been made to guide surface run-off to this artificial lake, thus preventing this water from flowing into the sea. Water from this lake is used for consumption in clinker plant and for raising plantation.



Water harvesting activities are also taken up in surrounding villages in the buffer zone of the lease area in *Mitiyala, Kagwadar, Balana, Balanivav, and Nana Sakariya* etc. The recharge from Rain Water Harvesting structure aids to an increase in water level and adds higher sweetness to water during the pre and post monsoon seasons in the locality by creating a barrier between fresh water and saline water zones. In spite of the effort to recharge fresh water, the sweet water level and the barrier effect between fresh-water and saline-water is affected with the annual rainfall. The harvesting structure aids in reducing the TDS level as well as also helps in restoring the local water table and reduces the pressure on ground water salinity ingress of surrounding areas considerably over the years. The combined network system of RWH and ground water recharging enhance sweet water level in the wells of surrounding villages indirectly reducing overall suction pressure on the wells and deep bore wells thereby minimising the sub-surface intrusion of oceanic water underground.





Network of garland drains for diverting surface runoff to main sump

Source : UltraTech Cement Ltd

The practised measures has improved the availability and quality of water for domestic consumption in both the residential colony and plant.



Rain Water Harvesting at Colony

Ground water Recharge in the Colony

Source : UltraTech Cement Ltd

Sustainable water management in buffer zone

In addition to the RWH, efforts for optimum conservation of water in the mining pits and rain water harvesting ponds, the UltraTech management under its CSR (corporate social responsibility) activity has undertaken significant work for water conservation and drinking water supply to the nearby villages (pl. see photo below).

At the time of commissioning of the Jafarabad Plant in late seventies, the lease area and surroundings was completely barren and devoid of vegetation. In particular the conditions were not favourable for plant growth due to the conditions, namely - high velocity saline winds from sea, constant shifting of sand by the wind currents, poor quality of soil in the area and scarcity of potable water. All these added up seemingly insurmountable unfavourable conditions were faced with challenges and UltraTech undertook extensive plantation in this area.





Reclamation of mined out area

The mined out pits, the statutory boundary along the lease and other vacant places are covered under reclamation & backfilling by using overburden and then spreading top soil (black cotton soil extracted during mining) over this area. Large-scale plantation has been carried out over the years. The task of plantation & taking complete aftercare has resulted in regeneration of barren land and more than 2.0 lakh trees are surviving as off now. The adverse effect of saline winds is reduced to great extent by the vegetation growth. The binding of soil and sand is becoming better and firm to support vegetation and retaining water for underground recharge.



PROJECT PARTICULARS

(Part – I & II)

Salient details

PART – I

1.	Project Title	Salinity Ingress Study With Special Reference to Hydro-Geological Regime in and around Narmada Cement-Jafarabad Works (NCJW) , UltraTech Cement Limited, Village-Babarkot, Taluka-Jafarabad, District - Amreli (Gujarat)
2.	Sponsoring Agency	ULTRATECH CEMENT LIMITED (A Private Limited Company Owned by Aditya Birla Group)
3.	Date of Commencement	• August, 2016
4.	Scheduled date of Completion	• September, 2017
5.	Status	Completed as per Schedule
6.	Objectives (Allotted to CMRI for Investigation)	a. Salinity Ingress and geo-hydrological study with respect to interference of ground water table. (Variation of Salinity) b. Impact of mining on groundwater quality and effect of salinity. c. Predictive assessment through ground water modelling. d. Ameliorative measures to combat adverse impact of mining on GW quality.
7.	Performance / Work Evaluation (Remark to be filled by sponsoring agency)	☐ Satisfactorily ☐ Not satisfactorily (Tick one box only)
8.	Report Details	Text Pages = 120 ; Tables = 22 ;Figures = 46; Annexure = 02
Signature (with date and seal of Institution)		
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PART – II

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