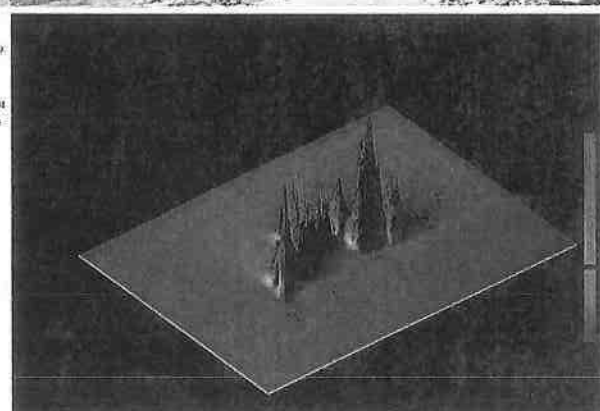
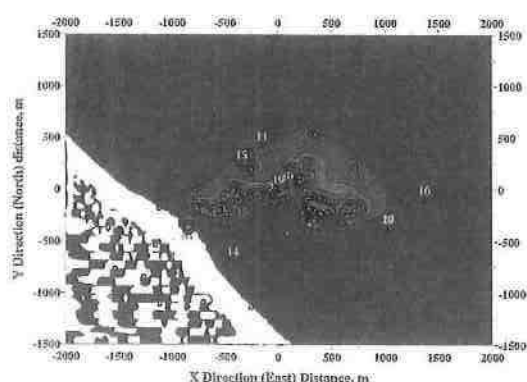




FINAL REPORT

Assessment of Dust Emissions from Stone Crushing Industry in Trisoolam Area, Tamil Nadu



for
Tamil Nadu Pollution Control Board



**National Environmental Engineering
Research Institute
Nagpur - 440 020**

March 2007



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FOREWORD

Stone crushers are small scale industries in the unorganized sector. They provide the basic material for road and building construction. They are highly labour intensive, where most of the operations are performed manually. The various unit operations involved in stone crushing namely size reduction, size classification and transfer operation have the potential to emit process and fugitive dust.

There are about 2000 units reported to be operating with low capital investment in the state of Tamil Nadu of which about 1800 units are located in residential areas. Many such stone crushing operations tend to be located relatively near populated areas to avoid transportation costs. This can result in dust associated health problems. The large number of stone crushers distributed all over Tamil Nadu, pose the problem of high levels of dust generation in the vicinity of the crushers and on the communities surrounding them during various operations of crushing.

With the sponsorship from the Tamil Nadu Pollution Control Board (TNPCB), NEERI undertook a detailed study at Pammal and Alathur Gate in 1997 and 1998 to assess the dust emissions and suggest possible measures for controlling the air pollution problems in these areas. In continuation of the good work done by NEERI, Chennai, in this direction, TNPCB, Chennai, approached NEERI, Chennai, once again in 2005 to submit a detailed report on the assessment of dust concentration at Trisoolam village near Chennai city.

With the support of the Tamil Nadu Pollution Control Board, the National Productivity Council has demonstrated a suitable dust suppression and containment system for stone crusher units. Most of the crusher units in Tamil Nadu have adopted the NPC system and hence the TNPCB approached NEERI to evaluate the adequacy of the pollution control measures and to establish siting criteria for stone crushers with respect to their distance from residential areas. The findings of NEERI are presented in this report.

The cooperation and assistance of the crusher owners at Trisoolam is gratefully acknowledged. Our sincere thanks are also due to the Tamil Nadu Pollution Control Board for sponsoring this work.

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LIST OF SYMBOLS & ABBREVIATIONS

mg	Milligram
µg	Microgram
AAQM	Ambient Air Quality Monitoring
AERMOD	AMS/EPA Regulatory Model
am	Fore Noon
AMS	American Meteorology Society
CPCB	Central Pollution Control Board
d	Index of Agreement
EPA	Environmental Protection Agency
FDM	Fugitive Dust Model
ISCDM	Industrial Source Complex Dispersion Model
ISCST3	Industrial Source Complex Short Term Model (Version 3)
Kg	Kilogram
m ³	Cubic Meter
MSE	Mean Square Error
MT	Metric Tonnes
NAAQS	National Ambient Air Quality Standard
O	Mean
O _i	Observed Concentration
P _i	Predicted Values
pm	After Noon
PM ₁₀	Particulate matter less than 10 micron
PM _{2.5}	Particulate matter less than 2.5 micron
RMSE	Root Mean Square Error
RPM	Respirable Particulate Matter
RSPM	Respirable Suspended Particulate Matter
SCU	Stone Crushing Unit
TSPM	Total Suspended Particulate Matter
γ	Correlation Coefficient



EXECUTIVE SUMMARY

1.0 Introduction

Stone crushers are small scale industries with low capital investment (varying between Rs. 5 to 10 lakhs). Stone crushing in India is basically a labour intensive operation where the loading of stone into the crusher, conveying the product materials from separating screens, loading and unloading operations are performed manually. The production capacity of stone crushers varies from 30 - 300 MT/day.)

There are about 2000 units reported to be operating with low capital investment in the state of Tamilnadu of which about 1800 units are located in residential areas. Many such stone crushing operations tend to be located relatively near populated areas to avoid transportation costs. This can result in dust associated health problems. The large number of stone crushers distributed all over Tamilnadu, pose the problem of high levels of dust generation in the vicinity of the crushers and on the communities surrounding them during various operations of crushing.

With the sponsorship from the Tamil Nadu Pollution Control Board (TNPCB), NEERI undertook a detailed study at Pammal and Alathur Gate in 1997 and 1998 to assess the dust emissions and suggest possible measures for controlling the air pollution problems in these areas. In continuation of the good work done by NEERI, Chennai, in this direction, TNPCB, Chennai approached NEERI, Chennai, once again in 2005 to submit a detailed report on the assessment of dust concentration at Trisoolam village near Chennai city.

1.1 Objective of the study

The objective of this study is to assess the dust concentration and its fallout in and around the work place and the delineation of control measures to arrest the dust to permissible limits.)

1.2 Study Area

The study area at Trisoolam is located at a distance of 20 km to the southwest of Chennai City. There are 72 crushers located west of a quarry. On the basis of a reconnaissance in the first week of May 2005, 10 stone crushing units were chosen for source sampling and 7 locations for ambient air quality monitoring. The ambient air quality locations were selected on the basis of the prevailing wind direction and speed and also giving due



consideration to the historical wind rose for Chennai city (1969 - 2001). In Trisoolam area, there are 72 crushing units where particulate sampling was carried out during June 24 - July 16, July 27 - August 5, 2005, both at source and in the ambient air. During the study each crusher was operating at a crushing capacity of 60 MT/day. The parameters studied were TSPM, RSPM and cyclone dust at the source and in ambient air.

The only pollutant emission of concern from stone crushing is particulate matter. Emission points for dust release from stone crushing typically include, loading of trucks, truck travel on dusty roads, fugitive dust loss from trucks, dumping into crusher, crushing, screening, transfer points on conveyor system, loading onto storage piles from conveyors, the wind blowing dust from storage piles and conveyors.

(The study was conducted in six phases: 1. with all the crushers running, 2. with half of the crushers running, 3. with quarter of the crushers running, 4. with 1/8 of the crushers running, 5. with only one crusher running and 6. With no crusher running to account for the background emissions.)

2.0 Micro-meteorological observations

The wind direction and wind speed recorded on hourly basis during the study period indicated that the dominant wind directions were from South West (19%), followed by the West (18.5%), West of South West (14%). The most prevalent wind speed was in the range of 5 - 10 kmph (25%) followed by 10 - 15 kmph (15%). The calm condition was observed only 0.52% of the time. The average wind speed observed during the above period was 16.9 kmph.

3.0 Sampling programme and results

3.1 Sampling with all the crushers in operation

All the crushers were operated during the period June 24 - 30, July 15 - 17 and July 28 - August 5, 2005 for 16 days continuously. Ambient air quality monitoring network consisting of 17 locations were identified based on prevailing wind pattern, stone crusher location and their geometry. Out of 72 stone crushing units in the locality, source dust monitoring was carried out at 10 stone crushing units. 10 air samplers were employed at source (TSPM 8, RSPM 2) and seven in ambient air (TSPM 4, RSPM 3).

3.1.1 Weather monitoring

The 24 hours wind rose shows that the dominant wind directions were from southwest (22%), followed by the West (21.5%) and West of South West (12.5%). The most



prevalent wind speed was in the range of 5 - 10 kmph (28%) followed by 10 - 15 (13.5%) kmph. The calm condition was observed 0.71% of the time. The average wind speed observed during the above period was 8.4 kmph.

3.1.2 Dust monitoring

3.1.2.1 Dust concentration at source

Out of 10 source air quality monitoring stations, eight (6 TSPM, 2 RSPM) were chosen in the upwind direction and two (2 TSPM) in the downwind direction. The average concentration of TSPM in the upwind direction varied from 1268 to 4108 $\mu\text{g}/\text{m}^3$ with a mean of 2630 $\mu\text{g}/\text{m}^3$. The average concentration of RSPM in the upwind direction varied from 274 to 654 $\mu\text{g}/\text{m}^3$ with a mean of 464 $\mu\text{g}/\text{m}^3$. The average concentration of TSPM in the downwind direction varied from 1754 to 3747 $\mu\text{g}/\text{m}^3$ with a mean of 2751 $\mu\text{g}/\text{m}^3$.

The overall source concentrations of TSPM varied from 1268 to 4108 with a mean of 2759 $\mu\text{g}/\text{m}^3$. The TSPM concentration at all locations exceeded the standard of 600 $\mu\text{g}/\text{m}^3$ at source at a distance of 3 - 10 m as recommended by CPCB. At all the locations, RSPM concentrations exceeded the standard of 100 $\mu\text{g}/\text{m}^3$. Among the 10 stations, the highest TSPM concentration was found at Ratna BM (4108 $\mu\text{g}/\text{m}^3$) and JR Nirmala BM (654 $\mu\text{g}/\text{m}^3$) whereas the highest RSPM concentration was found at Suguna BM (274 $\mu\text{g}/\text{m}^3$) respectively.

3.1.2.2 Dust concentration around stone crushing units

The average concentration of TSPM in the upwind direction varied from 65 to 152 $\mu\text{g}/\text{m}^3$, with a mean of 114 $\mu\text{g}/\text{m}^3$. The average concentration of RSPM in the upwind direction was 417 $\mu\text{g}/\text{m}^3$. The average concentration of RSPM in the downwind direction varied from 81 to 200 $\mu\text{g}/\text{m}^3$ with a mean of 165 $\mu\text{g}/\text{m}^3$. The average concentration in ambient air was very high in the downwind direction when compared to the upwind direction, of the order of 3 - 4 for TSPM and 1.5 for RSPM.

The overall concentrations of TSPM varied from 64 to 417 $\mu\text{g}/\text{m}^3$ with a mean of 190 $\mu\text{g}/\text{m}^3$. The TSPM concentration at Trisoolam-1 (417 $\mu\text{g}/\text{m}^3$) exceeded the standard of 200 $\mu\text{g}/\text{m}^3$ recommended by the CPCB. In other locations, the measured TSPM concentrations were within the permissible limits. The overall concentrations of RSPM varied from 81 to 200 with a mean of 149 $\mu\text{g}/\text{m}^3$. The RSPM concentrations at Trisoolam-2 (200 $\mu\text{g}/\text{m}^3$) and Kennedy Nagar (165 $\mu\text{g}/\text{m}^3$) exceeded the standard of 100 $\mu\text{g}/\text{m}^3$ recommended by the CPCB.



3.2 Sampling with half of the crushers in operation

Half of the Crushers (35) were operated during the period July 1 - 8, 2005 for 7 days continuously. For half of the stone crushers in operation, source dust monitoring was carried out at 10 locations of which 3 were employed at source (TSPM 3) and seven in ambient air (TSPM 4, RSPM 3).

3.2.1 Weather monitoring

The 24 hours wind rose shows that the dominant wind directions were from southwest (22%), followed by the West of South West (20.5%), West (18%), South of South East (14%) and South (10%). The most prevalent wind speed was in the range of 5 - 10 kmph (33.5%) followed by 10 - 15 kmph (21%) with no calm condition. The average wind speed observed during the above period was 7.8 kmph.

3.2.2 Dust monitoring

3.2.2.1 Dust concentration at source

Out of 3 source air quality monitoring stations, two (2 TSPM) were chosen in the upwind direction and one (1 TSPM) in the downwind direction. The average concentration of TSPM in the upwind direction varied from 2050 to 3071 $\mu\text{g}/\text{m}^3$ with a mean of 2560 $\mu\text{g}/\text{m}^3$. The average concentration of TSPM in the downwind direction was 1754 $\mu\text{g}/\text{m}^3$. The overall concentrations of TSPM varied from 1691 to 3735 $\mu\text{g}/\text{m}^3$ with a mean of 2796 $\mu\text{g}/\text{m}^3$. The highest TSPM average concentrations were found at Subalaxmi BM (3735 $\mu\text{g}/\text{m}^3$). The TSPM concentration at all locations exceeded the standard of 600 $\mu\text{g}/\text{m}^3$ at source.

3.2.2.2 Dust concentration around stone crushing units

The average concentration of TSPM in the upwind direction varied from 126 to 166 $\mu\text{g}/\text{m}^3$ with a mean of 150 $\mu\text{g}/\text{m}^3$. The average concentration of RSPM in the upwind direction was 250 $\mu\text{g}/\text{m}^3$. The average concentration of TSPM in the downwind direction was 521 $\mu\text{g}/\text{m}^3$. The average concentration of RSPM in the downwind direction varied from 56 - 155 $\mu\text{g}/\text{m}^3$ with a mean of 250 $\mu\text{g}/\text{m}^3$. The highest average concentration in ambient air was very high in the downwind direction when compared to the upwind direction, of the order of 2 to 3 for TSPM and 2 to 3 for RSPM. The overall concentrations of TSPM varied from 88 to 346 $\mu\text{g}/\text{m}^3$ with a mean of 189 $\mu\text{g}/\text{m}^3$. The average TSPM concentration at Trisoolam 1 (346 $\mu\text{g}/\text{m}^3$) exceeded the standard of 200 $\mu\text{g}/\text{m}^3$ recommended by the CPCB. In other locations, the measured TSPM concentrations were within the permissible limits. The average concentrations of RSPM varied from 56 to 250 $\mu\text{g}/\text{m}^3$ with a mean of 54 $\mu\text{g}/\text{m}^3$. The average



concentrations of RSPM at Trisoolam 2 and Kennedy Nagar exceeded the standard of $100 \mu\text{g}/\text{m}^3$ recommended by the CPCB.

3.3 Sampling with $1/4^{\text{th}}$ of the crushers in operation

During the period July 1 - 8, 2005, for about 7 days, $1/4^{\text{th}}$ of the crushers were operated (18) continuously. For $1/4^{\text{th}}$ of the stone crushers in operation, source dust monitoring was carried out at 3 stone crushing units of which 3 were employed at source (TSPM 3) and seven were in ambient air (TSPM 5, RSPM 2).

3.3.1 Weather monitoring

The 24 hours wind rose shows that the dominant wind directions were West of South West (14.5%), followed by the South East (11%), East (10%), South of South East (9.5%) and West (10%). The most prevalent wind speed was in the range of 5 - 10 kmph (22%) followed by 10 - 15 (12%) kmph. The calm condition was observed for about 0.6% of the time. The average wind speed observed during the above period was 12 kmph.

3.3.2 Dust monitoring

3.3.2.1 Dust concentration at source

The average concentration of TSPM in the upwind direction varied from 2014 to 2845 $\mu\text{g}/\text{m}^3$ with a mean of 2429 $\mu\text{g}/\text{m}^3$. The average concentration of TSPM in the downwind direction was 1691 $\mu\text{g}/\text{m}^3$. The overall concentrations of TSPM varied from 2014 to 2845 $\mu\text{g}/\text{m}^3$ with a mean of 2469 $\mu\text{g}/\text{m}^3$. The highest TSPM average concentrations were found at Subalaxmi BM (2845 $\mu\text{g}/\text{m}^3$). The TSPM concentrations at all locations exceeded the standard of 600 $\mu\text{g}/\text{m}^3$ at source.

3.3.2.2 Dust concentration around stone crushing units

The average concentration of TSPM in the upwind direction varied from 88 - 152 $\mu\text{g}/\text{m}^3$ with a mean of 122 $\mu\text{g}/\text{m}^3$. The average concentration of TSPM in the downwind direction varied from 306 - 418 $\mu\text{g}/\text{m}^3$ with a mean of 362 $\mu\text{g}/\text{m}^3$. The average concentration of RSPM in the upwind direction varied 80 - 165 $\mu\text{g}/\text{m}^3$ with a mean of 123 $\mu\text{g}/\text{m}^3$. The highest average concentration in ambient air was very high in the downwind direction when compared to the upwind direction, of the order of 1 to 1.5 for TSPM. The overall concentrations of TSPM varied from 306 - 716 $\mu\text{g}/\text{m}^3$ with a mean of 481 $\mu\text{g}/\text{m}^3$.



3.4 Sampling with 1/8th of the crushers in operation

During the period July 18 - 25, 2005 for about 7 days, 1/8th of the crushers were operated (9) continuously of which, 4 were employed at source (TSPM 4) and seven were in ambient air (TSPM 5, RSPM 2).

3.4.1 Weather monitoring

The 24 hours wind rose shows that the dominant wind directions were from west (17%), followed by the South East (10.5%), South (10%), South of South East (9.5%) and East of South East (9%). The most prevalent wind speed was in the range of 5 - 10 kmph (20%) followed by 10 - 15 (17%) kmph. The calm condition was observed for about 1.67%. The average wind speed observed during the above period was 26.2 kmph.

3.4.2 Dust monitoring

3.4.2.1 Dust concentration at source

The average concentration of TSPM in the upwind direction varied from 688 to 1574 $\mu\text{g}/\text{m}^3$ with a mean of 1089 $\mu\text{g}/\text{m}^3$. The average concentration of TSPM in the downwind direction was 1141 $\mu\text{g}/\text{m}^3$. The overall concentrations of TSPM varied from 687 to 1574 $\mu\text{g}/\text{m}^3$ with a mean of 1102 $\mu\text{g}/\text{m}^3$. The highest TSPM average concentrations were found at Subalaxmi BM (1574 $\mu\text{g}/\text{m}^3$). The TSPM concentration at all locations exceeded the standard of 600 $\mu\text{g}/\text{m}^3$ recommended by CPCB.

3.4.2.2 Dust concentration around stone crushing units

The average concentration of TSPM in the upwind direction varied from 66 to 123 $\mu\text{g}/\text{m}^3$ with a mean of 99 $\mu\text{g}/\text{m}^3$. The average concentration of TSPM in the downwind direction varied from 177 to 346 $\mu\text{g}/\text{m}^3$ with a mean of 262 $\mu\text{g}/\text{m}^3$. The average concentration of RSPM in the upwind direction varied from 56 to 155 $\mu\text{g}/\text{m}^3$ with a mean of 106 $\mu\text{g}/\text{m}^3$. The highest average concentration in ambient air was very high in the downwind direction when compared to the upwind direction, of the order of 2 to 3 for TSPM. The overall concentrations of TSPM varied 104 - 521 $\mu\text{g}/\text{m}^3$ with a mean of 211 $\mu\text{g}/\text{m}^3$.

3.5 Sampling with only one crusher in operation

Only one crusher, viz., Rajalakshmi BM was operated during the period July 23 - 25, 2005 for 2 days continuously. Ambient air quality monitoring network consisting of 17 locations were identified based on prevailing wind pattern, stone crusher location and their geometry, of which 4 were employed at source (TSPM 4) and seven in ambient air (TSPM 5, RSPM 2).



3.5.1 Weather monitoring

The 24 hours wind rose shows that the dominant wind directions were from southwest (39 %), followed by the west (20%) and West of Southwest (17%). The most prevalent wind speed was in the range of >25 kmph (36%) followed by 5 - 10 (28%) kmph, with no calm condition. The average wind speed observed during the above period was 57.8 kmph.

3.5.2 Dust monitoring

3.5.2.1 Dust concentration at source

The average concentration of TSPM in the upwind direction varied from 586 to 1266 $\mu\text{g}/\text{m}^3$ with a mean of 926 $\mu\text{g}/\text{m}^3$ respectively. The average concentration of TSPM in the downwind direction varied from 509 to 524 $\mu\text{g}/\text{m}^3$, with a mean of 517 $\mu\text{g}/\text{m}^3$. The overall concentrations of TSPM varied from 250 to 345 $\mu\text{g}/\text{m}^3$ with a mean of 296 $\mu\text{g}/\text{m}^3$. The highest TSPM average concentrations was recorded at Rajalaxmi BM (345 $\mu\text{g}/\text{m}^3$).

3.5.2.2 Dust concentration around stone crushing units

The average concentration of TSPM in the upwind direction varied from 55 to 73 $\mu\text{g}/\text{m}^3$, with a mean of 62 $\mu\text{g}/\text{m}^3$. The average concentration of TSPM in the downwind direction was 104 $\mu\text{g}/\text{m}^3$. The average concentration of RSPM in the downwind direction varied from 50 to 87 $\mu\text{g}/\text{m}^3$, with a mean of 68 $\mu\text{g}/\text{m}^3$. The highest average concentration in ambient air was very high in the downwind direction when compared to the upwind direction, of the order of 1 to 1.5 for TSPM. The overall concentrations of TSPM varied from 32 to 84 $\mu\text{g}/\text{m}^3$ with a mean of 63 $\mu\text{g}/\text{m}^3$.

3.6 Sampling with no crushing activity and only vehicle traffic/movement

No crusher was operated during July 26 - 27, 2005 for a day. Ambient air quality monitoring network consisting of 17 locations was designed based on prevailing wind pattern, stone crusher location and their geometry. For no crushing activity in the locality, source dust monitoring was carried out at 4 stone crushing units, of which 4 were employed at source (TSPM 4) and six in ambient air (TSPM 5, RSPM 1). During the same period micro-meteorological data were also collected at 3 identified locations, one inside stone crushing area near Subramaniam BM and two in the residential area viz., Trisoolam 2 and Kennedy valley.

3.6.1 Weather monitoring

The wind direction and wind speed were recorded on hourly basis during the study period July 26 - July 27, 2005. The 24 hours wind rose shows that the dominant wind



directions were from South West (34%), followed by the South (21%) and West (14.5%). The most prevalent wind speed was in the range of >25 Kmph (15.5%) followed by 5 - 10 (12%) kmph, with no calm condition. The average wind speed observed during the above period was 46.1 kmph.

3.6.2 Dust monitoring

3.6.2.1 Dust concentration at source

Out of 4 source air quality monitoring stations, two (2 TSPM) were chosen in the upwind direction and two (2 TSPM) in the downwind direction. Air quality monitoring was carried out simultaneously for all the locations during the period. The average concentration of TSPM in the upwind direction varied from 281 to 345 $\mu\text{g}/\text{m}^3$ with a mean of 313 $\mu\text{g}/\text{m}^3$. The average concentration of TSPM in the downwind direction varied from 250 to 306 $\mu\text{g}/\text{m}^3$ with a mean of 278 $\mu\text{g}/\text{m}^3$.

The overall concentrations of TSPM varied from 509 to 1266 $\mu\text{g}/\text{m}^3$ with a mean of 721 $\mu\text{g}/\text{m}^3$. The highest TSPM average concentrations were found at Subalaxmi BM (1266 $\mu\text{g}/\text{m}^3$). The TSPM concentration exceeded the standard of 600 $\mu\text{g}/\text{m}^3$ recommended by CPCB except at Vigneshwara BM.

3.6.2.2 Dust concentration around stone crushing units

Ambient dust monitoring was carried out around stone crushing units at 6 locations in the stone crushing area. Out of 6 ambient air quality monitoring stations, three were chosen in upwind (3 TSPM) and three (2 TSPM, 1 RSPM) in the downwind direction. Air quality monitoring was carried out simultaneously for all the locations for a day. The average concentration of TSPM in the upwind direction varied from 44 to 73 $\mu\text{g}/\text{m}^3$ with a mean of 60 $\mu\text{g}/\text{m}^3$. The average concentration of TSPM in the downwind direction varied from 49 to 84 $\mu\text{g}/\text{m}^3$ with a mean of 67 $\mu\text{g}/\text{m}^3$. The average concentration of RSPM in the downwind direction was 73 $\mu\text{g}/\text{m}^3$. The highest average concentration in ambient air was very high in the downwind direction when compared to the upwind direction, of the order of 1 to 1.5 for TSPM.

The overall concentrations of TSPM varied from 44 to 107 $\mu\text{g}/\text{m}^3$ with a mean of 67 $\mu\text{g}/\text{m}^3$. The TSPM concentration at any location did not exceed the standard of 200 $\mu\text{g}/\text{m}^3$ recommended by the CPCB. The average concentration of RSPM was 73 $\mu\text{g}/\text{m}^3$. The concentration of RSPM is within the limit of 100 $\mu\text{g}/\text{m}^3$ recommended by the CPCB at all the locations.



4.0 Particle size analysis

4.1 Particle size distribution of source dust

Particle size analysis was carried out for dust samples collected at the stone crushing unit, and the results are presented in the form of a cumulative distribution graph. The respirable particulate matter (PM_{10}), which is defined as the particles with an aerodynamic diameter not greater than $10\ \mu\text{m}$, was found to be 36.6 %, and the fine inhalable particulate matter or $PM_{2.5}$, the particles with an aerodynamic diameter $\leq 2.5\ \mu\text{m}$, was found to be 14.3 %. The respirable particulate matter (PM_{10}), was found to be 42.2 % and the fine inhalable particulate matter or $PM_{2.5}$, was found to be 14.6 %.

4.2 Particle size distribution of ambient air dust

The particle size distribution of ambient air dust was carried out to quantify the fraction of particles transported from the crusher to the receiver. The results show that the percentage of particulate fractions $PM_{2.5}$, PM_{10} , PM_{15} , and PM_{30} are 25.3, 60.5, 72.8 and 91 % respectively. The higher percentage of finer particles collected was due to the fact that the larger size particles were settling near the source, and the finer particles were able to remain in the air for a much longer time. The settleable particulate matter with an aerodynamic diameter greater than $15\ \mu\text{m}$ that would deposit or settle near the sources is 72.8 %. The differential distribution graphs show that maximum percentages (11%) of particles are in the range of $3 - 5\ \mu\text{m}$.

4.3 Fine respirable particulate matter ($PM_{2.5}$) at source and ambient air

Ambient air quality monitoring network consisting of 17 locations was designed based on prevailing wind pattern, stone crusher location and their geometry, of which, 10 were deployed at source (TSPM 8, RSPM 2) and seven in ambient air (TSPM 4, RSPM 3). During the same period micro-meteorological data were also collected at 3 identified locations, one inside stone crushing area near Subramaniam BM and two in the residential area viz., Trisoolam- 2 and Kennedy valley. Out of 10 source air quality monitoring stations, eight were chosen in the upwind direction and two in the downwind direction. Ambient dust monitoring was carried out around stone crushing units at 7 locations in the stone crushing area. Out of 7 ambient air quality monitoring stations, four were chosen in the upwind direction and three in the downwind direction. At source except Suguna BM all the $PM_{2.5}$ concentrations exceed the limit of $65\ \mu\text{g}/\text{m}^3$ (EPA Standards). In ambient air except Trisoolam-2 and Krishna Nagar $PM_{2.5}$ concentration exceeded the limit of $65\ \mu\text{g}/\text{m}^3$, in all



the stations. Also, PM_{10} concentration at source exceeded the standard of $100 \mu g/m^3$ in all the locations except Suguna BM and J.R Vimala BM. Also PM_{10} concentration in ambient air exceeded the standard of $100 \mu g/m^3$ in all the locations except at Zamin Pallavaram, Trisoolam 2, Krishna Nagar and Kennedy Nagar.

4.4 Assessment of occupational exposure level

Occupational exposures to total and respirable dusts were assessed on 72 workers through personal sampling. Eleven locations were identified for personal sampler measurements, one at the center of cluster of stone crushers, eight in the downwind, and two in the upwind directions. The respirable particulate matter at these locations varied from 26 to $87 \mu g/m^3$, with a mean of $56 \mu g/m^3$. The TSPM concentration at these locations varied from 49 to $117 mg/m^3$, with a mean of $91 \mu g/m^3$. The ratio of respirable particulate matter to total dust varied from 44 to 61 %, with a mean of 57 %. The total dust and respirable particulate matter exposure concentrations at all the stations exceeded the occupational environment standards (12 hours) recommended by the Occupational Safety and Health Administration (15 and $5 mg/m^3$ for TSPM and RSPM, respectively), the National Institute of Occupational Safety and Health ($10 mg/m^3$ for TSPM) (NTIS 1994), and the American Conference of Governmental Industrial Hygienists ($10 mg/m^3$ for both TSPM and RSPM) and were also in excess of permissible exposure limits prescribed by the Indian Factory Act.

5.0 Prediction of impact

Mathematical models are used to predict the impact of emissions on air quality. The concentrations are estimated from meteorology, source geometry, and receptor location. Mathematical models are the best tools to quantitatively describe the cause-effect relationship between source of pollution and different components of environment. In the present study, the mathematical models that have been used for predictions of air quality are Fugitive dust model (FDM), ISCST3 and AERMOD designed for predicting fugitive dust emissions.

FDM model is designed specially for computation of the impacts of fugitive dust sources. The model is generally based on the well-known Gaussian plume formulation for computing concentration, but the model has been specifically adapted to incorporate an improved gradient-transfer deposition algorithm. FDM employs an advanced gradient-transfer particle deposition algorithm.

The ISCST3 models are based on revisions to the algorithms contained in the ISCST2 models. A revised area source algorithm and revised dry deposition algorithm have been



incorporated in the models. The ISCST3 models also include an algorithm for modeling impacts of particulate emissions from open pit sources, such as surface coal mines. The Short Term model includes a new wet deposition algorithm, and also incorporates the COMPLEX1 screening model algorithms for use with complex and intermediate terrain.

AERMOD is a steady-state plume model. In the stable boundary layer (SBL), it assumes the concentration distribution to be Gaussian in both the vertical and horizontal. In the convective boundary layer (CBL), the horizontal distribution is also assumed to be Gaussian, but the vertical distribution is described with a bi-Gaussian probability density function (pdf). For sources in both the CBL and the SBL, AERMOD treats the enhancement of lateral dispersion resulting from plume meandering.

5.1 Recommended safe distance

Based on the ambient air quality monitoring results and model predicted concentration, impact zones for different crusher operating conditions were drawn. The impact zone was demarcated by drawing isopleths of concentration $200 \mu\text{g}/\text{m}^3$ for TSPM and $100 \mu\text{g}/\text{m}^3$ for PM_{10} which are the standard set by CPCB for 24 hour averaging time. The average safe distances were estimated for single crusher and cluster of crushers using measured and predicted concentrations.

5.1.1 Safe distance when all the crushers in operation

Safe distance for measured concentration varied from 211 to 1350 m with a mean of 784 m. Safe distance for predicted concentration of AERMOD varied from 59 to 1225 m with a mean of 679 m. The safe distance for predicted concentration of ISCST3 and FDM varied from 45 to 1056 m and 55 to 2650 m with a mean of 501 m and 1335 m respectively.

5.1.2 Safe distance when half of the crushers in operation

Safe distance for measured concentration varied from 126 to 1750 m with a mean of 776 m. Safe distance for predicted concentration of AERMOD varied from 47 to 1395 m with a mean of 582 m. The safe distance for predicted concentration of FDM and ISCST3 varied from 1650 to 26 m and 35 to 833 m with a mean of 1216 m and 433 m respectively.

5.1.3 Safe distance when 1/4th of the crushers in operation

Safe distance for measured concentration varied from 126 to 1242 m with a mean of 696 m. Safe distance for predicted concentration of AERMOD varied from 15 to 481 m with a mean of 262 m. The safe distance for predicted concentration of FDM and ISCST3 varied from 74 to 1138 m and 38 to 537 m with a mean of 731 m and 260 m respectively.



5.1.4 Safe distance when 1/8th of the crushers in operation

Safe distance for measured concentration varied from 25 to 1095 m with a mean of 524 m. Safe distance for predicted concentration of FDM varied from 50 to 1109 m with a mean of 184m. The safe distance for predicted concentration of AERMOD and ISCST3 varied from 27 to 325 m and 22 to 335 m with a mean of 116 m and 501m respectively.

5.1.5 Safe distance when only one crusher in operation.

Safe distance for measured concentration varied from 116 to 771 m with a mean of 379 m. Safe distance for predicted concentration of ISCST3 varied from 11 to 174 m with a mean of 90 m. The safe distance for predicted concentration of AERMOD and FDM varied from 32 to 95 m and 13 to 263 m with a mean of 59 m and 111 m respectively.

5.2 Model performance evaluation

Evaluation of performance of an air quality model generally focuses on assessing the accuracy of the model prediction relative to observed concentrations, and a model needs to be validated for correct interpretation. The performance of the models used in this study is tested by a comprehensive package of model accuracy assessment methods suggested in the literature. In this study, performances of three Gaussian models were evaluated.

A comparison of the measured and predicted concentrations indicated that AERMOD and ISCST3 model underpredicted the concentrations while the FDM model overpredicted them. Important statistical parameters of the observed and predicted concentrations were used for the comparison. In addition quantitative data analysis technique was also used to evaluate models' accuracy in prediction.

5.2.1 Classification of data

In the statistical analysis, comparison between measured and predicted concentration were done for the models, FDM, ISCST3 and AERMOD for the condition of 1. With all the crushers running, 2. with half of the crushers running, 3. with quarter of the crushers running, 4. with 1/8 of the crushers running, 5. with only one crusher running and 6. with no crusher running to account for the background emissions

5.2.2 All the data combined

All the data combined and put together for statistical analysis indicated that, the models exhibited comparable accuracies, with AERMOD (70%) proving to be better than ISCST3 (47%) and FDM (44%). The accuracy was less for ISCST3 and FDM compared to



AERMOD in this case due to more error ($1227 \mu\text{g}/\text{m}^3$ for ISCST; $33224 \mu\text{g}/\text{m}^3$ for FDM) than AERMOD ($1114 \mu\text{g}/\text{m}^3$).

5.2.3 All the Crushers running

From the observed and predicted mean concentrations, it is inferred that the model AERMOD predicted mean of $1094 \mu\text{g}/\text{m}^3$ is closer to the observed mean ($1285 \mu\text{g}/\text{m}^3$) than FDM ($4722 \mu\text{g}/\text{m}^3$) and ISCST3 ($661 \mu\text{g}/\text{m}^3$). Regression analysis indicated that the intercept a and slope b are nearer to 0 and 1 for the model AERMOD ($a = 776$, $b = 0.25$) than ISCST3 ($a = 551$, $b = 0.081$) and FDM ($a = 2638$, $b = 1.6$). The model AERMOD and model ISCST3 underpredicted the concentrations whereas FDM model overpredicted them. The difference measure 'd' indicated that the accuracy of the model was 55% for AERMOD compared to 46% for ISCST3 and 33% for FDM. The comparison of RMSE indicated that there was less error ($1669 \mu\text{g}/\text{m}^3$) in AERMOD results as compared to $1694 \mu\text{g}/\text{m}^3$ for ISCST3 and $5621 \mu\text{g}/\text{m}^3$ in FDM.

5.2.4 Half of the crushers in operation

From the observed and predicted mean concentrations, it is inferred that the model AERMOD predicted mean of $813 \mu\text{g}/\text{m}^3$ is closer to the observed mean ($961 \mu\text{g}/\text{m}^3$) than FDM ($1359 \mu\text{g}/\text{m}^3$) and ISCST3 ($152 \mu\text{g}/\text{m}^3$). Regression analysis indicated that the intercept a and slope b are nearer to 0 and 1 for the model AERMOD ($a = 152$, $b = 0.7$) than FDM ($a = 504$, $b = 0.89$) and ISCST3 ($a = 97.45$, $b = 0.057$). The model ISCST3 underpredicted the concentration whereas AERMOD and FDM model overpredicted them. The difference measure 'd' indicated that the accuracy of the model was 85% for AERMOD, 81% for FDM, and 47% for ISCST3. The comparison of RMSE indicated that there was less error in AERMOD ($896 \mu\text{g}/\text{m}^3$) results as compared to $1237 \mu\text{g}/\text{m}^3$ for FDM and $1470 \mu\text{g}/\text{m}^3$ for ISCST3.

5.2.5 1/4th of the crushers in operation

The RMSE analysis indicated that AERMOD model had the least error of 1139 than ISCST3 ($1144 \mu\text{g}/\text{m}^3$) and FDM ($1601 \mu\text{g}/\text{m}^3$). In general, accuracy was good when the receptors were in the downwind direction to the source and the accuracy decreased when the receptors were in upwind direction. This is not surprising since these models are meant to simulate air quality in the downwind direction.



5.2.6 1/8th of the crushers in operation

Under this condition, all three models underpredicted with the FDM proving to be better. The accuracy was more for FDM (67%) as compared to AERMOD (50%) and ISCST3 (47%).

5.2.7 Only one crusher in operation

Under this condition FDM and ISCST3 model overpredicted the concentration and AERMOD underpredicted the concentration and it is least for ISCST3 ($166 \mu\text{g}/\text{m}^3$) as compared to AERMOD ($68 \mu\text{g}/\text{m}^3$) and FDM ($572 \mu\text{g}/\text{m}^3$) against measured concentration. The accuracy of ISCST3 is more (56%) when compared to AERMOD (47%) and FDM (14%) which is the lowest among the all conditions tested. This is mainly due to the inability of FDM to take into account hourly variation of emission rate while modeling.

5.3 Quantitative data analysis

Quantitative data analysis was carried out to verify whether the model's predictions are within a factor of 2 for all the measurements. The model's predictions were also compared with observed concentrations and grouped under overprediction, exact prediction and underprediction for assessing their performance. This analysis will be of use for regulatory application to ensure compliance with the air quality standards.

The results of the quantitative data analysis done for the models indicated that the model FDM predicted the concentration within a factor of 2 most of the time with the least amount of underprediction. Most of the time, FDM overpredicted the concentration, where as AERMOD and ISCST3 underpredicted the concentration. On overall basis, the model AERMOD proved to be better.

Overall, the model AERMOD provided a better simulation than the ISCST3 and FDM. Its prediction accuracy (70%) was more when compared to ISCST3 (47%) and FDM (44%) for all the conditions under which the study was conducted. FDM predictions were within a factor of 2 of the observed concentrations for the most of the time. Of the three models FDM overpredicted to the highest degree. Based on the study it is appropriate to rank the models in the order of AERMOD, ISCST3 and FDM.

6.0 Green belt development

Urban green belts are considered as the lungs of the cities as they act as a sink for some of the harmful gases released by vehicles and industries operating in the area. Whether sprawling over a large or a smaller area, these green belts are found in all cities and play a



very important role. They serve as sink for the pollutants, check the flow of dust and bring down noise pollution level.

6.1 Design of green belt for Trisoolam quarry

There are 72 stone crushers in the site to be improved by tree planting. Each stone crusher has to be environmentally improved by planting trees apart from the main road bearing incessant plying vehicles augmenting dust and noise. It is proposed to plant tree species, around the stone crushers initially and gradually grow green belt on the road side also. Soil samples were collected at a depth of 3 feet and tested for macro and micronutrients. It was found that the electrical conductivity is normal i.e. less than 1.0 and the pH was ranging from 6.0 to 7.0 which is again normal. The soil test values for micro nutrients viz., Zinc, Copper, Iron, and Manganese are well above 3 to 5 ppm. The macronutrient, Nitrogen was in a lower availability level, Phosphorous at a medium level and Potassium at a higher level. It is proposed to apply abundant quantities of Vermicastings, an ecofriendly bionutrient which will supply the nutrients as well as act as a binding agent.

Planting was designed to include: 1. Peripheral planting to protect the nearby residential areas, 2. Avenue planting, 3. Planting around crushers, 4. Planting around quarry, 5. Hill top planting, to arrest dust pollution in the stone crushing areas at Trisoolam. It is proposed to apply abundant quantities of Vermicastings, an ecofriendly bionutrient which will supply the nutrients as well as act as a binding agent.

7.0 Control measures

Control measures for reducing or eliminating fugitive emissions from stone crushing plants include the following:

- ❖ Wetting of material or surfaces with water with or without surfactants or foaming agents
- ❖ Covering open operations to prevent dust entrainment by the wind
- ❖ Reducing the drop height of dusty material
- ❖ Using hooding, industrial ventilation systems and dust collectors (e.g. Bag houses) on dusty processes amenable to enclosure

7.1 Cluster of crushers

Emissions from stone processing are considered to be fugitive when the sources are not vented to a bag house or contained in an enclosure with a forced air vent or stack. Water sprinkling at dust discharge points wets the dust particles and augments settling. The other



control measures for reducing dust emission should include the following good housekeeping practices:

- A minimum distance of 500 m with a green belt of 100 m width should be provided around the periphery of the crushing area at Trisoolam
- Raising a green belt around the crushing area to arrest the spread of particulate matter is advocated along the boundary of the crushing area on all the sides with evergreen high foliage trees like Neem, Ashoka, Coconut, Tamarind and other local trees belonging to *cesalpinaceae* like Gul Mohar and Fire of the Forest. On the road sides also trees should be planted to arrest the dust from vehicular movement
- Sprinkling of water should be increased to arrest the spread of dust (RSPM & TSPM) with periodical cleaning of spray nozzles
- Fine dust accumulated in the crushing area should be periodically cleared and the dumps should be covered with tarpaulins to arrest the spread of dust
- Construction of metalled road (paved) within the premises
- No more stone crushers should be allowed in this area
- The drop height should be kept at a minimum while loading and unloading
- Fine powder should be collected at the ground level and disposed off immediately
- Conveyor chutes should be provided at the discharge points
- Covering open operations to prevent dust entrainment by the wind
- As an occupational safety measure all the workers should be provide with nose masks to avoid dust entering the respiratory system
- Evergreen trees like Neem, Ashoka, Tamarind and other local trees belonging to the family *cesalpinaceae* like Gul Mohar and Fire of the Forest should be planted all around the crushing area. Similarly trees should be planted along the roads to arrest the spread of particulate arising from vehicular movement inside the area
- Roads leading to the individual crushers should be paved
- The fine powder accumulated so far should be immediately disposed off and the crushers should follow periodical disposal practice in consultation with TNPCB
- Good house keeping by way of spraying water at the vulnerable points/locations to arrest the spread of dust particles should be practiced
- Drop height of the conveyors should be kept at the minimum



- Wind breaking wall/net should be provided all along the stone crushers adjacent to residential areas.
- If for other pressing reasons more than one stone crushers are required to come in existence, then they should be as much close to each other as may be permitted without causing difficulty in operation. In such a situation the source would be recognized as a collective one and the safe distance is to be estimated accordingly.
- Special recommendation for stone crushers located near Kennedy Valley on the eastern side of the crushing area: should be provided an enclosure of suitable material (brick) to a height of 5m on all sides adjacent to the residential area

7.2 Single crusher

Based on the study conducted at Trisoolam stone crushing area by operating only one crusher the following recommendations are made:

- NPC dust containment and dust suppression system should be provided
- Paving of roads should be adopted
- The minimum distance from single crusher source should be kept as 100m with a 25m green belt within it at the periphery
- Fine powder should be collected at the ground level
- Conveyor chute should be provided at the discharge points
- Drop height for the conveyor operations should kept at the minimum
- The fine powder should be disposed off periodically
- Covering of fine dust with tarpaulin during storage and transport to final destination should be practiced

In addition to the above control measures suggested, wind breaks/ barrier of length 100m x 15m (50m x 15m at periphery of Parthibhan BM and 50m x 15m at periphery of Geetha BM) should be constructed at the periphery of the stone crushers at North (Parthibhan BM) and South (Getha BM) of the Moovarasampet road.

It is estimated that the above control measures will bring down the emissions from stone crushers by 50%. Prediction carried out with control measures indicated that the safe distance for single and cluster of crushers for FDM, ISCT3 and AERMOD models can be reduced by 50%.



8.0 Conclusions

The dust generated from stone crushing activities contains a significant amount of fine inhalable matter. The effect of fine particulate matter can be disproportionately large even though it constitutes only a small fraction of the total suspended particulate matter. The presence of a high percentage of silica in the dust and the particle size distribution further suggest that the occupational environment of the workers and surrounding areas may be hazardous to human health. Air quality and the health survey conducted at the site indicate that the observed dust caused significant damage to respiratory health.

Most of the stone crushers have inadequate dust control systems. Mostly all units have neither enclosures nor water spraying arrangements. As a result, the dust emissions are substantial which leads to adverse impacts on workers as well as the surrounding environment. The existing control measures such as dust containment enclosures, water spray arrangements etc are generally found to be inadequate, largely due to reasons like inadequate containment, inadequate water quantity and pressure, dirt in the water leading to choking of spray nozzles, inappropriate spray locations, etc. The re-entrainment of settled dust from unpaved roads and surfaces is another phenomenon which seriously contributes to dust pollution in these areas which should be controlled immediately by paving the roads and surfaces inside crushing area and reducing the drop heights and covering potential fugitive dust emission sources.



CHAPTER 1 INTRODUCTION

1.1 Preamble

Stone crushers are small scale industries with low capital investment (varying between Rs. 5 to 10 lakhs). Stone crushing in India is basically a labour intensive operation where the loading of stone into the crusher, conveying the product materials from separating screens, loading and unloading operations are performed manually. The production capacity of stone crushers varies from 30 - 300 MT/day.

Crushed stone, as the name implies, is mined in an open quarry or pit and crushed to the desired product size. After transfer to the processing plant by various means, quarried stone is subjected to various size reduction, size classification, and transfer operations, all of which have the potential to emit process and fugitive dust.

Stone crushers are small scale industries in the unorganized sector. They provide the basic material for road and building construction. They are highly labour intensive, where most of the operations are performed manually. The various unit operations involved in stone crushing namely size reduction, size classification and transfer operation have the potential to emit process and fugitive dust.

There are about 2000 units reported to be operating with low capital investment in the state of Tamil Nadu of which about 1800 units are located in residential areas. Many such stone crushing operations tend to be located relatively near populated area to avoid transportation costs. This can result in dust associated health problems. The large number of stone crushers distributed all over Tamil Nadu, pose the problem of high levels of dust generation in the vicinity of the crushers and on the communities surrounding them during various operations of crushing.

Crushed rock is basically a construction material (e.g. road bed, paving materials and concrete mixing), and distances between the quarry and processing plant and its point of use must be kept to a minimum to avoid high transportation costs. Thus many crushed stone operations tend to be located relatively near population areas. Further more since the life of a quarry will be a number of decades many such operations that were originally located in undeveloped or rural areas may eventually be surrounded by residential developments, with homeowners complaining about dust settling on their property.



With the sponsorship from the Tamil Nadu Pollution Control Board (TNPCB), NEERI undertook a detailed study at Pammal and Alathur Gate in 1997 and 1998 to assess the dust emissions and suggest possible measures for controlling the air pollution problems in these areas. In continuation of the good work done by NEERI, Chennai in this direction, TNPCB, Chennai approached NEERI, Chennai, once again in 2005 to submit a detailed report on the assessment of dust concentration at Trisoolam village near Chennai city.

With the support of the Tamil Nadu Pollution Control Board, the National Productivity Council has demonstrated a suitable dust suppression and containment system for stone crusher units. NEERI and TNPCB had recommended the dust suppression system. While some SCUs have adopted the system many have not. Hence TNPCB approached NEERI to evaluate the adequacy of the pollution control measures being adopted by the SCUs and to establish siting criteria for stone crushers with respect to their distance from residential areas.

1.2 Stone crushers at Trisoolam

There are 72 stone crushers located in Trisoolam and Moovandar village adjacent to Chennai metropolitan city, in Tambaram Taluk, Kancheepuram District, each with a daily crushing capacity of about 60 MT, operating very close to each other by the side of a quarry as given in **Table 1.1**. Stone crushing and quarrying operations are carried out in these areas since 1965. There is a complaint from Kennedy Valley residential colony in the eastern direction of stone crushing units receiving dust impact. With a view to assess the dust concentration in and around stone crushing units and the adequacy of control measures, TNPCB, Chennai, has approached NEERI to carry out a detailed study for controlling the dust concentration in the Trisoolam area.

1.3 Objective of the study

The objective of this study is to assess the dust concentration and its fallout in and around the work place and the delineation of control measures to arrest the dust to permissible limits.

1.4 Scope of the study

The scope of the study consists of

- ❖ Assessment of dust concentration in and around the stone crushing units
- ❖ Measurement of respirable and non respirable fraction of dust concentration
- ❖ Assessment of dust concentration of the work place (occupational exposure level)



Table 1.1 List of stone crushing units at Trisoolam

S. No.	Name of the Crusher
1	New Yashwanth BM
2	Praveena BM
3	K.Thirugnanam BM
4	Parthiban BM
5	Geetha BM
6	Rathna BM
7	Athi Lakshmi BM
8	Vetrivelan BM
9	Loganayagi BM
10	Vasudevan BM
11	MahaLakshmi BM
12	Sri Ramajayam BM
13	Rani BM
14	Balamurugan BM
15	Star BM
16	Kaladevan BM
17	Ayya BM
18	Karumariamman BM
19	King BM
20	Vigneshwara (Sri Ambigai) BM
21	Sri Buvaneshwari BM
22	J.R.Vimala BM
23	Iyyappa 1 BM
24	Shivagami BM
25	Subam BM
26	New Shivagami BM
27	Durga BM
28	V.K.S BM
29	Makeshwari BM
30	Gururajan BM
31	Hindustan BM
32	Janakiraman BM
33	New Lawanaya BM
34	Subramanium BM
35	Subalakshmi BM
36	Shakthi Priya BM
37	Abirami BM
38	Venkateshwara BM
39	A.S MurthyB.M
40	Sri Raja Lakshmi BM
41	Kamatchi BM
42	Sri Ram BM
43	Yashwanth BM
44	Jaya Shakthi BM



45	Suguna BM
46	T.L. Vishwanathan BM
47	Shivagaminatesh BM
48	Sri Ganesh BM
49	Swaminathan BM
50	Brammashakthi BM
51	Ashok BM
52	Vijayaram BM
53	Vinetha BM
54	Sivasankaran BM
55	Duvaraka-SMT BM
56	Sri Lakshmi BM
57	Balaji BM
58	Radhakrishnan BM
59	Lawanya 1 BM
60	Pattabiram BM
61	Gnanaselvam BM
62	Suraka BM
63	Maragatham BM
64	Thirumalaiyan BM
65	Lawanya 11 BM
66	D.K.Srither BM
67	Karthic BM
68	New Karthic BM
69	Amman Arul BM
70	Sri Thandumariamman BM
71	Pachaiyammal BM
72	Iyyappa 1 BM

Table 1.2 Characteristics of stone used for crushing

S. No.	Parameter	Percentage
Mineralogical composition		
1	Light minerals	
	Undulose quartz	10
	Plagioclase feldspar	30
	Alkali feldspar	10
2	Heavy minerals	
	Pyroxene	40
	Biotite	2 - 5
	Rest including magnetite	2 - 5
3	Free silica	18.8
	Stone characteristics	
4	Density, g/cm ³	3.15
5	Cold compressive strength, kg/cm	90
6	Moisture content	Nil



- ❖ Monitoring of micro-meteorological data to assess the extent of spread of dust pollution
- ❖ Particle size distribution of dust at source and ambient air to assess dispersal of dust to various distances
- ❖ Prediction of fugitive dust emission from the stone crushers and their impact on the surrounding areas
- ❖ Design of Green Belt around stone crushers
- ❖ Delineation of control measures

1.5 Process description

Stone crushing is a mechanical operation by which large size stone as mined from quarries, in size range of 200 - 300 mm, is crushed to smaller usable sizes, generally 6, 15, 25 mm. The crushed material is segregated size wise by screening and is then ready for dispatch and use in road and building construction. Quarried stone is normally delivered to the processing plant by truck and is dumped in storage pit or bunker. The stone crusher is usually a jaw crusher.

The crushed material from the jaw crusher is separated into various fractions i.e. 25mm, 15mm, 6 mm and stone dust in a rotary/vibratory screen. The oversized material is sent back to the jaw crusher for further crushing, reducing the size of the stones to below 20 mm. The different sized products are transferred from the bottom of the screen by belt conveyors to the stockpiles and further transported, usually by trucks, to the consumer. The characteristics of stone used for crushing are given in Table 1.2.

1.6 Nature of emissions from the stone crushers

The only pollutant emission of concern from stone crushing is particulate matter. Emissions from stone processing should be considered to be fugitive as the sources are not vented to a bag house or contained in an enclosure with a forced air vent stack.

Emission points for dust release from stone crushing typically include the following:

- ❖ Loading of trucks
- ❖ Truck travel on dusty roads
- ❖ Fugitive dust loss from trucks
- ❖ Dumping into crusher
- ❖ Crushing
- ❖ Screening



- ❖ Transfer points on conveyor system
- ❖ Loading onto storage piles from conveyers
- ❖ The wind blowing dust from storage piles and conveyors

1.7 Assessment of dust emissions

1.7.1 Source and ambient air quality monitoring

The study area at Trisoolam is located at a distance of 20 km to the southwest of Chennai City (Fig. 1.1). There are 72 crushers located west of a quarry as listed in Table 1.1. On the basis of a reconnaissance in the first week of May 2005, 10 stone crushing units were chosen for source sampling and 7 locations for ambient air quality monitoring. The ambient air quality locations were selected on the basis of the prevailing wind direction and speed and also giving due consideration to the historical wind rose for Chennai city (1969 - 2001). A maximum of 5 respirable particulate samplers and 12 high volume samplers were deployed for the work. At 5 locations both high volume sampler and respirable particulate sampler were operated. All the samplers were operated continuously from June 16, 2005 to August 8, 2005.

The study was conducted in six phases: 1. with all the crushers running, 2. with half of the crushers running, 3. with quarter of the crushers running, 4. with 1/8 of the crushers running, 5. with only one crusher running and 6. with no crusher running to account for the background emissions.

1.8 Reconnaissance survey

A reconnaissance survey was conducted prior to air sampling programme to fix up upwind and downwind directions of the study area and to design ambient air quality monitoring network. Three weather stations consisting of a wind vane, a cup anemometer and a thermo hygrometer were stationed in an open space, one at the centre of the Stone Crushing Units near Subramani Crusher and the other two at Trisoolam and Kennedy Valley. Wind speed, wind direction, temperature and humidity were monitored hourly for a period of 7 days from June 16 - 23, 2005. The predominant wind directions were from West and Southwest.

1.9 Study area

The study area is located in Trisoolam at a distance of 20 km to the southwest of Chennai city. The study area covered 72 crushers, each with a daily crushing capacity of about 60 T operating very close to each other by the side of a quarry. The extent of the area is



Pouch (Fig. 1.1)



about 3 km² for quarrying and 1.5 km² for stone crushing operation. The major residential areas are: Kennedy Valley with a population of about 375 people located in the South east at a distance of 500 m, Sara Nagar with a population of about 375 people in the South west at a distance of 500 m and Trisoolam with a population of about 10000 people in the Northwest at a distance of 1500 m from the stone crushing boundary. Other residential areas are Everedy Nagar with a population of about 750 people located in the South west at a distance of 1000 m from the stone crushing units, yet Zamin Pallavaram with a population of about 500 people located in the South at a distance of 1000 m from the stone crushing units and Rani Anna Nagar with a population of about 375 people located in the East at a distance of 500 m from the stone crushing units. These localities received the maximum dust impact due to stone crushing activities.

1.10 Micro-meteorological observations

The wind direction and wind speed were recorded on hourly basis during the study period June 16 - June 23, 2005 prior to air sampling programme and presented in the form of a wind rose diagram as shown in Fig. 1.2. The 24 hours wind rose shows that the dominant wind directions were from West (30% of the time), followed by the West of South West (23%) and South West (19%). The most prevalent wind speed was in the range of 10 - 15 kmph (24%) followed by 5 - 10 kmph (21%) with no calm condition. The average wind speed observed during the above period was 10.1 kmph. The photographs depicting stone crushers and their environment are given in Plates 1.1 - 1.8.

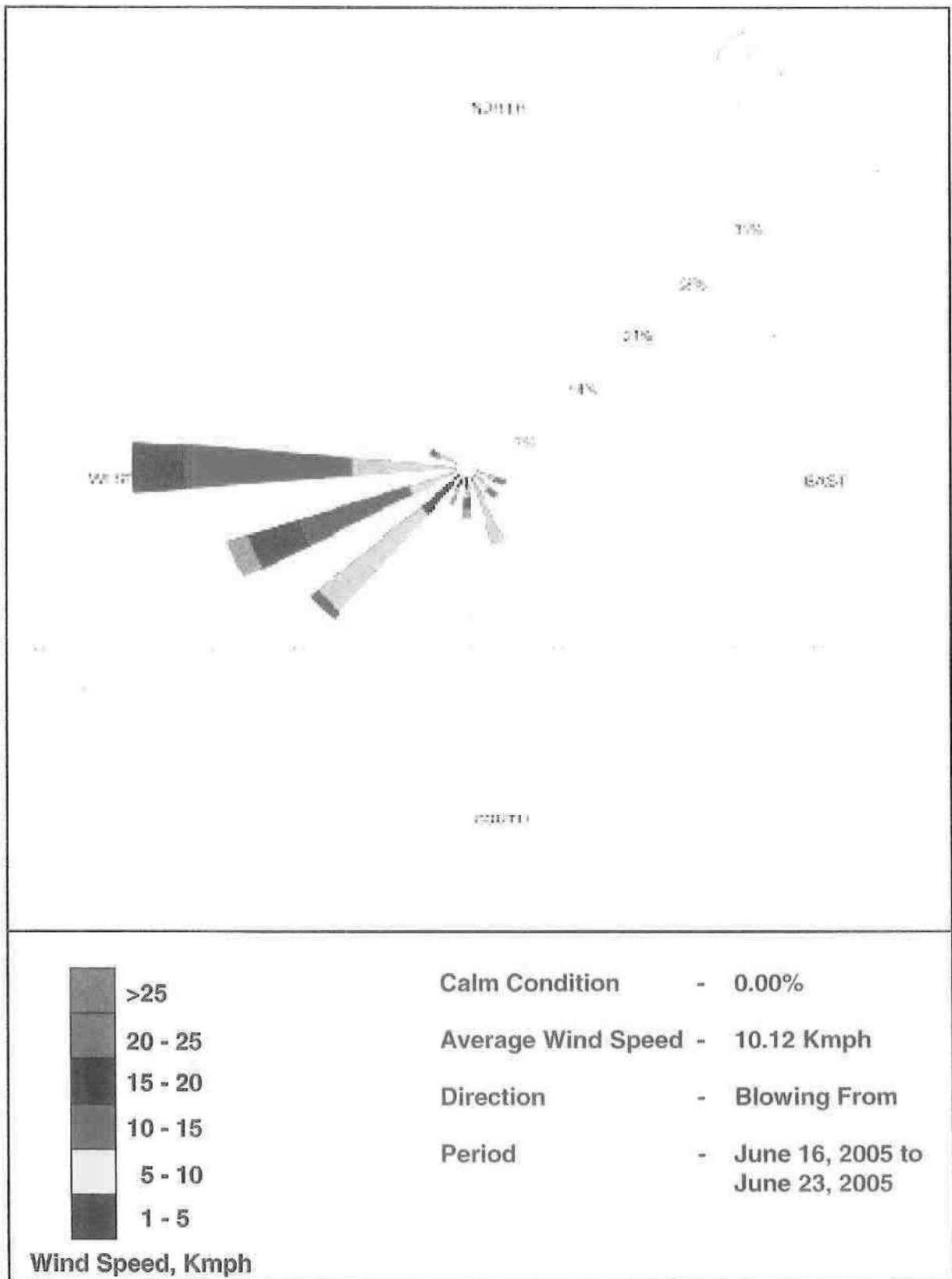


Fig. 1.2 Windrose Pattern at Stone Crushing Units, Trisoolam (Preliminary Survey)



Plate No. 1.1 A View of the Stone Quarry

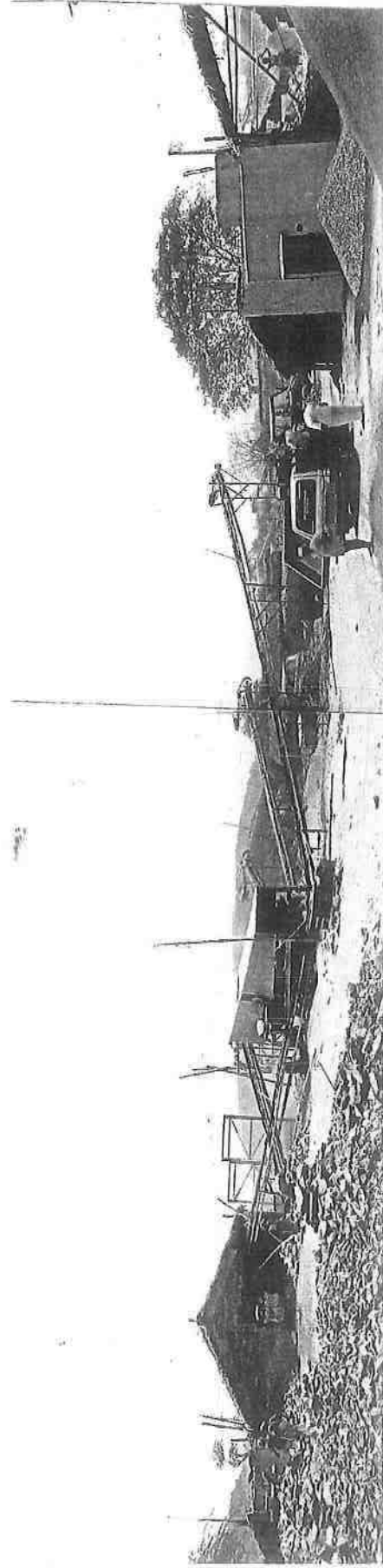
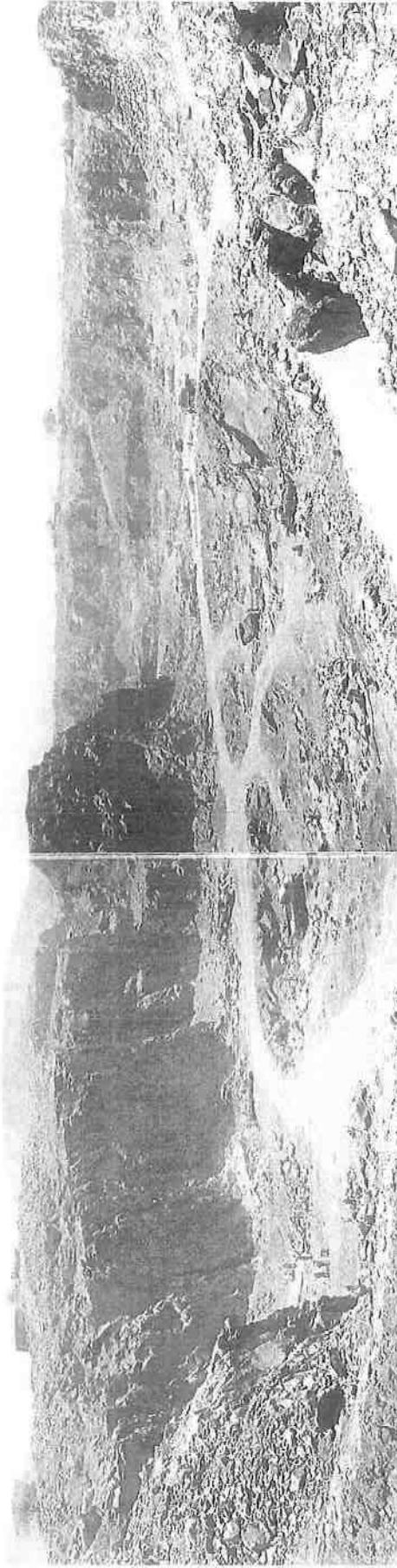


Plate No. 1.2 Transportation of Quarried Material to Stone Crushers

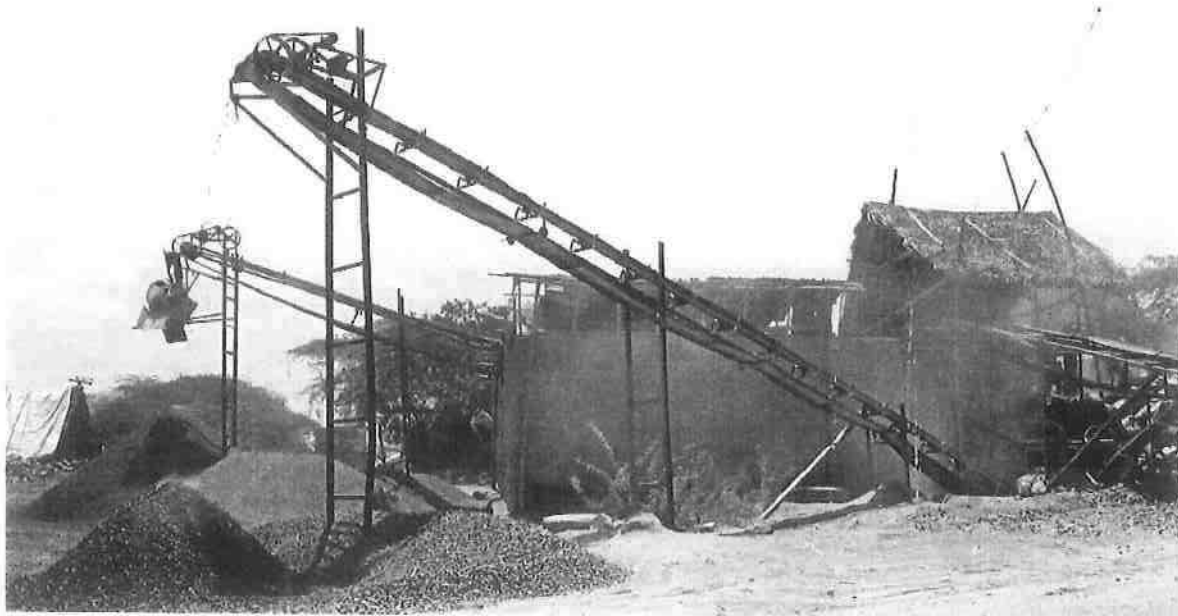


Plate No. 1.3 A View of Stone Crusher in Operation

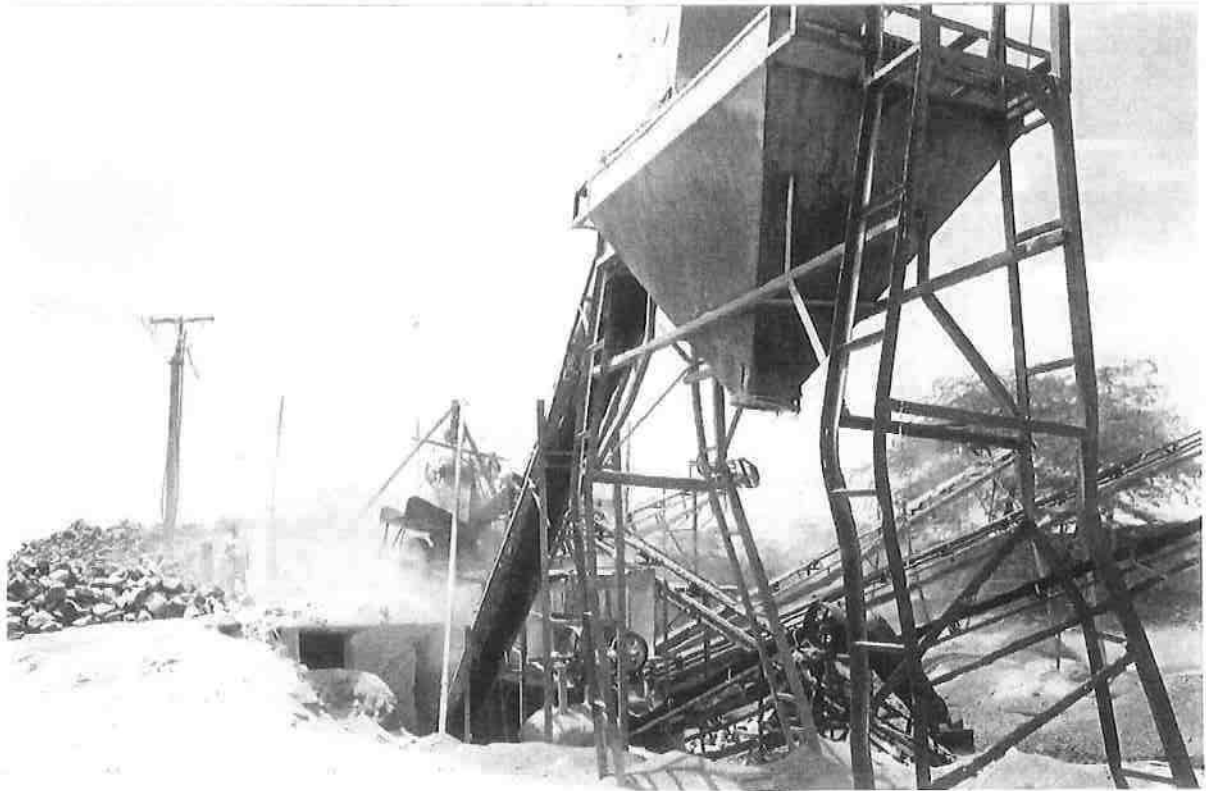


Plate No. 1.4 A View of Stone Crusher in Operation

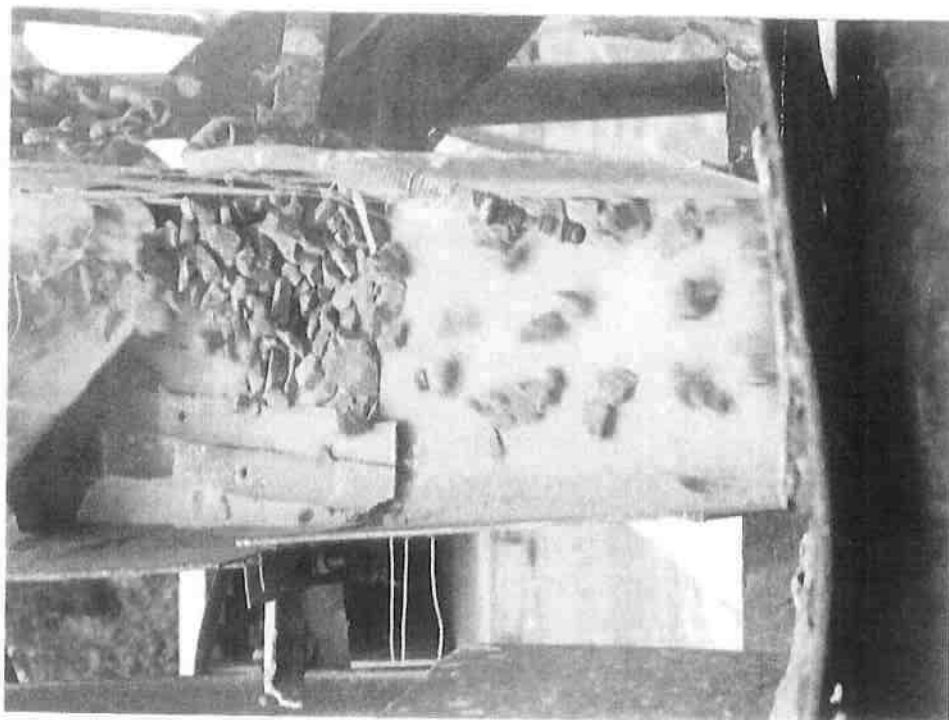
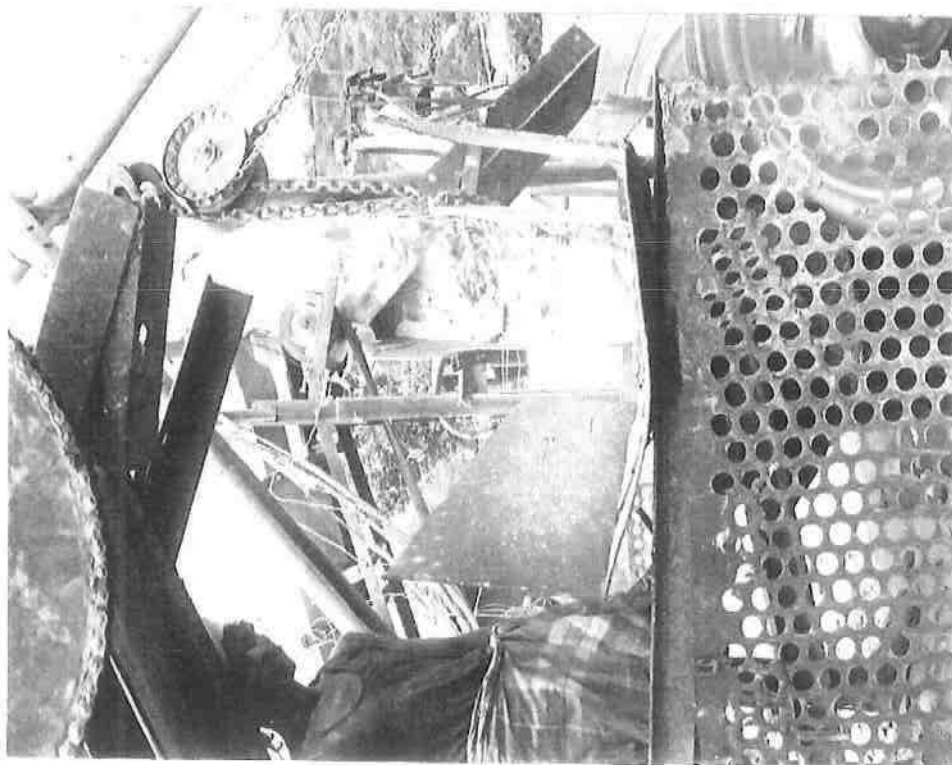


Plate No. 1.5 A Close View of Stone Crusher

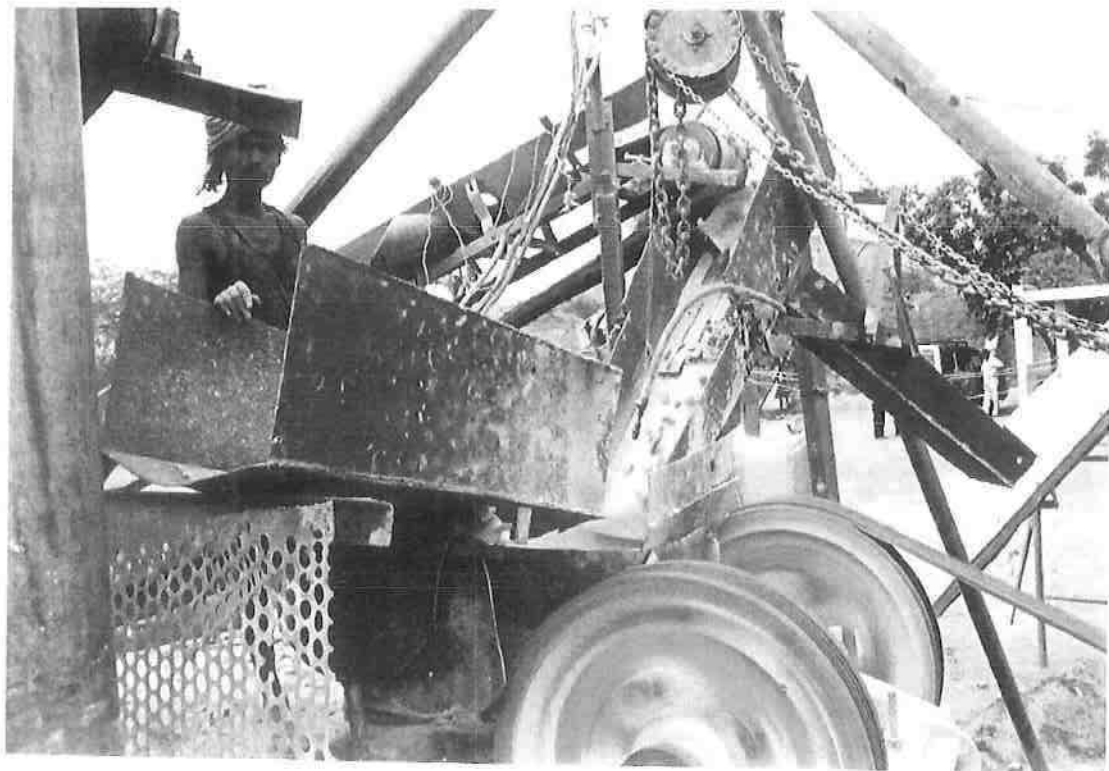


Plate No. 1.6 A Close View of Stone Crusher



**Plate No. 1.7 Location of Automatic Weather Station
inside the Stone Crusher Area**

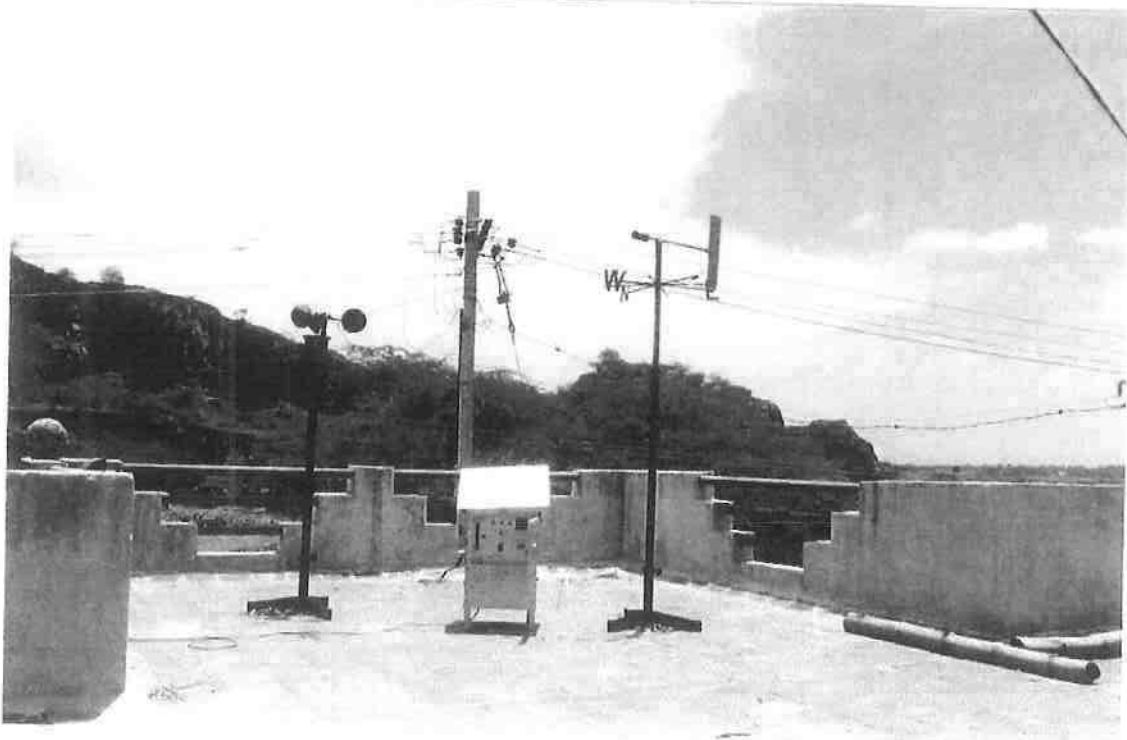


Plate No. 1.8 Location of Wind Monitor inside the Residential Area

CHAPTER 2

MATERIALS AND METHODS

2.1 Ambient air quality monitoring network design

A weather station was installed near the crushing area, prior to the schedule of sampling. Wind parameters like wind direction and wind speed were measured prior to the sampling programme, so as to enable fixing up of the upwind and downwind sampling locations for the Ambient Air Quality Programme with respect to the particulate matter. Based on the pilot observations the air sampling network was designed and implemented. Data collection was continued throughout the course of the study. Besides wind direction and wind speed, parameters like temperature and relative humidity were also recorded during the study period.

2.2 Weather monitoring

A weather station consisting of wind vane, cup anemometer, and thermo-hygrometer was installed at a height of 3 m in an open space on the southeastern side of the crushing area prior to the dust sampling program. Wind speed and direction were monitored continuously for every 1 hour to determine the upwind and downwind directions for the air quality monitoring program. One hour average values were observed for 24 hours continuously over a period of 7 days. Besides wind speed and direction, parameters such as temperature, pressure, rainfall, and humidity were also recorded.

2.3 Air quality monitoring

The dust was collected on Whatman GF/A (size 25.4 cm x 20.32 cm) glass fiber filter paper with a pore size of 1 μm using high volume samplers (Envirotech APM 460 and 430, Envirotech, New Delhi, India), operating at a flow rate of 0.8–1.0 m^3/min . The volumetric flow rate was measured using a calibrated orifice meter (attached part of APM 460 and 430 samplers). All the high volume samplers were calibrated prior to and after each sampling exercise using a field calibration kit consisting of a standard orifice calibrator (APM 421, Envirotech, New Delhi, India). Dust monitoring was carried out by employing an ambient air quality monitoring network consisting of 17 sampling locations, designed based on meteorology, number of stone crushing units, and their spacing and cluster area (Fig. 1.1). Ambient air quality monitoring (AAQM) was carried out for 42 days continuously on a 12 hourly basis (6 am - 6 pm) and the concentrations were averaged for 24 hours to facilitate comparison with the Indian standards. The dust concentration was calculated from the difference in the weight of the filter paper before and after the sample collection.

2.4 Particle size analysis

The particle size distribution was carried out by the laser beam technology using CILAS 1180 model particle size analyzer after subjecting the collected dust to suspension as discrete particles in a liquid media. The particle sizes determined by this method were compared with PM₁₀ and PM_{2.5} concentrations monitored by using samplers at the site and were found to be equivalent to aerodynamic size, depending on the density and shape of the particles. The dust collected was completely subjected to particle size analysis so as to avoid undercount of small particles. Of the many particle size measuring methods, the laser beam technology has distinct advantages, such as simplified operation, excellent repeatability, and a short measuring time of 3 minutes.

2.5 Assessment of occupational exposure level

Personal samplers were employed for the assessment of total dust and respirable particulate matter exposure on the workers and were worn by them, with the collection media clipped close to their collars. The monitoring was carried out for 30 days for 12 hours continuously (6 am - 6 pm being the 12 hours operation period of all stone crushing units). Respirable dust samples were collected using 10 mm nylon cyclones (SKC Inc., Pa.) equipped with a 37 mm diameter poly vinyl chloride (PVC) filter (pore size 5 μ m) at a flow rate of 1.7 lpm using constant flow pump supplied by Technovations, Mumbai, India (Model AS-2). This achieves a median cut point of 4 μ m and meets the criteria of respirable dust. Total dust samples were collected using the same devices but without the cyclones in the sampling train. All pumps were calibrated prior to and after each sampling exercise using a field soap bubble meter. Pumps were also calibrated after each field exercise using a minibuck soap bubble meter (SKC Inc., United States) in the laboratory. In total, 10% of all the samples were subjected to analysis as field blanks.

All filters were conditioned for 24 hours before weighing. Respirable dust concentrations were calculated by dividing the blank corrected filter weight increase by the total air volume sampled. Gravimetric analyses were conducted using a Mettler 10 μ g microbalance calibrated against standards provided by the National Physical Laboratory in New Delhi, India. Since the dust concentrations were extremely high and filters exceeded the maximal loading volume within 15 - 30 min of sampling, 24 - 48 samples were taken during the entire work shift period and 12 hour average concentration was computed.

2.6 Prediction of fugitive dust emissions

Prediction is a crucial and important step in any air quality monitoring programme. Fugitive dust model (FDM), ISCST3 and AERMOD were employed for prediction of dust emission from stone crushers surrounding areas. FDM is a computerized Gaussian-plume air quality dispersion model, specifically designed for estimation of concentrations and deposition impacts from fugitive dust sources. FDM is capable of handling upto maximum of 121 sources and 200 receptors at a time. FDM employs an advanced gradient-transfer particle deposition algorithm. Gravitational settling velocity and deposition velocity are calculated by FDM for each of upto 20 user-specified particle size classes for 1200 receptors at a time.

Industrial Source Complex Short Term (ISCST3, version 3) model provides options to model emissions from a wide range of sources. The ISCST3 models include several new features. A revised area source algorithm and revised dry deposition algorithm have been incorporated in the models. The ISCST3 models also include an algorithm for modeling impacts of particulate emissions from open pit sources, such as surface coal mines. The Short Term model includes a new wet deposition algorithm, and also incorporates the COMPLEX1 screening model algorithms for use with complex and intermediate terrain.

AMS/EPA regulatory model (AERMOD) serves as a complete replacement for ISC3, with the exception of treating pollutant deposition. AERMOD is a steady-state plume model. In the stable boundary layer (SBL), it assumes the concentration distribution to be Gaussian in both the vertical and horizontal. In the convective boundary layer (CBL), the horizontal distribution is also assumed to be Gaussian, but the vertical distribution is described with a bi-Gaussian probability density function (pdf). One of the major improvements that AERMOD brings to applied dispersion modeling is its ability to characterize the PBL through both surface and mixed layer scaling.

2.7 Design of green belt development

Trees are one of the nature's most generous gifts to mankind. Grownup trees are important for shelter for all, protect from summer, absorbing carbon dioxide and releasing oxygen, prevent soil erosion, and control soil fertility, minimize air, dust and noise pollution. Planting was designed to include: 1. Peripheral planting to protect the nearby residential areas, 2. Avenue planting, 3. Planting around crushers, 4. Planting around quarry, 5. Hill top planting, to arrest dust pollution in the stone crushing areas at Trisoolam. The photographs depicting air sampling programme are shown in **Plates 2.1 - 2.3**.



Plate No. 2.1 Ambient Air Quality Monitoring at Stone Crusher



Plate No. 2.2 Ambient Air Quality Monitoring at Stone Crusher



Plate No. 2.3 Ambient Air Quality Monitoring at Residential Area



CHAPTER 3

SAMPLING PROGRAMME AND RESULTS

Sampling programme was designed to assess the dust emissions from source and ambient air while (1) all the crushers were in operation (2) half of the crushers were in operation (3) $1/4^{\text{th}}$ of the crushers were in operation (4) $1/8^{\text{th}}$ of the crushers were in operation (5) only one crusher was in operation (6) there was no crushing activity, only vehicle traffic/movement. This sampling programme as listed in Table 3.1 will facilitate in fixing the permissible distance from habitation and highways from the periphery of the crushing area on all sides.

Accordingly, reconnaissance survey was conducted during the period June 16 - 23, 2005 for about 7 days for monitoring wind speed and wind direction for fixing air quality monitoring stations.

3.1 Sampling with all the crushers in operation

All the crushers (69) were operated during the period June 24 - 30, July 15 - 17, and July 28 - August 5, 2005 for 16 days continuously. Ambient air quality monitoring network consisting of 17 locations were identified based on prevailing wind pattern, stone crusher location and their geometry. The list of stone crushers in operation during the above period is given in Table 3.2 and their locations are depicted in Fig. 3.1. Out of 72 stone crushing units in the locality, source dust monitoring was carried out at 10 stone crushing units. 10 air samplers were employed at source (TSPM 8, RSPM 2) and seven in ambient air (TSPM 4, RSPM 3). During the same period micro-meteorological data were also collected at 3 identified locations, one inside stone crushing area near Subramaniam BM and two in the residential area viz., Trisoolam-2 and Kennedy valley. The distance and direction of ambient air quality monitoring stations with reference to stone crushers are given in Table 3.3.

3.1.1 Weather monitoring

Total Suspended and Respirable Particulate Matter (RSPM) were collected using high volume samplers (a cyclone separator unit was used in the high volume sampler to separate PM_{10} and higher fractions) placed at selected locations to determine the dust concentrations near the source and in the surrounding areas. The sampling locations were selected based on



Table 3.1 Air quality surveillance program schedule

S. No.	Sampling	Period
1	Preliminary Survey	June 16 - 23, 2005
2	All Crushers in Operation	June 24 - 30, July 15 - 17, July 28 - Aug 5, 2005
3	35 Crushers in operation	July 1 - 7, 2005
4	18 Crushers in operation	July 8 - 14, 2005
5	9 Crushers in operation	July 18 - 22, 2005
6	Only one Crusher in operation	July 23 - 25, 2005
7	No Crushing activity only Vehicle Traffic/Movement	July 26 - 27, 2005
8	Overall study period	June 16 - Aug 5, 2005

Table 3.2
List of all the crushers in operation at Trisoolam

S. No.	Name of the Crusher	Crusher No. in the map (Fig 3.1)
1	Thirumalaiyan BM	64
2	Pattabiram BM	60
3	K. Thirugnanam BM	3
4	Gnanaselvam BM	61
5	Maragatham BM	63
6	Radhakrishnan BM	58
7	Sri Lakshmi BM	56
8	Balaji BM	57
9	Lawanya 1 BM	59
10	Lawanya 11 BM	65
11	Brammashakthi BM	50
12	Swaminathan BM	49
13	Bharani BM	53
14	Ashok BM	51
15	Sri Ram BM	42
16	Sivasankaran BM	54
17	Vijayaram BM	52
18	Suraka BM	62
19	Duvaraka-SMT	55
20	Kamatchi BM	41
21	Yashwanth BM	43
22	New Yashwanth BM	1
23	Jaya Shakthi BM	44
24	Suguna BM	45



25	Praveena BM	2
26	Venkateshwara BM	38
27	T.L. Vishwanathan BM	46
28	Sriramajaya BM	12
29	Shivagaminatesh BM	47
30	Shakthi Priya BM	36
31	A.S. Murthy B.M	39
32	New Lawanaya BM	33
33	Abirami BM	37
34	Sri Raja Lakshmi BM	40
35	Subalakshmi BM	35
36	Subramanium BM	34
37	Gururajan BM	30
38	Rani BM	13
39	Hindustan BM	31
40	Janakiraman BM	32
41	Makeshwari BM	29
42	V.K.S BM	28
43	Durga BM	27
44	Shivagami BM	24
45	New Shivagami BM	26
46	Subam BM	25
47	King BM	19
48	Balamurugan BM	14
49	Vasudevan BM	10
50	Star BM	15
51	Ayya BM	17
52	Athi Lakshmi BM	7
53	Rathna BM	6
54	Kandimathi BM	4
55	Geetha BM	5
56	Vetrivelan BM	8
57	Loganayagi BM	9
58	karumariamman BM	18
59	Vigneshwara (Sri Ambigai) BM	20
60	Sri Buvaneshwari BM	21
61	Pachaiyammal BM	71
62	D.K.Srither BM	66
63	Karthic BM	67
64	New Karthic BM	68
65	Amman Arul BM	69
66	Sri Thandumariamman BM	70
67	J.R.Vimala BM	22
68	Iyyappa 1 BM	23
69	Sri Ganesh BM	48



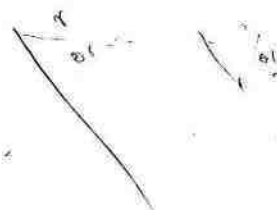
Pouch (Fig. 3.1)



Table 3.3
Location of source and ambient air quality monitoring and meteorological stations at Trisoolam (All crushers in operation)

S. No.	Sampling Locations	Direction* (deg)	Distance* (m)	Nearest Crusher from the Sampling locations	No. in the map (Fig 3.1)
Source Monitoring Locations					
1	Vigneshwara BM	235	37.5	Sri Thandumariamman BM	70
2	Subalaxmi BM	90	75	New Lawanaya BM	33
3	Rajalaxmi BM	160	37.5	A.S MurthyB.M	39
4	Ashok BM	30	75	Vijayaram BM	52
5	Suguna BM	15	93.75	Jaya Shakthi BM	44
6	JR Vimala BM	130	37.5	Karumariamman BM	18
7	Rathna BM	15	37.5	Athi Lakshmi BM	7
8	Sivakami BM	90	37.5	New Shivagami BM	26
9	Sivagami Natesan BM	100	75	Sri Ramajayam BM	12
10	Rani Anna Nagar	69	93.75	Subramaniam BM	34
Ambient air quality monitoring locations					
11	Trisoolam 1	57	188	Sri Ganesh BM	48
12	Trisoolam 2	60	56	Viswanathan BM	46
13	Sara Nagar	200	319	Thirumalaiyan BM	64
14	Zamin Pallavaram	150	375	Dwarga BM	55
15	Everedy Nagar	163	94	Vigneshwaran BM	20
16	Krishna Nagar	85	645	Praveena BM	2
17	Kennady Nagar	113	413	Thirugnanam BM	3
Meteorological locations					
18	Trisoolam II	60	56	Viswanathan BM	46
19	Subramaniam Crusher	45	1.4	Subhalakshmi BM	35
20	Kennady Valley	113	413	Loganayaki BM	9

* Direction and distance from the periphery of the nearest stone crusher





the prevalent wind direction and speed at the site, topography, location of stone crushing units, and their working schedule.

The wind direction and wind speed were recorded on hourly basis during the study period June 24 - June 30, 2005, July 15 - July 17, 2005, July 28 - August 5, 2005 and presented in the form of a wind rose diagram as shown in Fig. 3.2. The 24 hours wind rose shows that the dominant wind directions were from southwest (22%), followed by the west (21.5%) and West of South West (12.5%). The most prevalent wind speed was in the range of 5 - 10 kmph (28%) followed by 10 - 15 (13.5%) kmph. The calm condition was observed 0.71% of the time. The average wind speed observed during the above period was 8.4 kmph.

3.1.2 Dust monitoring

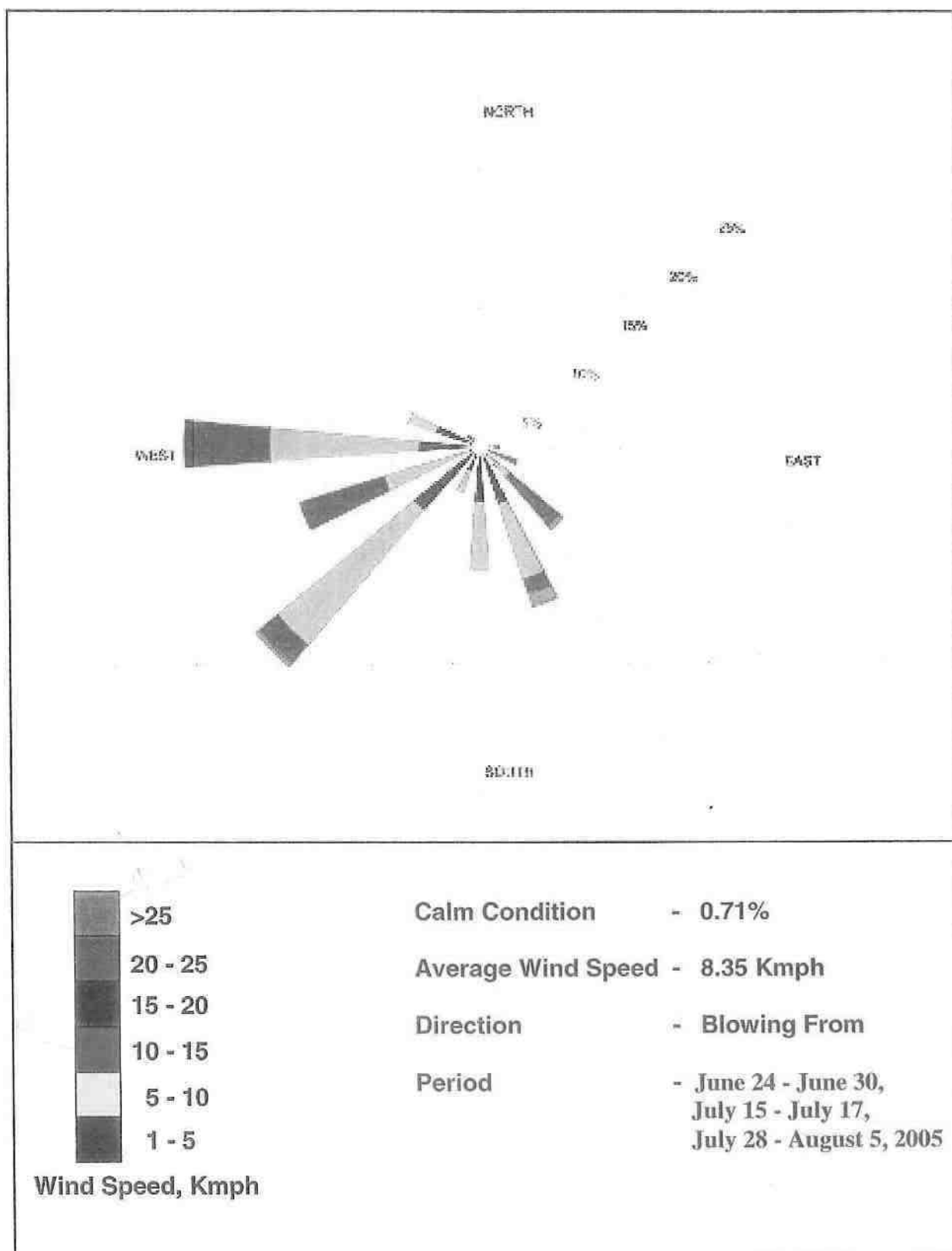
3.1.2.1 Dust concentration at source

Out of 10 source air quality monitoring stations, eight (6 TSPM, 2 RSPM) were chosen in the upwind direction and two (2 TSPM) in the downwind direction. Air quality monitoring was carried out simultaneously for all the locations during the period. The average concentration of TSPM in the upwind direction varied from 1268 to 4108 $\mu\text{g}/\text{m}^3$ with a mean of 2630 $\mu\text{g}/\text{m}^3$, as shown in Table 3.4. The average concentration of RSPM in the upwind direction varied from 274 to 754 $\mu\text{g}/\text{m}^3$ with a mean of 464 $\mu\text{g}/\text{m}^3$. The average concentration of TSPM in the downwind direction varied from 1754 to 3747 $\mu\text{g}/\text{m}^3$ with a mean of 2751 $\mu\text{g}/\text{m}^3$.

The overall source concentrations of TSPM varied from 1268 to 4108 with a mean of 2759 $\mu\text{g}/\text{m}^3$. The TSPM concentration at all locations exceeded the standard of 600 $\mu\text{g}/\text{m}^3$ at source at a distance of 3 - 10 m as recommended by Central Pollution Control Board (CPCB 1998). At all the locations, RSPM concentrations exceeded the standard of 100 $\mu\text{g}/\text{m}^3$ as shown in Table 3.5. Among the 10 stations, the highest TSPM concentration was found at Ratna BM (4108 $\mu\text{g}/\text{m}^3$) and JR Nirmala BM (654 $\mu\text{g}/\text{m}^3$) whereas the highest RSPM concentration was found at Suguna BM (274 $\mu\text{g}/\text{m}^3$) respectively.

3.1.2.2 Dust concentration around stone crushing units

Ambient dust monitoring was carried out around stone crushing units at 7 locations in the stone crushing area. Out of 7 ambient air quality monitoring stations, four (3 TSPM, 1 RSPM) were chosen in the upwind direction and three (1 TSPM, 2 RSPM) in the downwind direction. The distance and direction of ambient air quality monitoring stations with reference to stone crushers are given in Table 3.3. Air quality monitoring was carried



**Fig. 3.2 Windrose Pattern at Stone Crushing Units, Trisoolam
(With all the Crushers in Operation)**

Table 3.4
TSPM sampling at source (All crushers in operation)

S. No.	Sampling Location	No. in the map (Fig 3.1)	TSPM ($\mu\text{g}/\text{m}^3$)		
			Min.	Max.	Avg.
1	Vigneshwara BM	1	77	7465	2050 ✓
2	Subalaxmi BM	2	486	8714	3070 ✓
3	Rajalaxmi BM	3	202	3142	1268 ✓
4	Ashok BM	4	447	4839	2282 ✓
5	Rathna BM	7	604	13153	4108 ✓
6	Sivakami BM	8	201	3052	1424 ✓
7	Sivakami Nadesan BM	9	30	11063	3747
8	Rani Anna Nagar	10	139	3944	1754

Table 3.5
Respirable particulate matter and cyclone dust sampling at source (All crushers in operation)

S. No.	Sampling Location	No. in the map (Fig 3.1)	RSPM ($\mu\text{g}/\text{m}^3$)			Cyclone Dust ($\mu\text{g}/\text{m}^3$)		
			Min.	Max.	Avg.	Min.	Max.	Avg.
1	Suguna BM	5	30	1411	274 ✓	70	1342	608 ✓
2	JR Vimala BM	6	38	2647	654 ✓	146	6527	2180

Table 3.6
TSPM sampling in ambient air (All crushers in operation)

S. No.	Sampling Location	No. in the map (Fig 3.1)	TSPM ($\mu\text{g}/\text{m}^3$)		
			Min.	Max.	Avg.
1	Trisoolam 1	11	24	2445	417 ✓
2	Sara Nagar	13	21	141	65 ✓
3	Zamin Pallavaram	14	4	295	125 ✓
4	Everedy Nagar	15	13	413	152 ✓



out simultaneously for all the locations for 16 days. The average concentration of TSPM in the upwind direction varied from 65 to 152 $\mu\text{g}/\text{m}^3$, with a mean of 114 $\mu\text{g}/\text{m}^3$. The average concentration of RSPM in the upwind direction was 417 $\mu\text{g}/\text{m}^3$. The average concentration of RSPM in the downwind direction varied from 81 to 200 $\mu\text{g}/\text{m}^3$ with a mean of 165 $\mu\text{g}/\text{m}^3$. The average concentration in ambient air was very high in the downwind direction when compared to the upwind direction, of the order of 3 - 4 for TSPM and 1.5 for RSPM.

The overall concentrations of TSPM varied from 64 to 417 $\mu\text{g}/\text{m}^3$ with a mean of 190 $\mu\text{g}/\text{m}^3$. The TSPM concentration at Trisoolam-1 (417 $\mu\text{g}/\text{m}^3$) exceeded the standard of 200 $\mu\text{g}/\text{m}^3$ recommended by the CPCB as shown in Table 3.6. In other locations, the measured TSPM concentrations were within the permissible limits. The overall concentrations of RSPM varied from 81 to 200 with a mean of 149 $\mu\text{g}/\text{m}^3$ as shown in Table 3.7. The RSPM concentrations at Trisoolam-2 (200 $\mu\text{g}/\text{m}^3$) and Kennedy Nagar (165 $\mu\text{g}/\text{m}^3$) exceeded the standard of 100 $\mu\text{g}/\text{m}^3$ recommended by the CPCB.

It was observed that during working period of 12 hours in the day time (6 am to 6 pm) TSPM concentration in ambient air was about 3 - 4 times more than that of the following 12 hours (6 pm - 6 am) in the night time during which there was no crusher activity but transportation activity was carried out. During Sundays (6 pm to 6 am) when there were no crushing and transportation activities, the TSPM concentration measured corresponds to background concentration of 67 $\mu\text{g}/\text{m}^3$ and it was found to be 1/6 - 1/7 of measured concentration (all crushers running) for the working period of 6 am to 6 pm. The spatial distribution of measured concentration when all the crushers in operation are presented in the form of isopleths and surfer as shown in Fig. 3.3 and 3.4. The impact zone for all the crushers in operation is depicted in Fig. 3.5.

3.2 Sampling with half of the crushers in operation

Half of the Crushers (35) were operated during the period July 1 - 8, 2005 for 7 days continuously. Ambient air quality monitoring network consisting of 17 locations were identified based on prevailing wind pattern, stone crusher location and their geometry. The list of stone crushers in operation during the same period is given in Table 3.8 and their locations are depicted in Fig. 3.1. For half of the stone crushers in operation, source dust monitoring was carried out at 10 locations of which 3 were employed at source (TSPM 3) and seven in ambient air (TSPM 4, RSPM 3). During the same period micro-meteorological data were also collected at 3 identified locations one inside stone crushing area near Subramaniam



Table 3.7
Respirable particulate matter and cyclone dust sampling in ambient air
(All crushers in operation)

S. No.	Sampling Location	No. in the map (Fig 3.1)	RSPM ($\mu\text{g}/\text{m}^3$)			Cyclone Dust ($\mu\text{g}/\text{m}^3$)		
			Min.	Max.	Avg.	Min.	Max.	Avg.
1	Trisoolam 2	12	10	1103	200	1	190	75
2	Krishna Nagar	16	5	311	88	3	349	117
3	Kennady Nagar	17	59	406	165	27	997	307

Table 3.8
List of half of the crushers in operation at Trisoolam
(35 crushers)

S. No	Name of the Crusher	Crusher No. in the map (Fig 3.1)
1	Thirumalaiyan BM	64 ✓
2	Pattabiram BM	60 ✓
3	Radhakrishnan BM	58 ✓
4	Sri Lakshmi BM	56 ✓
5	Lawanya 1 BM	59 ✓
6	Swaminathan BM	49
7	Vinetha BM	53 ✓
8	Sri Ram BM	42
9	Sivasankaran BM	54 ✓
10	Vijayaram BM	52 ✓
11	Kamatchi BM	41
12	Yashwanth BM	43
13	Praveena BM	2
14	Sriramajayam BM	12
15	A.S Murthy B.M	39
16	Abirami BM	37
17	Subalakshmi BM	35
18	Gururajan BM	30
19	Janakiraman BM	32
20	Makeshwari BM	29
21	Durga BM	27
22	Shivagami BM	24
23	Subam BM	25
24	Balamurugan BM	14
25	Ayya BM	17
26	Athi Lakshmi BM	7
27	Geetha BM	5
28	Loganayagi BM	9
29	Karumariamman BM	18

30	Sri Buvaneshwari BM	21
31	D.K.Srither BM	66 ✓
32	Karthic BM	67 ✓
33	Amman Arul BM	69 ✓
34	Sri Thandumariamman BM	1770
35	Sri Ganesh BM	48

Table 3.9
Locations of source and ambient air quality monitoring and meteorological stations at Trisoolam (Half of the crushers in operation)

S. No.	Sampling Locations	Direction* (deg)	Distance* (m)	Nearest Crusher from the Sampling locations	No. in the map (Fig 3.1)
Source Monitoring Locations					
1	Vigneshwara BM	227	75	Amman Arul BM	69
2	Subalaxmi BM	90	131.25	Abirami BM	37
10	Rani Anna Nagar	300	156	Durga BM	27
Ambient air quality monitoring locations					
11	Trisoolam 1	58	188	Sri Ganesh BM	48
12	Trisoolam 2	203	86	Sri Ganesh BM	48
13	Sara Nagar	198	319	Thirumalaiyan BM	64
14	Zamin Pallavaram	148	458	Lakshmi BM	56
15	Everedy Nagar	186	139	Karumariamman BM	18
16	Krishna Nagar	85	656	Praveena BM	2
17	Kennady Nagar	120	356	Praveena BM	2
Meteorological locations					
18	Trisoolam II	203	86	Sri Ganesh BM	48
19	Subramaniam Crusher	45	53	Subhalakshmi BM	35
20	Kennady Valley	120	356	Praveena BM	2

* Direction and distance from the periphery of the nearest stone crusher

Table 3.10
TSPM sampling at source (35 crushers in operation)

S. No.	Sampling Location	No. in the map (Fig 3.1)	TSPM ($\mu\text{g}/\text{m}^3$)		
			Min.	Max.	Avg.
1	Vigneshwara BM	1	1537	5922	2962
2	Subalaxmi BM	2	1961	5283	3735
3	Rani Anna Nagar	10	576	3390	1691

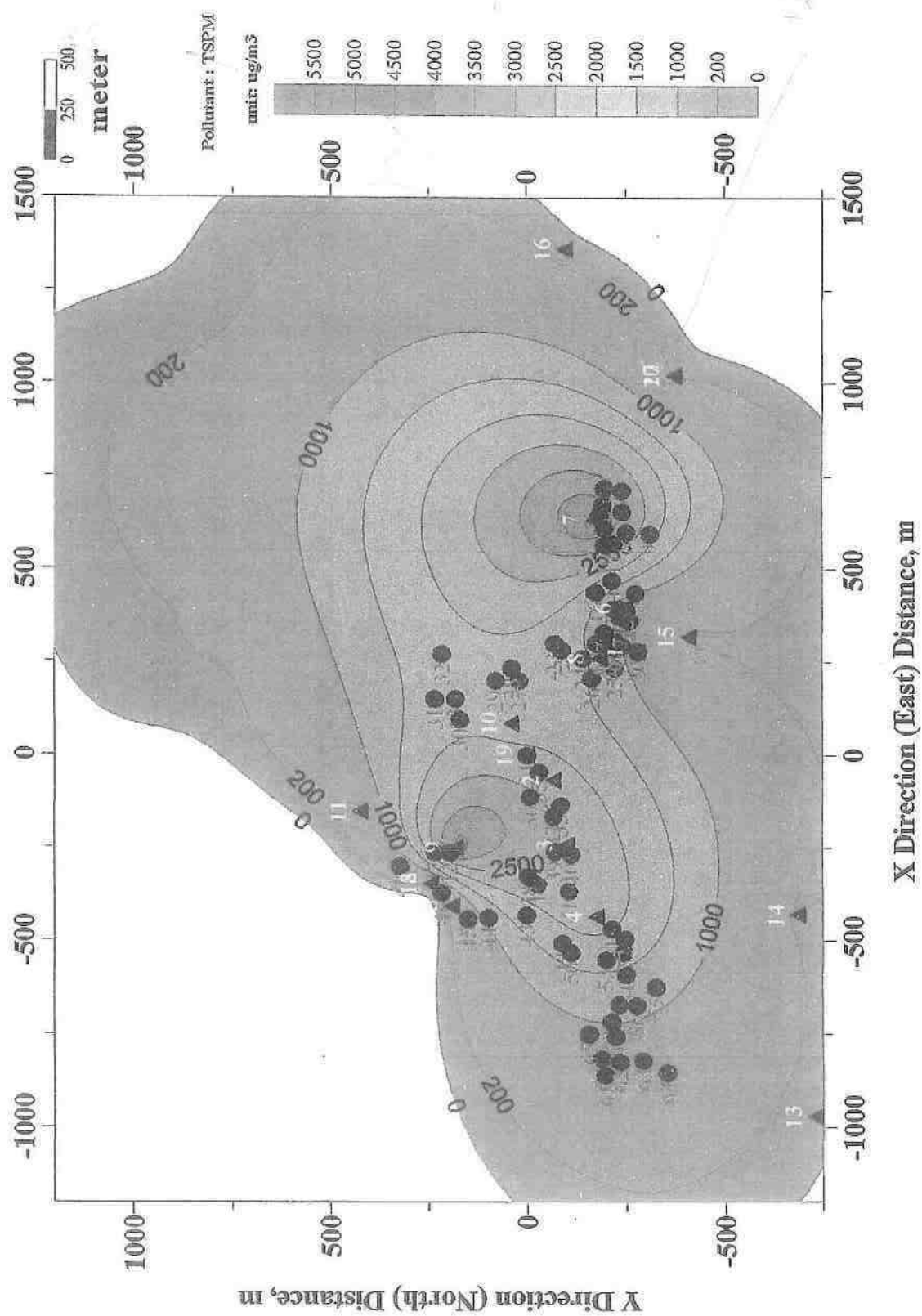


Fig. 3.3 Isopleths showing measured concentration (all the crushers in operation)

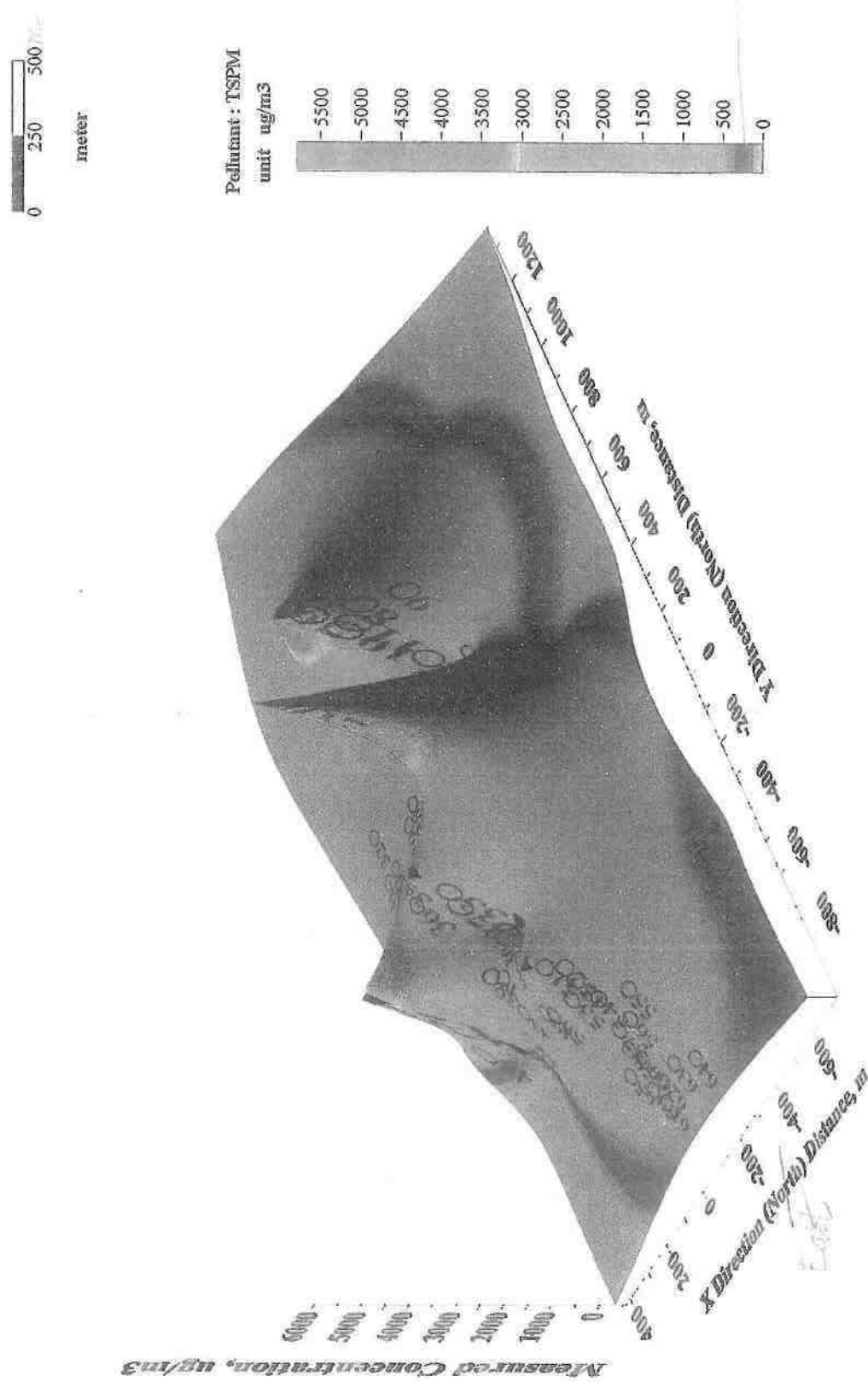
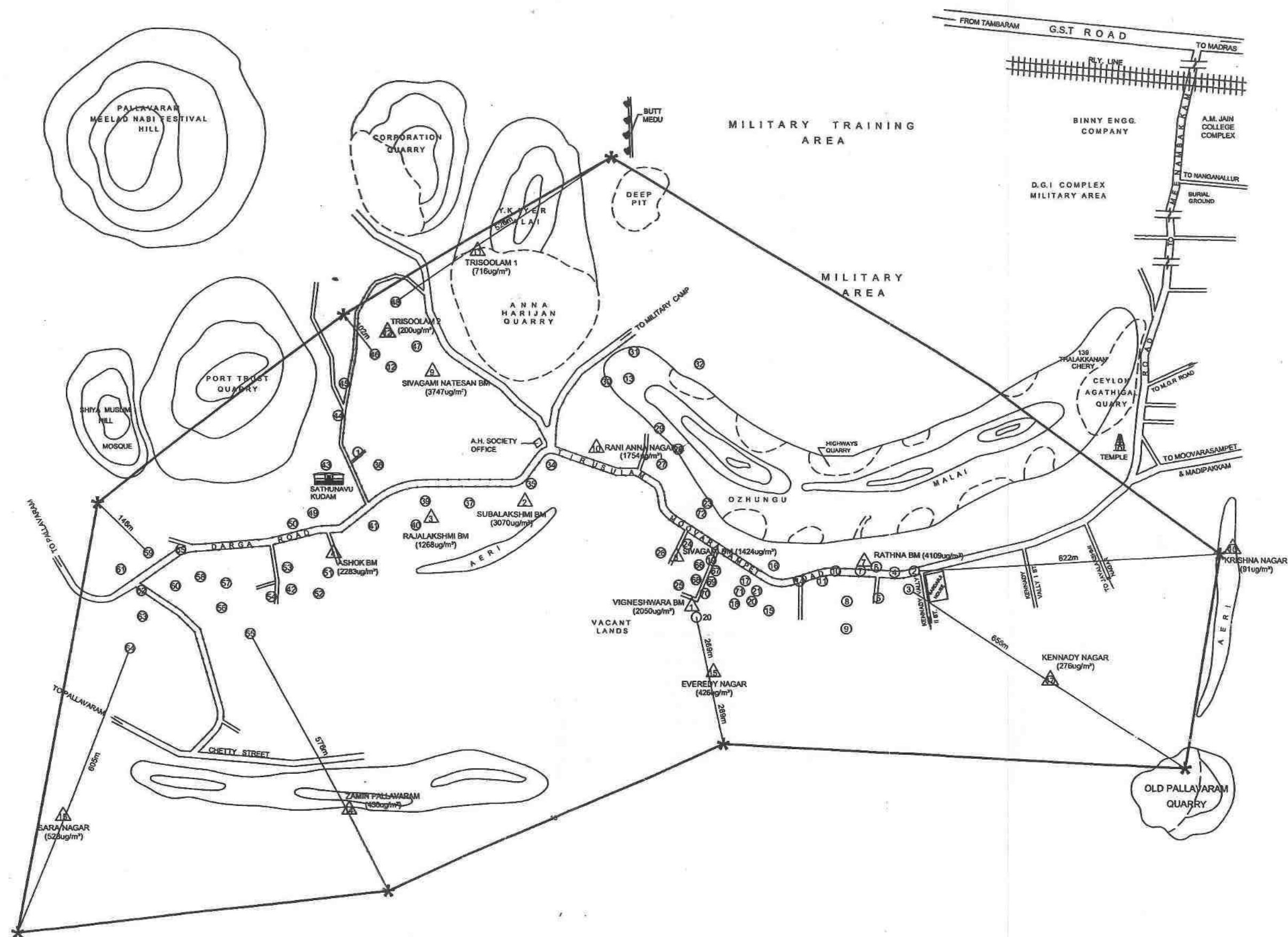


Fig. 3.4 Surfer showing measured concentration (all the crushers in operation)



37



BM and two in the residential area viz., Trisoolam 2 and Kennedy valley. The distance and direction of ambient air quality monitoring stations with reference to stone crushers are given in Table 3.9.

3.2.1 Weather monitoring

The wind direction and wind speed were recorded on hourly basis during the study period July 1 - July 7, 2005 and presented in the form of a wind rose diagram as shown in Fig. 3.6. The 24 hours wind rose shows that the dominant wind directions were from southwest (22%), followed by the West of South West (20.5%), West (18%), South of South East (14%) and South (10%). The most prevalent wind speed was in the range of 5 - 10 kmph (33.5%) followed by 10 - 15 kmph (21%) with no calm condition. The average wind speed observed during the above period was 7.8 kmph.

3.2.2 Dust monitoring

3.2.2.1 Dust concentration at source

Out of 3 source air quality monitoring stations, two (2 TSPM) were chosen in the upwind direction and one (1 TSPM) in the downwind direction. Air quality monitoring was carried out simultaneously for all the locations during the period. The average concentration of TSPM in the upwind direction varied from 2050 to 3071 $\mu\text{g}/\text{m}^3$ with a mean of 2560 $\mu\text{g}/\text{m}^3$. The average concentration of TSPM in the downwind direction was 1754 $\mu\text{g}/\text{m}^3$.

The overall concentrations of TSPM varied from 1691 to 3735 $\mu\text{g}/\text{m}^3$ with a mean of 2796 $\mu\text{g}/\text{m}^3$. The highest TSPM average concentrations ^{were recorded} were found at Subalaxmi BM (3735 $\mu\text{g}/\text{m}^3$) as shown in Table 3.10. The TSPM concentration at all locations exceeded the standard of 600 $\mu\text{g}/\text{m}^3$ at source at a distance of 3 - 10 m as recommended by CPCB.

3.2.2.2 Dust concentration around stone crushing units

Ambient dust monitoring was carried out around stone crushing units at 7 locations in the stone crushing area. The distance and direction of ambient air quality monitoring stations with reference to stone crushers are given in Table 3.9. Air quality monitoring was carried out simultaneously for all the locations for 7 days. Out of 7 ambient air quality monitoring stations, four (3 TSPM, 1 RSPM) were chosen in the upwind and three (1 TSPM, 2 RSPM) in the downwind direction. The average concentration of TSPM in the upwind direction varied from 126 to 166 $\mu\text{g}/\text{m}^3$ with a mean of 150 $\mu\text{g}/\text{m}^3$. The average concentration of RSPM in the upwind direction was 250 $\mu\text{g}/\text{m}^3$. The average concentration of TSPM in the downwind direction was 521 $\mu\text{g}/\text{m}^3$. The average concentration of RSPM in the downwind direction

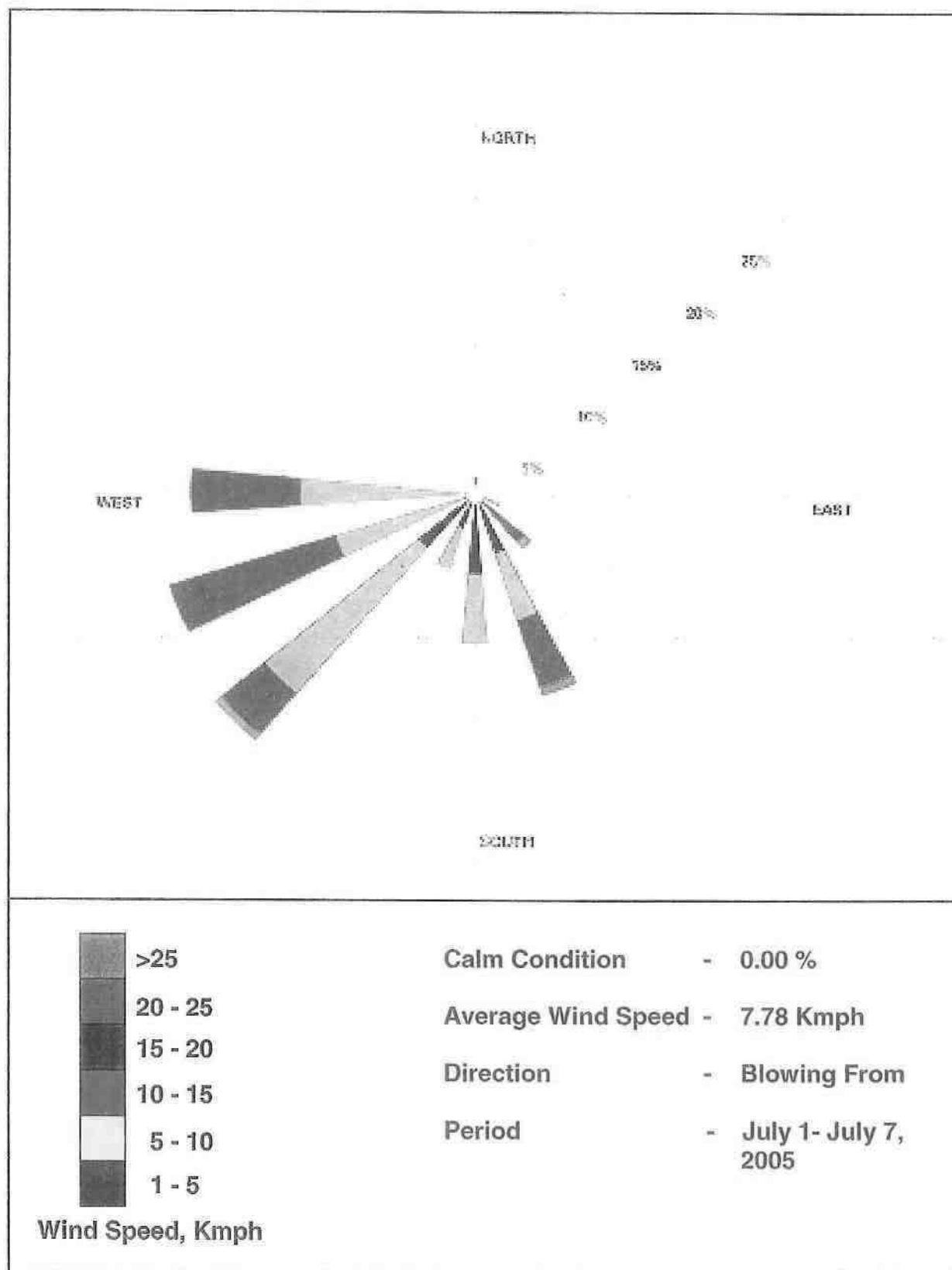


Fig. 3.6 Wind rose Pattern at Stone Crushing Units, Trisoolam
(With Half of the Crushers in Operation)



varied from 56 - 155 $\mu\text{g}/\text{m}^3$ with a mean of 250 $\mu\text{g}/\text{m}^3$. The highest average concentration in ambient air was very high in the downwind direction when compared to the upwind direction, of the order of 2 to 3 for TSPM and 2 to 3 for RSPM.

The overall concentrations of TSPM varied from 88 to 346 $\mu\text{g}/\text{m}^3$ with a mean of 189 $\mu\text{g}/\text{m}^3$. The average TSPM concentration at Trisoolam 1 (346 $\mu\text{g}/\text{m}^3$) exceeded the standard of 200 $\mu\text{g}/\text{m}^3$ recommended by the Central Pollution Control Board (CPCB 1998) as shown in **Table 3.11**. In other locations, the measured TSPM concentrations were within the permissible limits. The average concentrations of RSPM varied from 56 to 250 $\mu\text{g}/\text{m}^3$ with a mean of 54 $\mu\text{g}/\text{m}^3$ as shown in **Table 3.12**. The average concentrations of RSPM at Trisoolam 2 and Kennedy Nagar exceeded the standard of 100 $\mu\text{g}/\text{m}^3$ recommended by the CPCB.

It was observed that during the working period of 12 hours in the day time (6 am to 6 pm) TSPM concentrations in ambient air were about 2 - 3 times more than that of the following 12 hours in the night time (6 pm - 6 am) during which there was no crusher activity but transportation activity was carried out. During Sundays (6 pm to 6 am) there were no crushing and transportation activities, the TSPM concentration measured corresponds to background concentration of 67 $\mu\text{g}/\text{m}^3$ and it was found to be 1/2 - 1/3 of measured concentration (half of the crushers in operation) for the working period of 6 am to 6 pm. The spatial distribution of measured concentration when all the crushers in operation are presented in the form of isopleths and surfer as shown in **Fig. 3.7 and 3.8**. The impact zone for all the crushers in operation is depicted in **Fig. 3.9**.

3.3 Sampling with 1/4th of the crushers in operation

During the period July 1 - 8, 2005, for about 7 days, 1/4th of the crushers were operated (18) continuously. Ambient air quality monitoring network consisting of 17 locations were identified based on prevailing wind pattern, stone crusher location and their geometry. The list of stone crushers in operation during the same period is given in **Table 3.13** and their locations are depicted in **Fig. 3.1**. For 1/4th of the stone crushers in operation, source dust monitoring was carried out at 3 stone crushing units of which 3 were employed at source (TSPM 3) and seven were in ambient air (TSPM 5, RSPM 2). During the same period micro-meteorological data were also collected at 3 identified locations one inside stone crushing area near Subramaniam BM and two in the residential area viz., Trisoolam- 2



Table 3.11
TSPM sampling in ambient air (35 crushers in operation)

S. No.	Sampling Location	No. in the map (Fig 3.1)	TSPM ($\mu\text{g}/\text{m}^3$)		
			Min.	Max.	Avg.
1	Trisoolam 1	11	68	1140	346
2	Sara Nagar	13	26	174	88
3	Zamin Pallavaram	14	48	296	157
4	Everedy Nagar	15	17	359	166

Table 3.12
Respirable particulate matter and cyclone dust sampling in ambient air (35 crushers in operation)

S. No.	Sampling Location	No. in the map (Fig 3.1)	RSPM ($\mu\text{g}/\text{m}^3$)			Cyclone Dust ($\mu\text{g}/\text{m}^3$)		
			Min.	Max.	Avg.	Min.	Max.	Avg.
1	Trisoolam 2	12	17	209	155	21	104	63
2	Krishna Nagar	16	28	109	56	14	193	66
3	Kennady Nagar	17	89	499	250	6	753	324

Table 3.13
List of 1/4th of the crushers in operation at Trisoolam (18 crushers)

S. No.	Name of the Crusher	Crusher No. in the map (Fig 3.1)
1	Vijayaram BM	52
2	Kamatchi BM	41
3	Yashwanth BM	43
4	New Yashwanth BM	1
5	Jaya Shakthi BM	44
6	Suguna BM	45
7	Praveena BM	2
8	New Mahalakshmi BM	38
9	T.L.Vishwanathan BM	46
10	Sriramajayam BM	12
11	Shivagami Natesan BM	47
12	Shakthi Priya BM	36
13	A.S Murthy	39
14	Abirami BM	37
15	Sri Raja Lakshmi BM	40
16	Subalakshmi BM	35
17	Subramanium BM	34
18	Sri Ganesh BM	48

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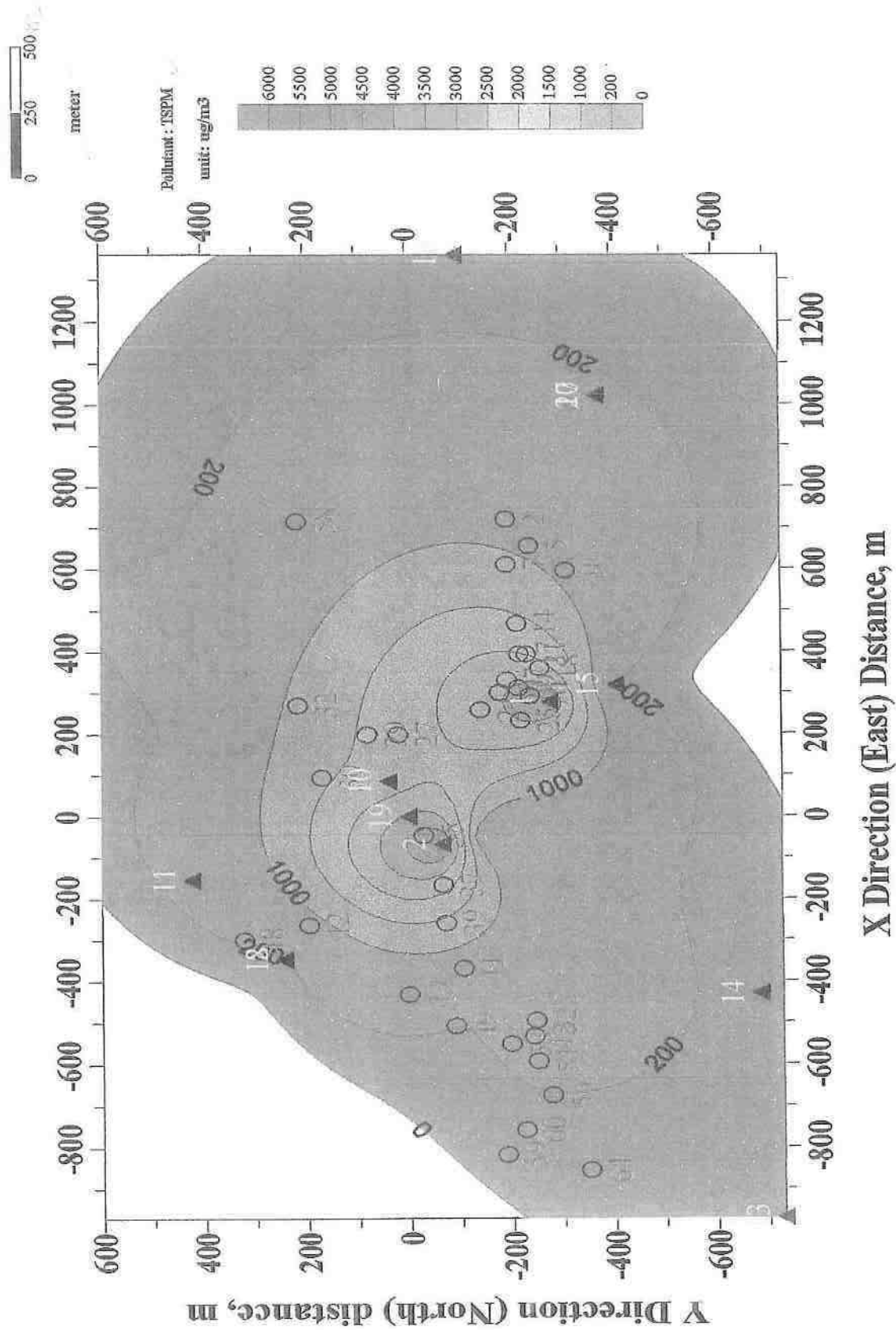


Fig. 3.7 Isopleths showing measured concentration (half of the crushers in operation)

Handwritten notes and a small sketch of a rectangular area with a line across it.

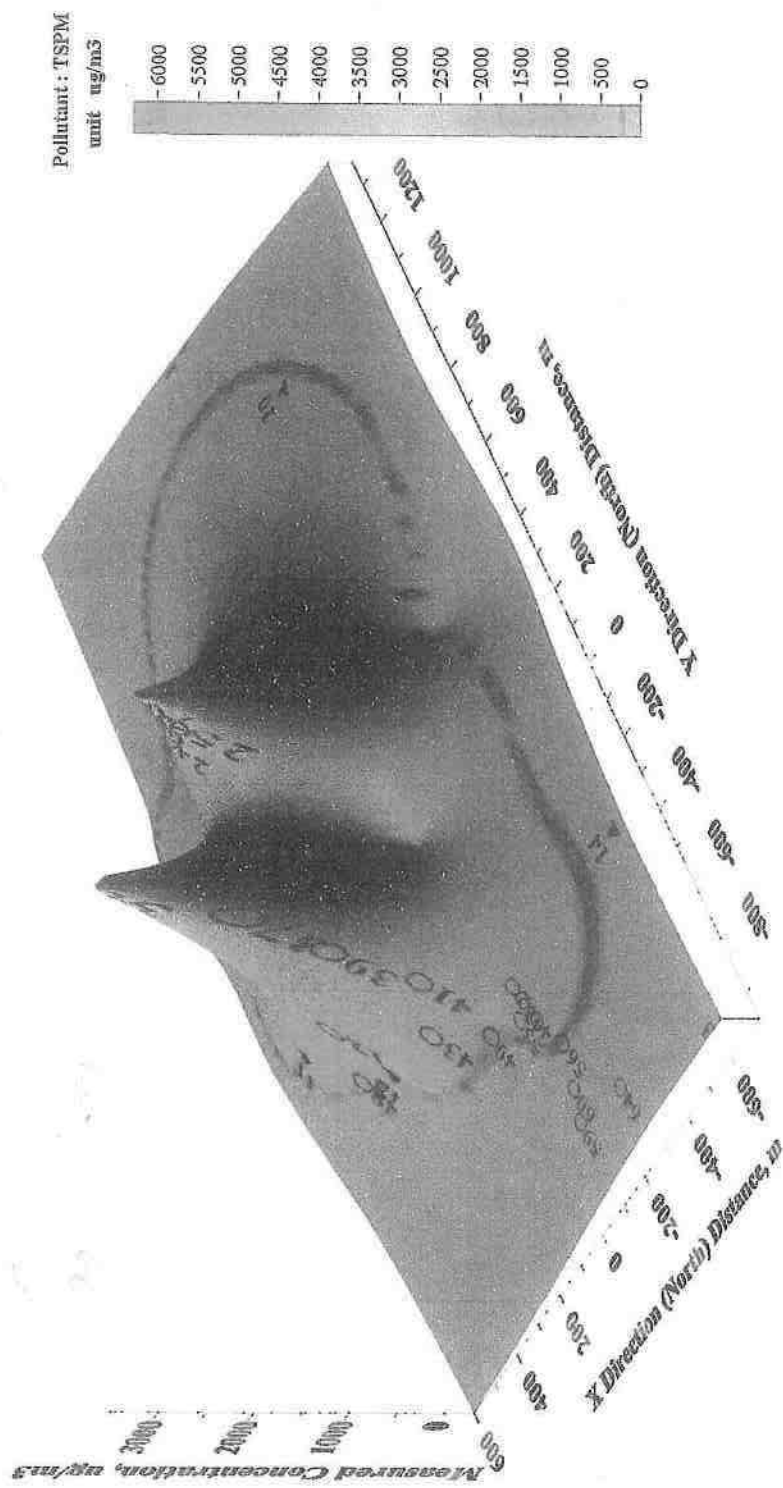


Fig. 3.8 Surfer showing measured concentration (half of the crushers in operation)





and Kennedy valley. The distance and direction of ambient air quality monitoring stations with reference to stone crushers are given in **Table 3.14**.

3.3.1 Weather monitoring

The wind direction and wind speed were recorded on hourly basis during the study period July 8 - July 14, 2005 and presented in the form of a wind rose diagram as shown in **Fig. 3.10**. The 24 hours wind rose shows that the dominant wind directions were West of South West (14.5%), followed by the South East (11%), East (10%), South of South East (9.5%) and West (10%). The most prevalent wind speed was in the range of 5 - 10 kmph (22%) followed by 10 - 15 (12%) kmph. The calm condition was observed for about 0.6% of the time. The average wind speed observed during the above period was 12 kmph.

3.3.2 Dust monitoring

3.3.2.1 Dust concentration at source

Out of 3 source air quality monitoring stations, two (2 TSPM) were chosen in the upwind direction and one (1 TSPM) in the downwind direction. Air quality monitoring was carried out simultaneously for all the locations during the period. The average concentration of TSPM in the upwind direction varied from 2014 to 2845 $\mu\text{g}/\text{m}^3$ with a mean of 2429 $\mu\text{g}/\text{m}^3$. The average concentration of TSPM in the downwind direction was 1691 $\mu\text{g}/\text{m}^3$.

The overall concentrations of TSPM varied from 2014 to 2845 $\mu\text{g}/\text{m}^3$ with a mean of 2469 $\mu\text{g}/\text{m}^3$. The highest TSPM average concentrations were found at Subalaxmi BM (2845 $\mu\text{g}/\text{m}^3$) as shown in **Table 3.15**. The TSPM concentrations at all locations exceeded the standard of 600 $\mu\text{g}/\text{m}^3$ at source at a distance of 3 - 10 m as recommended by CPCB.

3.3.2.2 Dust concentration around stone crushing units

Ambient dust monitoring was carried out around stone crushing units at 7 locations in the stone crushing area. The distance and direction of ambient air quality monitoring stations with reference to stone crushers are given in **Table 3.14**. Air quality monitoring was carried out simultaneously for all the locations for 7 days. Out of 7 ambient air quality monitoring stations, two (2 TSPM) were chosen in the upwind and five (3 TSPM, 2 RSPM) in the downwind direction. The average concentration of TSPM in the upwind direction varied from 88 - 152 $\mu\text{g}/\text{m}^3$ with a mean of 122 $\mu\text{g}/\text{m}^3$. The average concentration of TSPM in the downwind direction varied from 306 - 418 $\mu\text{g}/\text{m}^3$ with a mean of 362 $\mu\text{g}/\text{m}^3$. The average concentration of RSPM in the upwind direction varied from 80 - 165 $\mu\text{g}/\text{m}^3$ with a mean of



Table 3.14
Location of source and ambient air quality monitoring and meteorological stations at Trisoolam (18 crushers in operation)

S. No.	Sampling Locations	Direction* (deg)	Distance* (m)	Nearest Crusher from the Sampling locations	No. in the map (Fig 3.1)
Source Monitoring Locations					
1	Vigneshwara BM	135	375	Subramaniam BM	34
2	Subalaxmi BM	215	75	Subramaniam BM	34
10	Rani Anna Nagar	45	107.5	Subramaniam BM	34
Ambient air quality monitoring locations					
11	Trisoolam 1	56	191	Sri Ganesh BM	48
12	Trisoolam 2	208	83	Sri Ganesh BM	48
13	Sara Nagar	228	615	Vijayaram BM	52
14	Zamin Pallavaram	170	446	Vijayaram BM	52
15	Everedy Nagar	240	443	Praveena BM	2
16	Krishna Nagar	85	645	Praveena BM	2
17	Kennady Nagar	115	368	Praveena BM	2
Meteorological locations					
18	Trisoolam II	208	83	Sri Ganesh BM	48
19	Subramaniam Crusher	45	53	Subhalakshmi BM	35
20	Kennady Valley	115	368	Praveena BM	2

* Direction and distance from the periphery of the nearest stone crusher

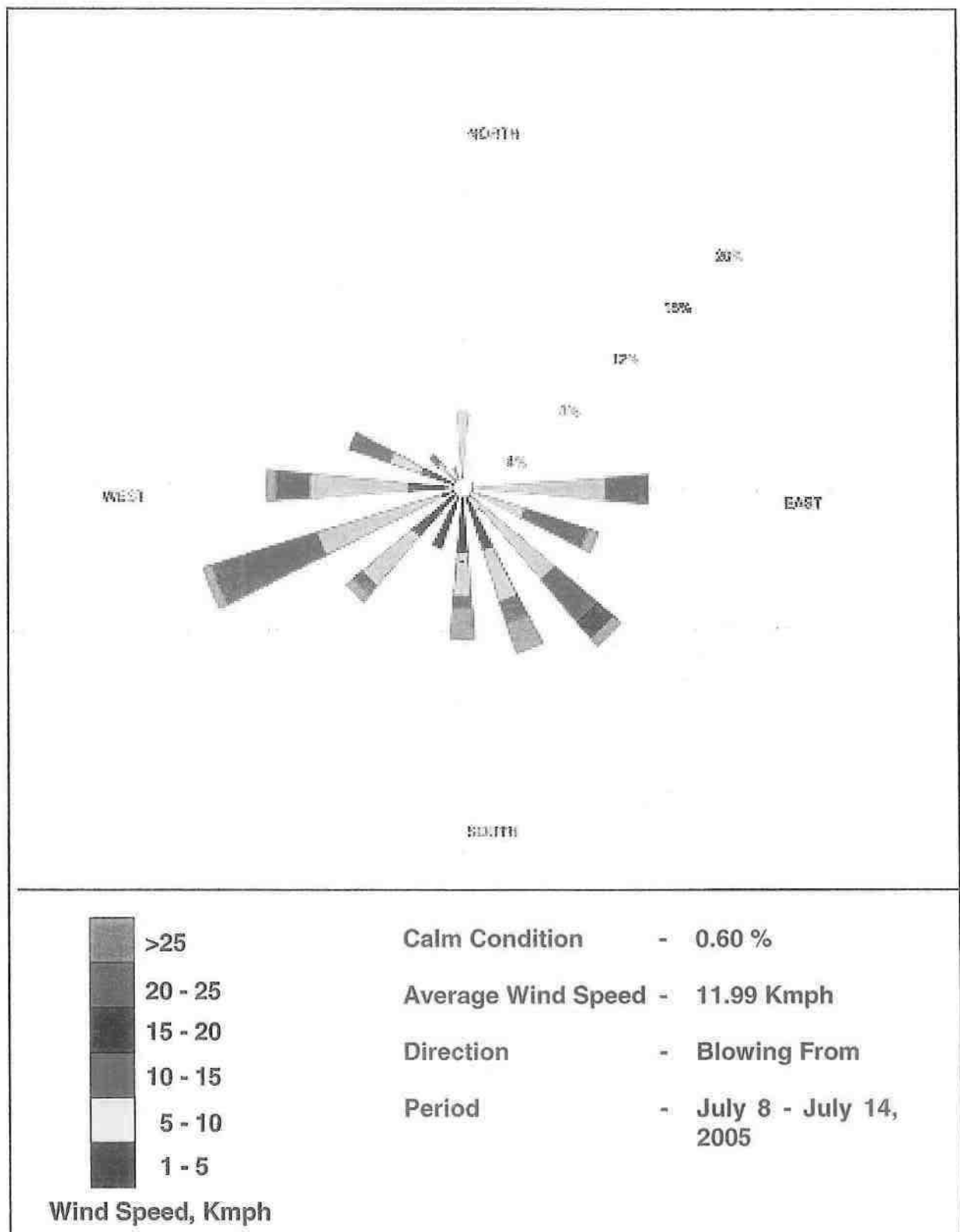


Fig. 3.10 Wind rose Pattern at Stone Crushing Units, Trisoolam
(With 1/4th of the Crushers in Operation)

Table 3.15
TSPM sampling at source (18 crushers in operation)

S. No.	Sampling Location	No. in the map (Fig 3.1)	TSPM ($\mu\text{g}/\text{m}^3$)		
			Min.	Max.	Avg.
1	Vigneshwara BM	1	186	9356	2014
2	Subalaxmi BM	2	950	4867	2845
3	Rani Anna Nagar	10	199	17622	2548

Table 3.16
TSPM sampling in ambient air (18 crushers in operation)

S. No.	Sampling Location	No. in the map (Fig 3.1)	TSPM ($\mu\text{g}/\text{m}^3$)		
			Min.	Max.	Avg.
1	Trisoolam 1	11	86	1968	716
2	Trisoolam 2	12	86	857	306
3	Sara Nagar	13	24	4494	528
4	Zamin Pallavaram	14	91	2600	430
5	Everedy Nagar	15	36	1511	426

Table 3.17
Respirable particulate matter and cyclone dust sampling in ambient air (18 crushers in operation)

S. No.	Sampling Location	No. in the map (Fig 3.1)	RSPM ($\mu\text{g}/\text{m}^3$)			Cyclone Dust ($\mu\text{g}/\text{m}^3$)		
			Min.	Max.	Avg.	Min.	Max.	Avg.
1	Krishna Nagar	16	31	170	91	3	388	127
2	Kennady Nagar	17	46	1176	276	88	744	290



123 $\mu\text{g}/\text{m}^3$. The highest average concentration ambient air was very high in the downwind direction when compared to the upwind direction, of the order of 1 to 1.5 for TSPM.

The overall concentrations of TSPM varied from 306 - 716 $\mu\text{g}/\text{m}^3$ with a mean of 481 $\mu\text{g}/\text{m}^3$. The TSPM concentration at all the six stations as shown in Table 3.16 exceeded the standard of 200 $\mu\text{g}/\text{m}^3$ recommended by the CPCB. The concentrations of RSPM varied 91 - 276 $\mu\text{g}/\text{m}^3$ with a mean of 184 $\mu\text{g}/\text{m}^3$ (Table 3.17). The concentrations of RSPM at Kennady Nagar (276 $\mu\text{g}/\text{m}^3$) exceeded the standard of 100 $\mu\text{g}/\text{m}^3$ recommended by the CPCB.

It was observed that during working period of 12 hours in the day time (6 am to 6 pm) TSPM concentrations in ambient air was about 1 - 1.5 times more than that of the following 12 hours in the night time (6 pm - 6 am) during which there was no crusher activity but transportation activity was carried out. During Sundays (6 pm to 6 am) there were no crushing and transportation activities, the TSPM concentration measured corresponds to background concentration of 67 $\mu\text{g}/\text{m}^3$ and it was found to be 1/2 - 1/3 of measured concentration ($1/4^{\text{th}}$ of the crushers in operation) for the working period of 6 am to 6 pm. The spatial distribution of measured concentration when all the crushers in operation are presented in the form of isopleths and surfer as shown in Fig. 3.11 and 3.12. The impact zone for all the crushers in operation is depicted in Fig. 3.13.

3.4 Sampling with $1/8^{\text{th}}$ of the crushers in operation

During the period July 18 - 25, 2005 for about 7 days, $1/8^{\text{th}}$ of the crushers were operated (9) continuously. Ambient air quality monitoring network consisting of 17 locations were identified based on prevailing wind pattern, stone crusher location and their geometry. The list of stone crushers in operation during the same period was given in Table 3.18 and their locations are depicted in Fig. 3.1. For $1/8^{\text{th}}$ of the stone crushing units in the locality, source dust monitoring was carried out at 4 stone crushing units. Of which, 4 were employed at source (TSPM 4) and seven were in ambient air (TSPM 5, RSPM 2). During the same period micro-meteorological data were also collected at 3 identified locations one inside stone crushing area near Subramaniam BM and two in the residential area viz., Trisoolam 2 and Kennedy valley. The distance and direction of ambient air quality monitoring stations with reference to stone crushers are given in Table 3.19.

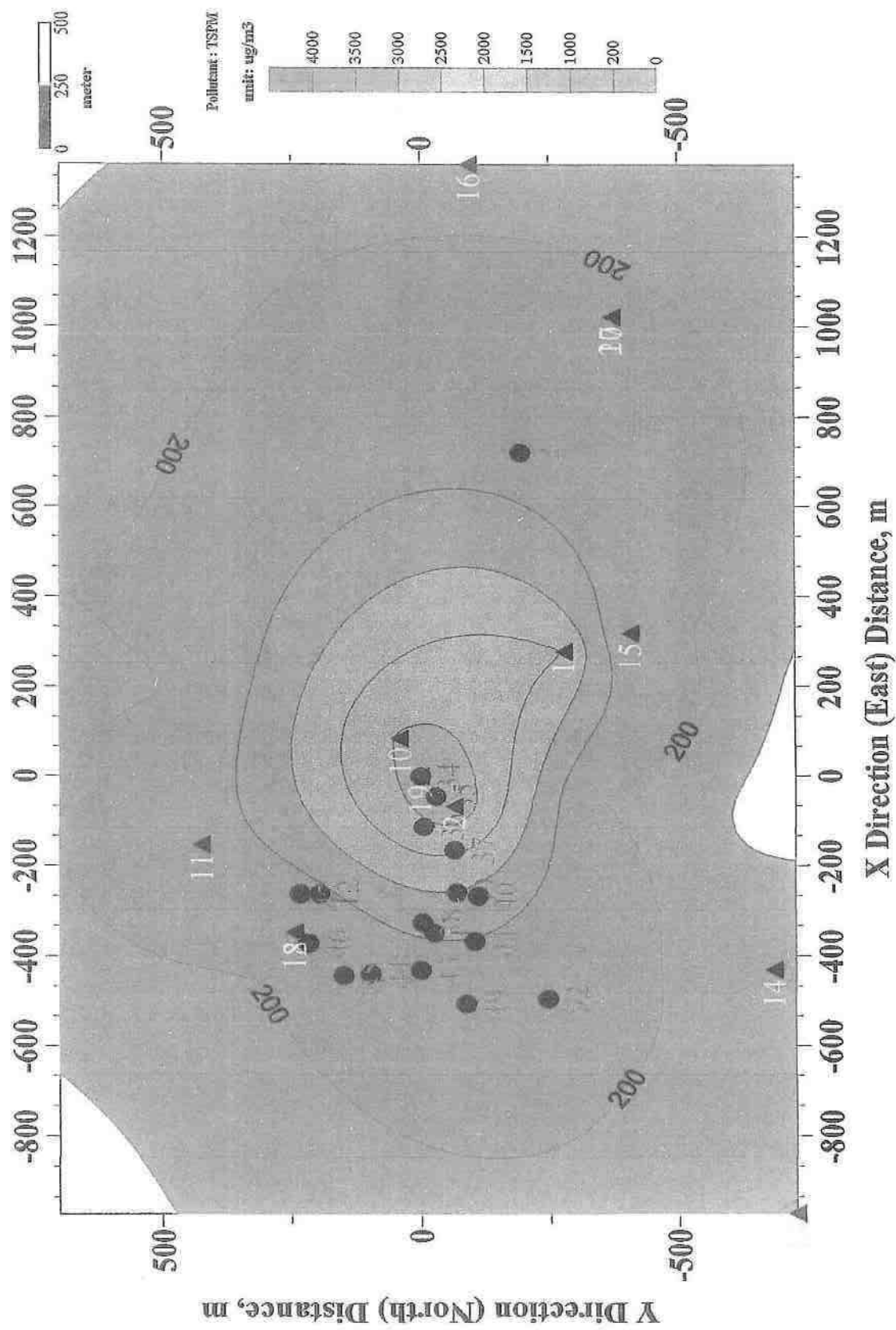


Fig. 3.11 Isopleths showing measured concentration (1/4th of the crushers in operation)

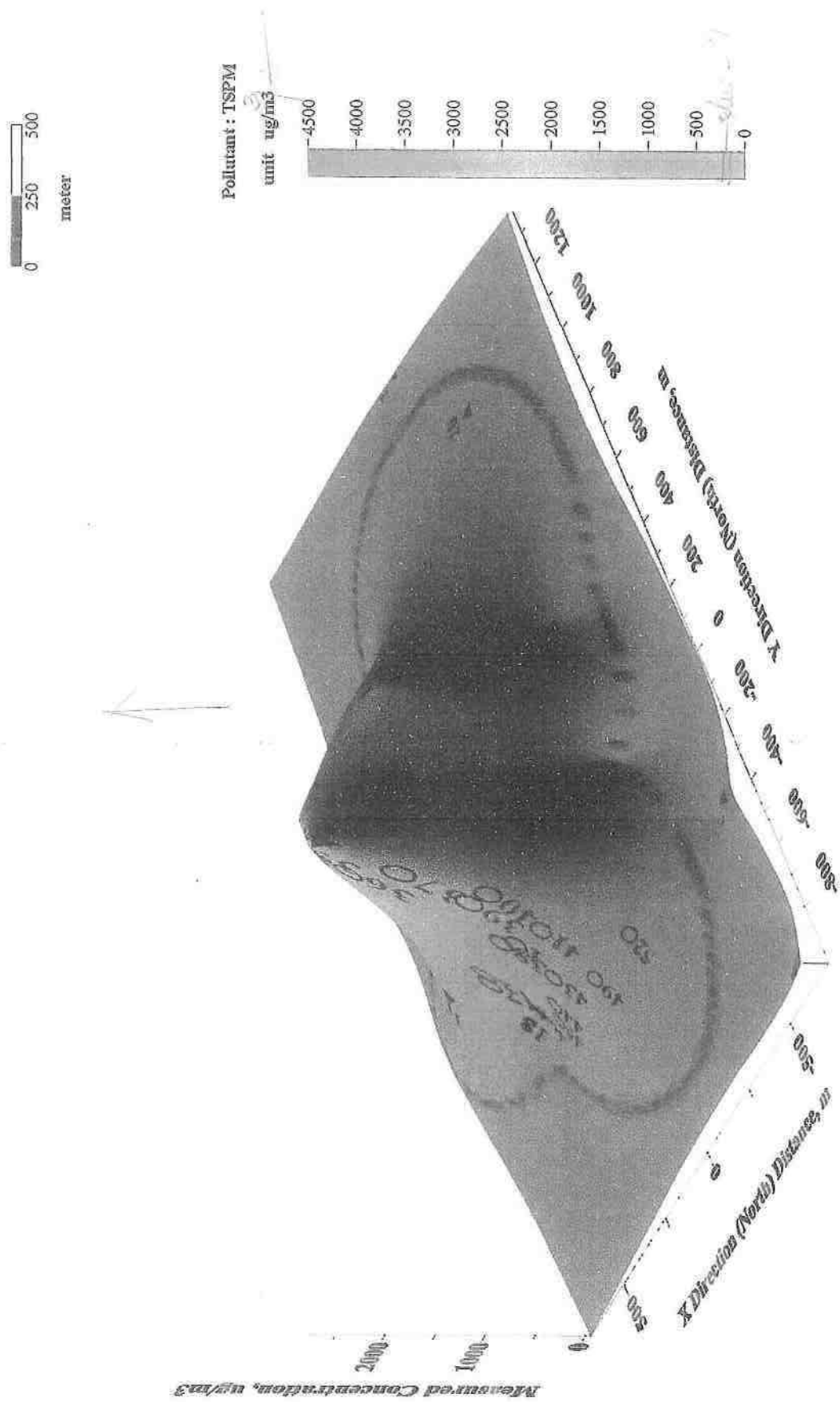
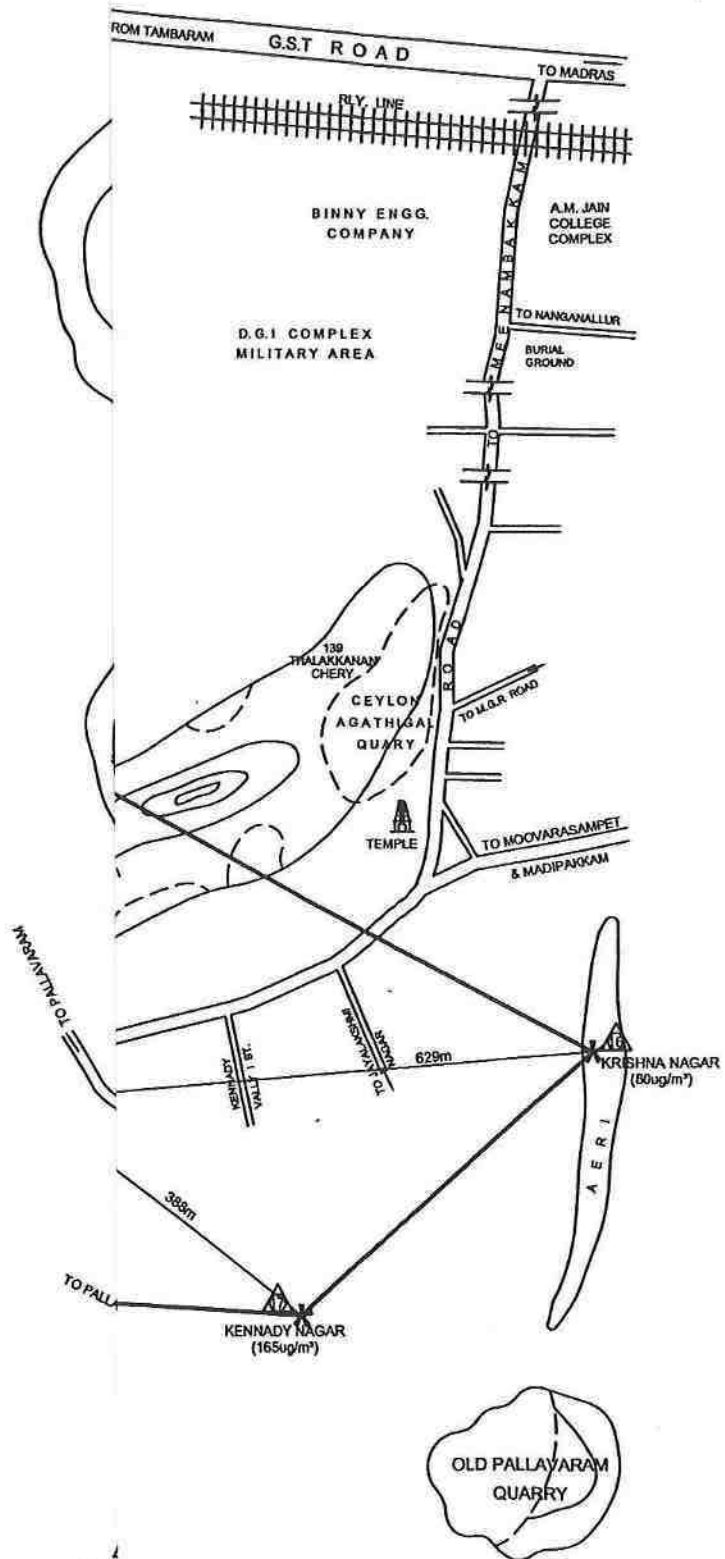
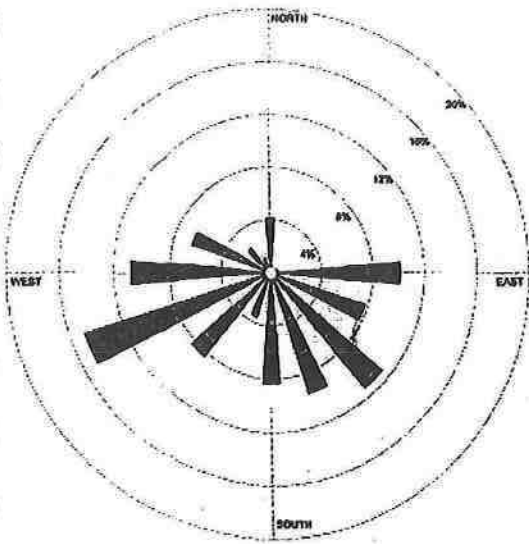


Fig. 3.12 Surfer showing measured concentration (1/4th of the crushers in operation)



SARA
(88)



Table 3.18
List of 1/8th of the crushers in
operation at Trisoolam (9 crushers)

S. No	Name of the Crusher	Crusher No. in the map (Fig 3.1)
1	Makeshwari BM	29
2	V.K.S BM	28
3	Durga BM	27
4	Shivagami BM	24
5	Subam BM	25
6	King BM	19
7	Balamurugan BM	14
8	Vasudevan	10
9	Star BM	15

10, 14, 19
10, 15, 19
24, 25, 27, 28, 29

Table 3.19
Locations of source and ambient air quality monitoring and
meteorological stations at Trisoolam (9 crushers in operation)

S. No.	Sampling Locations	Direction* (deg)	Distance* (m)	Nearest Crusher from the Sampling locations	No. in the map (Fig 3.1)
Source Monitoring Locations					
1	Vigneshwara BM	154	56.25	Subam BM	25
2	Subalaxmi BM	245	281.25	Durga BM	27
3	Rajalaxmi BM	255	472.5	Durga BM	27
10	Rani Anna Nagar	305	15	Durga BM	27
Ambient air quality monitoring locations					
11	Trisoolam 1	315	491	Makeshwari BM	29
12	Trisoolam 2	286	566	Makeshwari BM	29
13	Sara Nagar	250	1275	Subam BM	25
14	Zamin Pallavaram	234	803	Subam BM	25
15	Everedy Nagar	222	165	Star BM	15
16	Krishna Nagar	85	806	Vasudevan BM	10
17	Kennady Nagar	111	518	Vasudevan BM	10
Meteorological locations					
18	Trisoolam II	286	566	Rajalakshmi BM	40
19	Subramaniam Crusher	269	218	Durga BM	27
20	Kennady Valley	111	518	Vasudevan BM	10

* Direction and distance from the periphery of the nearest stone crusher



3.4.1 Weather monitoring

The wind direction and wind speed were recorded on hourly basis during the study period July 18 - July 22, 2005 and presented in the form of a wind rose diagram as shown in Fig. 3.14. The 24 hours wind rose shows that the dominant wind directions were from west (17%), followed by the South East (10.5%), South (10%), South of South East (9.5%) and East of South East (9%). The most prevalent wind speed was in the range of 5 - 10 kmph (20%) followed by 10 - 15 (17%) kmph. The calm condition was observed for about 1.67%. The average wind speed observed during the above period was 26.2 kmph.

3.4.2 Dust monitoring

3.4.2.1 Dust concentration at source

Out of 4 source air quality monitoring stations, three (3 TSPM) were chosen in the upwind direction and one (1 TSPM) in the downwind direction. Air quality monitoring was carried out simultaneously for all the locations during the period. The average concentration of TSPM in the upwind direction varied from 688 to 1574 $\mu\text{g}/\text{m}^3$ with a mean of 1089 $\mu\text{g}/\text{m}^3$. The average concentration of TSPM in the downwind direction was 1141 $\mu\text{g}/\text{m}^3$.

The overall concentrations of TSPM varied from 687 to 1574 $\mu\text{g}/\text{m}^3$ with a mean of 1102 $\mu\text{g}/\text{m}^3$. The highest TSPM average concentrations were found at Subalaxmi BM (1574 $\mu\text{g}/\text{m}^3$) as shown in Table 3.20. The TSPM concentration at all locations exceeded the standard of 600 $\mu\text{g}/\text{m}^3$ recommended by Central Pollution Control Board (CPCB, 1998).

3.4.2.2 Dust concentration around stone crushing units

Ambient dust monitoring was carried out around stone crushing units at 7 locations in the stone crushing area. The distance and direction of ambient air quality monitoring stations with reference to stone crushers are given in Table 3.19. Air quality monitoring was carried out simultaneously for all the locations for 7 days. Out of 7 ambient air quality monitoring stations, two (2 TSPM) were chosen in the upwind and five (3 TSPM, 2 RSPM) in the downwind direction. The average concentration of TSPM in the upwind direction varied from 66 to 123 $\mu\text{g}/\text{m}^3$ with a mean of 99 $\mu\text{g}/\text{m}^3$. The average concentration of TSPM in the downwind direction varied from 177 to 346 $\mu\text{g}/\text{m}^3$ with a mean of 262 $\mu\text{g}/\text{m}^3$. The average concentration of RSPM in the upwind direction varied from 56 to 155 $\mu\text{g}/\text{m}^3$ with a mean of 106 $\mu\text{g}/\text{m}^3$. The highest average concentration in ambient air will be very high in the downwind direction when compared to the upwind direction, in the order of 2 to 3 for TSPM.

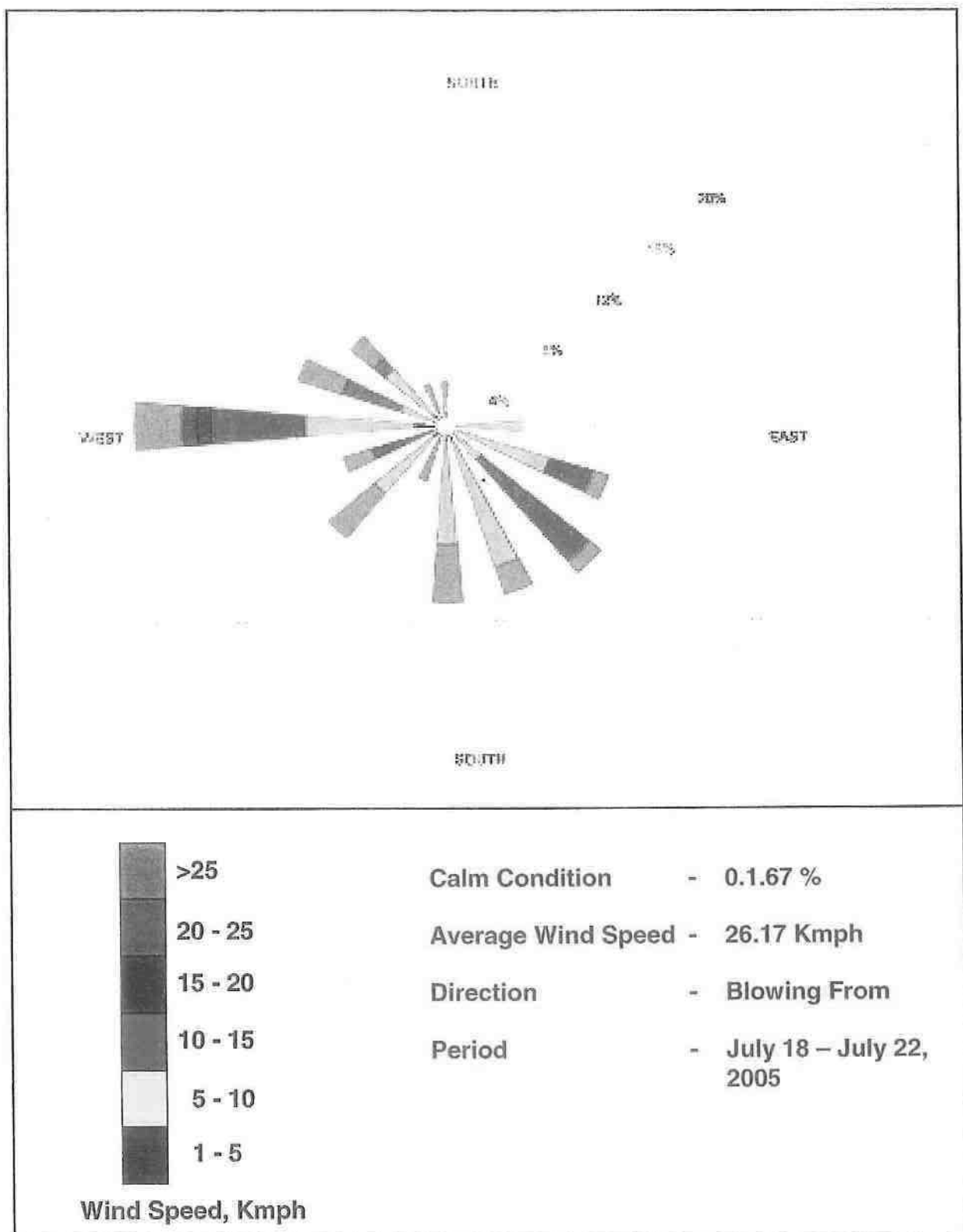


Fig. 3.14 Wind rose Pattern at Stone Crushing Units, Trisoolam
(With 1/8th of the Crushers in Operation)

Table 3.20
TSPM sampling at source (9 crushers in operation)

S. No.	Sampling Location	No. in the map (Fig 3.1)	TSPM ($\mu\text{g}/\text{m}^3$)		
			Min.	Max.	Avg.
1	Vigneshwara BM	1	383	2384	1004
2	Subalaxmi BM	2	429	4940	1574
3	Rajalaxmi BM	3	526	936	688
4	Ranni Anna Nagar	10	299	1663	1141

Table 3.21
TSPM sampling in ambient air (9 crushers in operation)

S. No.	Sampling Location	No. in the map (Fig 3.1)	TSPM ($\mu\text{g}/\text{m}^3$)		
			Min.	Max.	Avg.
1	Trisoolam 1	11	76	1258	521
2	Trisoolam 2	12	52	403	178
3	Sara Nagar	13	67	185	126
4	Zamin Pallavaram	14	18	219	123
5	Everedy Nagar	15	26	201	104

Table 3.22
Respirable particulate matter and cyclone dust sampling in ambient air (9 crushers in operation)

S. No.	Sampling Location	No. in the map (Fig 3.1)	RSPM ($\mu\text{g}/\text{m}^3$)			Cyclone Dust ($\mu\text{g}/\text{m}^3$)		
			Min.	Max.	Avg.	Min.	Max.	Avg.
1	Krishna Nagar	16	24	221	80	33	147	84
2	Kennady Nagar	17	52	265	155	6	879	253



The overall concentrations of TSPM varied 104 - 521 $\mu\text{g}/\text{m}^3$ with a mean of 211 $\mu\text{g}/\text{m}^3$. The TSPM concentration at Trisoolam 1 (521 $\mu\text{g}/\text{m}^3$) exceeded the standard of 200 $\mu\text{g}/\text{m}^3$ recommended by the CPCB as shown in Table 3.21. In other locations, the measured TSPM concentrations were within the permissible limits. The concentrations of RSPM varied from 80 to 155 $\mu\text{g}/\text{m}^3$, (Table 3.22). The concentrations of RSPM at Kennedy Nagar (155 $\mu\text{g}/\text{m}^3$) exceeded the standard of 100 $\mu\text{g}/\text{m}^3$ recommended by the CPCB 1998.

It was observed that during the working period of 12 hours in the day time (6 am to 6 pm) TSPM concentrations in ambient air were about 2 - 3 times more than that of the following 12 hours in the night time (6 pm - 6 am) during which there was no crusher activity but transportation activity was carried out. During Sundays (6 pm to 6 am) there were no crushing and transportation activities, the TSPM concentration measured corresponds to background concentration of 67 $\mu\text{g}/\text{m}^3$ and it was found to be 1/2 - 1/3 of measured concentration (1/8th of the crushers in operation) for the working period of 6 am to 6 pm. The spatial distribution of measured concentration when all the crushers in operation are presented in the form of isopleths and surfer as shown in Fig. 3.15 and 3.16. The impact zone for all the crushers in operation is depicted in Fig. 3.17.

3.5 Sampling with only one crusher in operation

Only one crusher, viz., Rajalakshmi BM was operated during the period July 23 - 25, 2005 for 2 days continuously. Ambient air quality monitoring network consisting of 17 locations were identified based on prevailing wind pattern, stone crusher location and their geometry. For only one crushing unit in the locality, source dust monitoring was carried out at 4 stone crushing units, of which 4 were employed at source (TSPM 4) and seven in ambient air (TSPM 5, RSPM 2). During the same period micro-meteorological data were also collected at 3 identified locations one inside stone crushing area near Subramaniam BM and two in the residential area viz., Trisoolam 2 and Kennedy valley. The distance and direction of ambient air quality monitoring stations with reference to stone crushers are given in Table 3.23.

3.5.1 Weather monitoring

The wind direction and wind speed were recorded on hourly basis during the study period July 23 - July 25, 2005 and presented in the form of a wind rose (Fig. 3.18). The 24 hours wind rose shows that the dominant wind directions were from southwest (39 %), followed by the west (20%) and West of Southwest (17%). The most prevalent wind speed

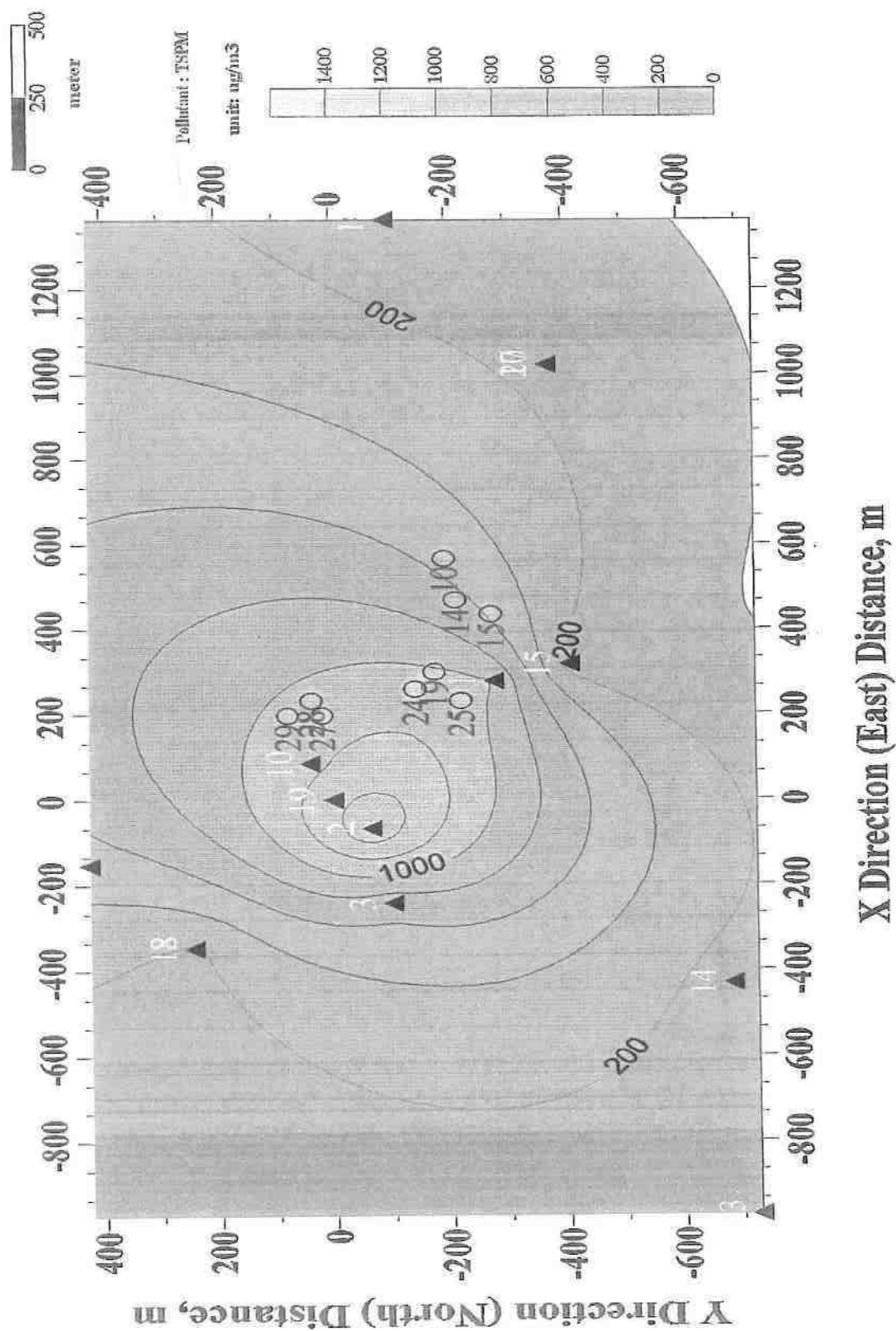


Fig. 3.15 Isopleths showing measured concentration (1/8th of the crushers in operation)

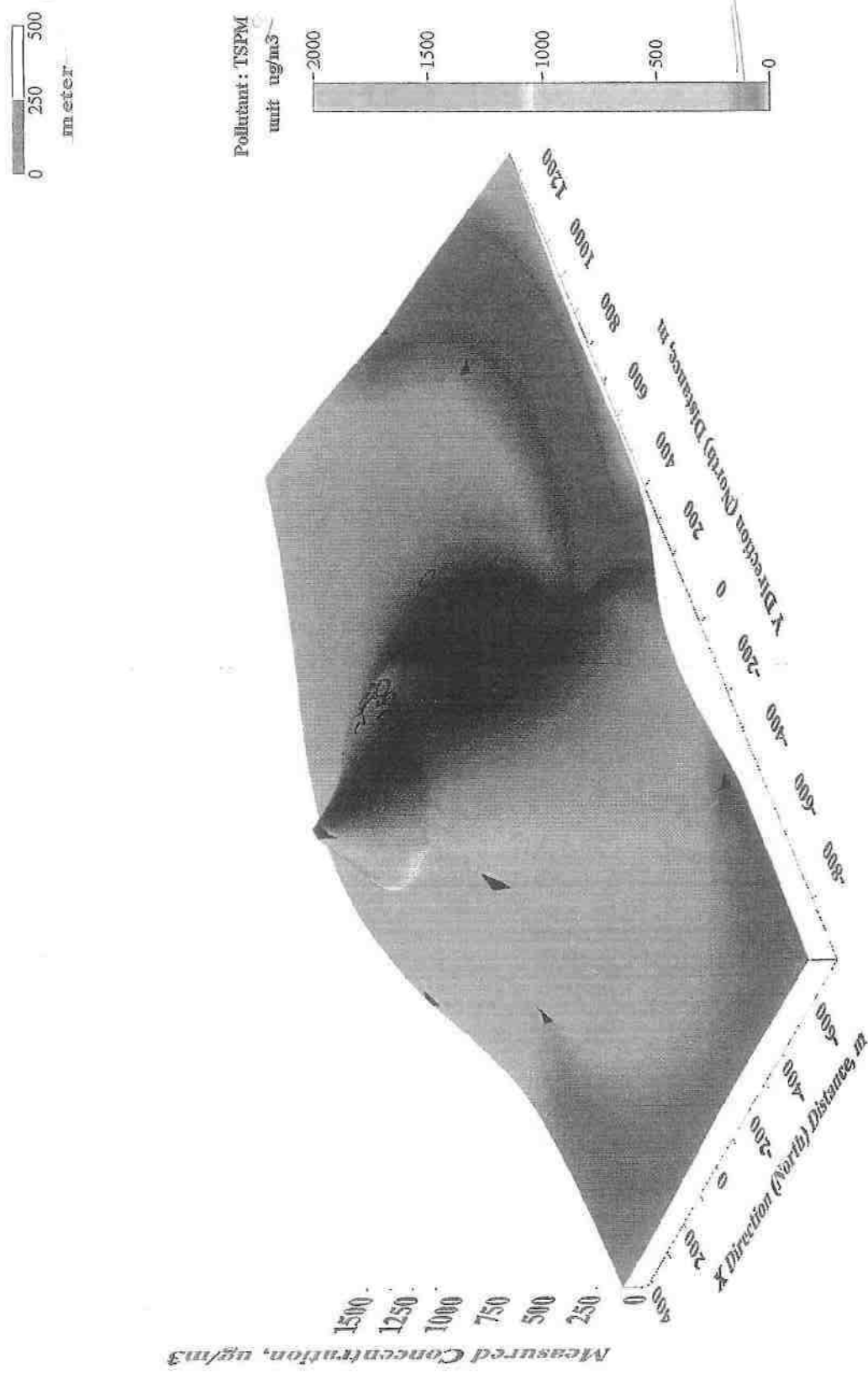
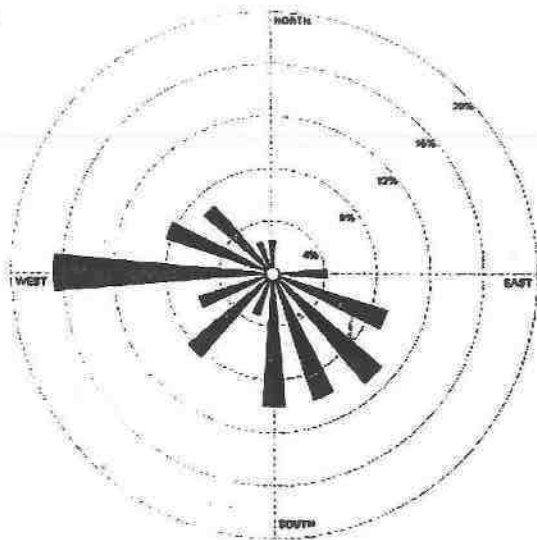


Fig. 3.16 Surfer showing measured concentration (1/8th of the crushers in operation)



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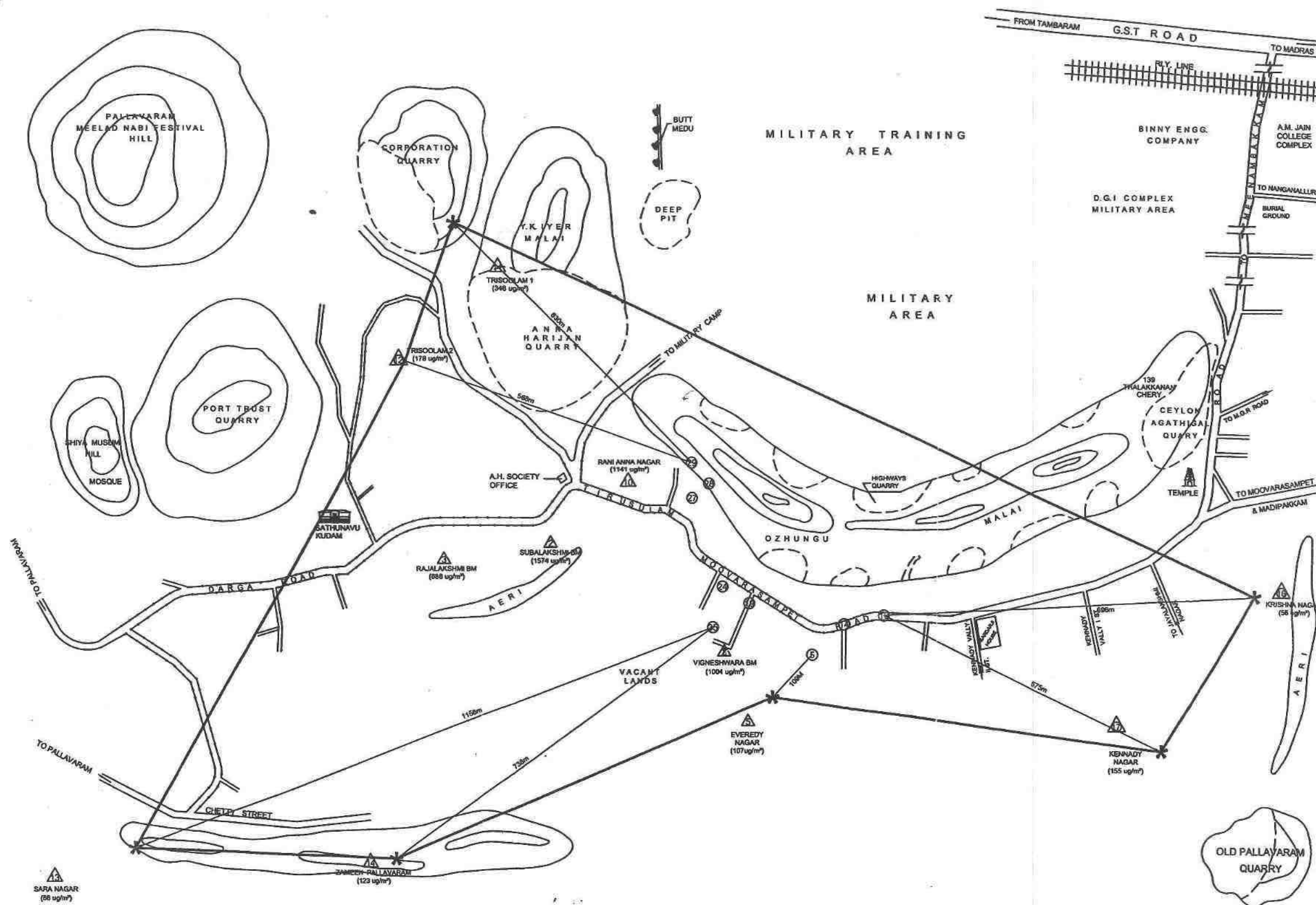


FIG. 3.17 Impact zone for 1/8th crushers in operation



Table 3.23
Locations of source and ambient air quality monitoring and meteorological stations at Trisoolam (Only one crusher in operation¹)

S. No.	Sampling Locations	Direction* (deg)	Distance* (m)	Nearest Crusher from the Sampling locations	No. in the map (Fig 3.1)
Source Monitoring Locations					
1	Vigneshwara BM	105	570	Rajalakshmi BM	40
2	Subalaxmi BM	80	225	Rajalakshmi BM	40
3	Rajalaxmi BM	70	37.5	Rajalakshmi BM	40
10	Rani Anna Nagar	60	395	Rajalakshmi BM	40
Ambient air quality monitoring locations					
11	Trisoolam 1	12	555	Rajalakshmi BM	40
12	Trisoolam 2	348	368	Rajalakshmi BM	40
13	Sara Nagar	231	881	Rajalakshmi BM	40
14	Zamin Pallavaram	194	600	Rajalakshmi BM	40
15	Everedy Nagar	115	656	Rajalakshmi BM	40
16	Krishna Nagar	90	1639	Rajalakshmi BM	40
17	Kennady Nagar	102	1331	Rajalakshmi BM	40
Meteorological locations					
18	Trisoolam II	348	368	Rajalakshmi BM	40
19	Subramaniam Crusher	68	293	Rajalakshmi BM	40
20	Kennady Valley	102	1331	Rajalakshmi BM	40

* Direction and distance from the periphery of the nearest stone crusher Rajalakshmi BM

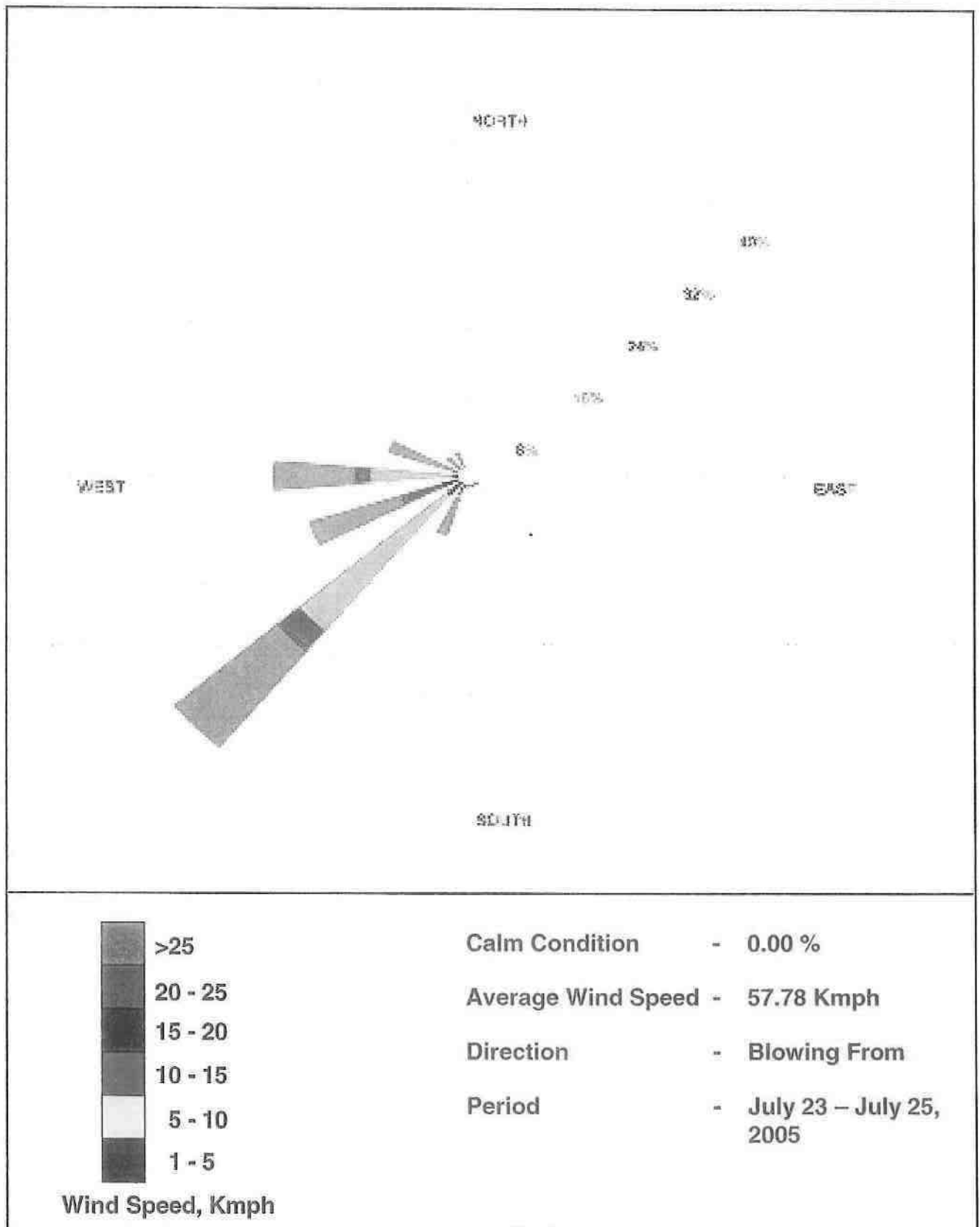


Fig. 3.18 Wind rose Pattern at Stone Crushing Units, Trisoolam
(Only One Crusher in Operation)



was in the range of >25 kmph (36%) followed by 5 - 10 (28%) kmph, with no calm condition. The average wind speed observed during the above period was 57.8 kmph.

3.5.2 Dust monitoring

3.5.2.1 Dust concentration at source

Out of 4 source air quality monitoring stations, two (2 TSPM) were chosen in the upwind direction and two (2 TSPM) in the downwind direction. Air quality monitoring was carried out simultaneously for all the locations during the period. The average concentration of TSPM in the upwind direction varied from 586 to 1266 $\mu\text{g}/\text{m}^3$ with a mean of 926 $\mu\text{g}/\text{m}^3$ respectively. The average concentration of TSPM in the downwind direction varied from 509 to 524 $\mu\text{g}/\text{m}^3$, with a mean of 517 $\mu\text{g}/\text{m}^3$.

The overall concentrations of TSPM varied from 250 to 345 $\mu\text{g}/\text{m}^3$ with a mean of 296 $\mu\text{g}/\text{m}^3$. The highest TSPM average concentrations ^{were} recorded at Rajalaxmi BM (345 $\mu\text{g}/\text{m}^3$) as given Table 3.24.

3.5.2.2 Dust concentration around stone crushing units

Ambient dust monitoring was carried out around stone crushing units at 7 locations in the stone crushing area. The distance and direction of ambient air quality monitoring stations with reference to stone crushers are given in Table 3.23. Air quality monitoring was carried out simultaneously for all the locations for 2 days. Out of 7 ambient air quality monitoring stations, four (4 TSPM) were chosen in the upwind and three (1 TSPM, 2 RSPM) in the downwind direction. The average concentration of TSPM in the upwind direction varied from 55 to 73 $\mu\text{g}/\text{m}^3$, with a mean of 62 $\mu\text{g}/\text{m}^3$. The average concentration of TSPM in the downwind direction was 104 $\mu\text{g}/\text{m}^3$. The average concentration of RSPM in the downwind direction varied from 50 to 87 $\mu\text{g}/\text{m}^3$, with a mean of 68 $\mu\text{g}/\text{m}^3$. The highest average concentration in ambient air was very high in the downwind direction when compared to the upwind direction, in the order of 1 to 1.5 for TSPM.

The overall concentrations of TSPM varied from 32 to 84 $\mu\text{g}/\text{m}^3$ with a mean of 63 $\mu\text{g}/\text{m}^3$. The TSPM concentration does not exceeded the standard of 200 $\mu\text{g}/\text{m}^3$ recommended by the CPCB (Table 3.25). The concentrations of RSPM varied from 48 to 87 with a mean of 67 $\mu\text{g}/\text{m}^3$ (Table 3.26). The concentrations of is within the limit at all the locations, standard of 100 $\mu\text{g}/\text{m}^3$ recommended by the CPCB.

It was observed that during the working period of 12 hours in the day time (6 am to 6 pm) TSPM concentrations in ambient air were about 1 - 1.5 times more than that of the

Table 3.24
TSPM sampling at source
(Only one crusher running: Rajalakshmi BM, No: 40)

S. No.	Sampling Location	No. in the map (Fig 3.1)	TSPM ($\mu\text{g}/\text{m}^3$)		
			Min.	Max.	Avg.
1	Vigneshwara BM	1	99	559	306
2	Subalaxmi BM	2	80	576	281
3	Rajalaxmi BM	3	65	731	345
4	Ranni Anna Nagar	10	149	373	250

Table 3.25
TSPM sampling in ambient air
(Only one crusher running: Rajalakshmi BM, No: 40)

S. No.	Sampling Location	No. in the map (Fig 3.1)	TSPM ($\mu\text{g}/\text{m}^3$)		
			Min.	Max.	Avg.
1	Trisoolam 1	11	13	136	56
2	Trisoolam 2	12	12	55	32
3	Sara Nagar	13	26	134	65
4	Zamin Pallavaram	14	9	161	73
5	Everedy Nagar	15	40	130	84

Table 3.26
Respirable particulate matter and cyclone dust sampling in ambient air
(Only one crusher running: Rajalakshmi BM, No: 40)

S. No.	Sampling Location	No. in the map (Fig 3.1)	RSPM ($\mu\text{g}/\text{m}^3$)			Cyclone Dust ($\mu\text{g}/\text{m}^3$)		
			Min.	Max.	Avg.	Min.	Max.	Avg.
1	Krishna Nagar	16	19	81	48	12	32	19
2	Kennady Nagar	17	18	138	87	9	108	50



following 12 hours in the night time (6 pm - 6 am) during which there was no crusher activity but transportation activity was carried out. During Sundays (6 pm to 6 am) there were no crushing and transportation activities, the TSPM concentration measured corresponds to background concentration of $67 \mu\text{g}/\text{m}^3$ and it was found to be 1/1.5 - 1/2 of measured concentration (only one crusher in operation) for the working period of 6 am to 6 pm. The spatial distribution of measured concentration when all the crushers in operation are presented in the form of isopleths and surfer as shown in Fig. 3.19 and 3.20. The impact zone for all the crushers in operation is depicted in Fig. 3.21.

3.6 Sampling with no crushing activity and only vehicle traffic/movement

No crusher was operated during July 26 - 27, 2005 for a day. Ambient air quality monitoring network consisting of 17 locations was designed based on prevailing wind pattern, stone crusher location and their geometry. For no crushing activity in the locality, source dust monitoring was carried out at 4 stone crushing units. Of which 4 were employed at source (TSPM 4) and six in ambient air (TSPM 5, RSPM 1). During the same period micro-meteorological data were also collected at 3 identified locations, one inside stone crushing area near Subramaniam BM and two in the residential area viz., Trisoolam 2 and Kennedy valley. The distance and direction of ambient air quality monitoring stations with reference to stone crushers are given in Table 3.27.

3.6.1 Weather monitoring

The wind direction and wind speed were recorded on hourly basis during the study period July 26 - July 27, 2005 and presented in the form of a wind rose (Fig. 3.22). The 24 hours wind rose shows that the dominant wind directions were from Southwest (34%), followed by the South (21%) and West (14.5%). The most prevalent wind speed was in the range of >25 Kmph (15.5%) followed by 5 - 10 (12%) kmph, with no calm condition. The average wind speed observed during the above period was 46.1 kmph.

3.6.2 Dust monitoring

3.6.2.1 Dust concentration at source

Out of 4 source air quality monitoring stations, two (2 TSPM) were chosen in the upwind direction and two (2 TSPM) in the downwind direction. Air quality monitoring was carried out simultaneously for all the locations during the period. The average concentration of TSPM in the upwind direction varied from 281 to $345 \mu\text{g}/\text{m}^3$ with a mean of $313 \mu\text{g}/\text{m}^3$.

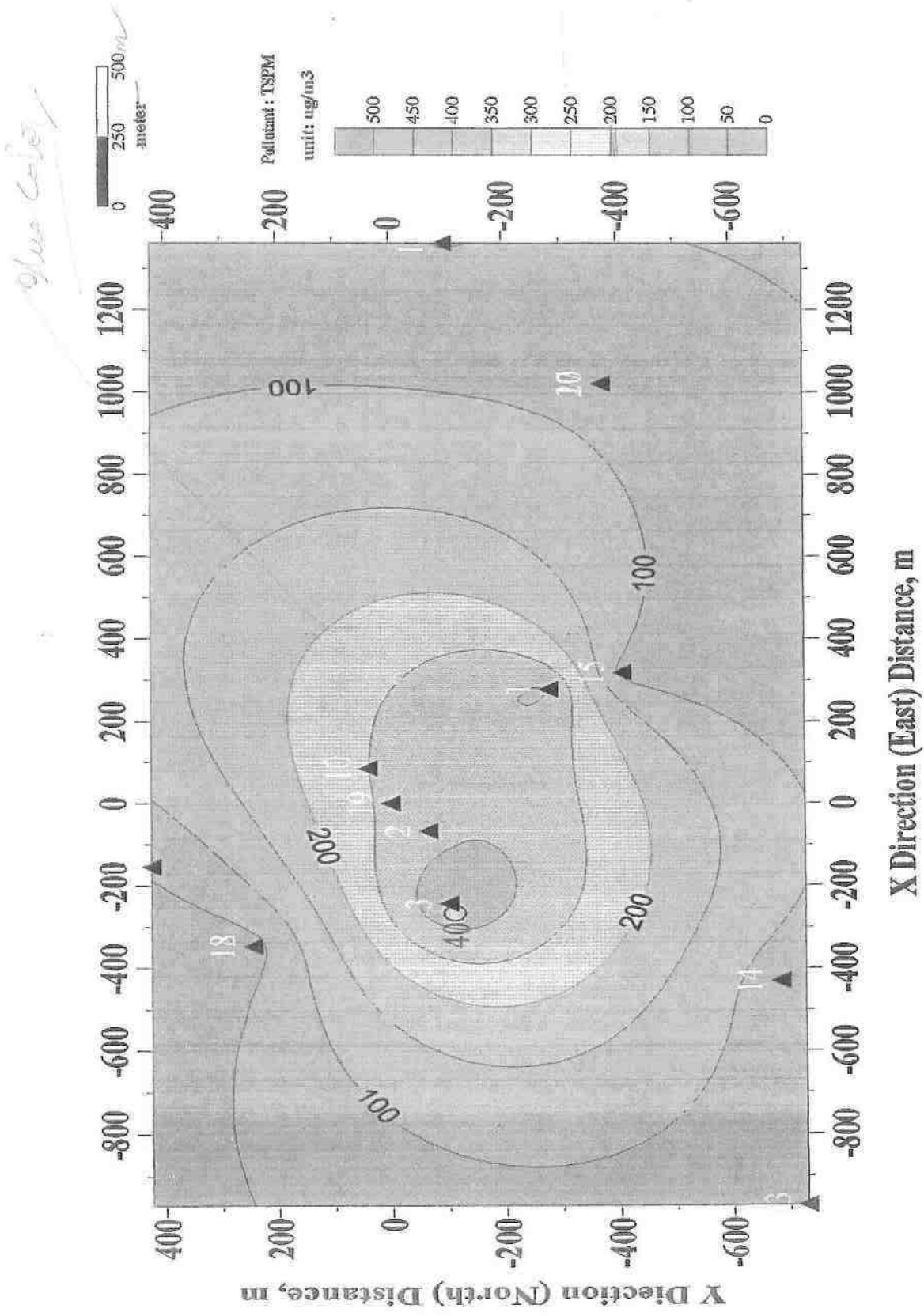


Fig. 3.19 Isopleths showing measured concentration (only one crusher in operation)

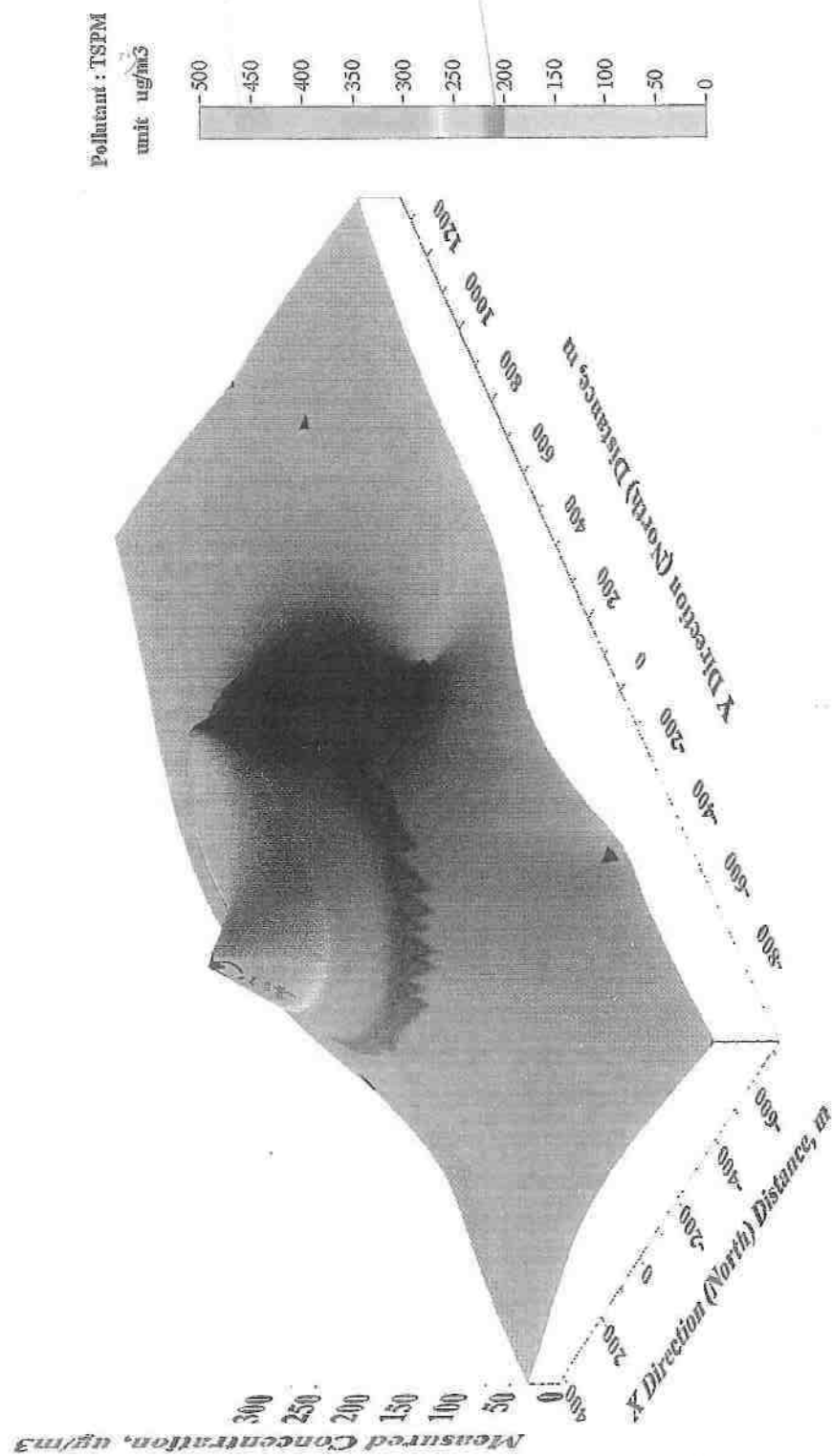


Fig. 3: 20 Surfer showing measured concentration (only one crusher in operation)

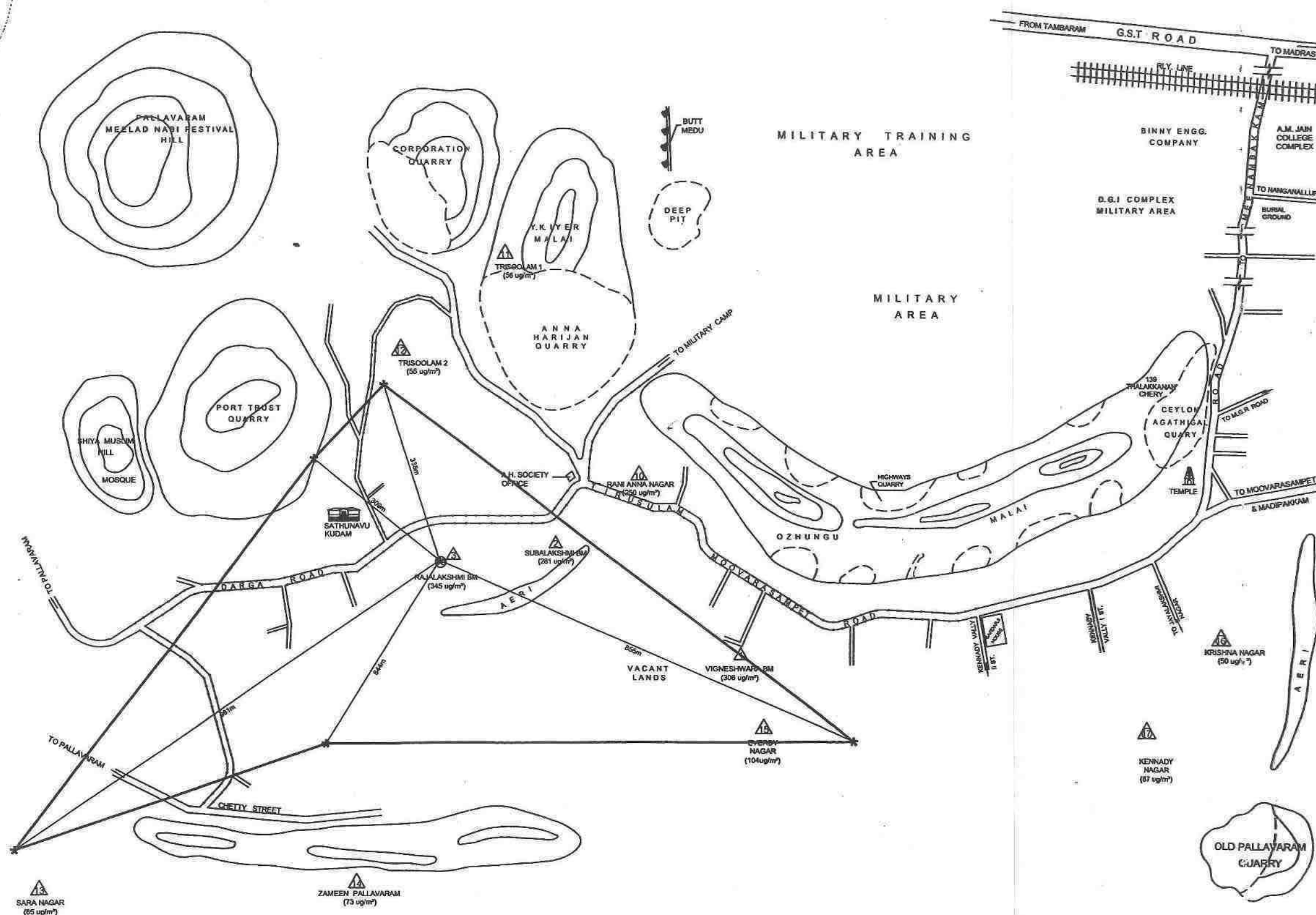
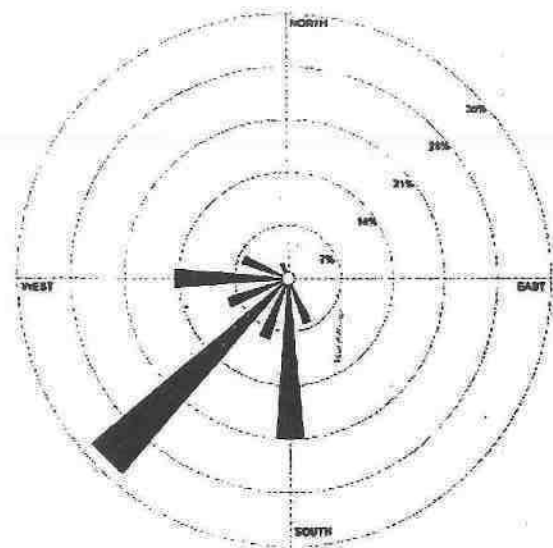


FIG. 3.21 Impact zone for only one crusher in operation



Table 3.27

Locations of source and ambient air quality monitoring and meteorological stations at Trisoolam (No crushing activity and only vehicle traffic/movement)

S. No.	Sampling Locations	Direction* (deg)	Distance* (m)	Nearest Crusher from the Sampling locations	No. in the map (Fig 3.1)
Source Monitoring Locations					
1	Vigneshwara BM	135	386.25	-	-
2	Subalaxmi BM	213	93.75	-	-
3	Rajalaxmi BM	246	260.25	-	-
10	Rani Anna Nagar	40	93.75	-	-
Ambient air quality monitoring locations					
11	Trisoolam 1	341	446	-	-
12	Trisoolam 2	305	413	-	-
13	Sara Nagar	331	1163	-	-
14	Zamin Pallavaram	210	806	-	-
15	Everedy Nagar	141	510	-	-
17	Kennady Nagar	113	1091	-	-
Meteorological locations					
18	Trisoolam II	305	413	-	-
19	Subramaniam Crusher	-	-	-	-
20	Kennady Valley	113	1091	-	-

* Direction and distance from the periphery of the nearest stone crusher

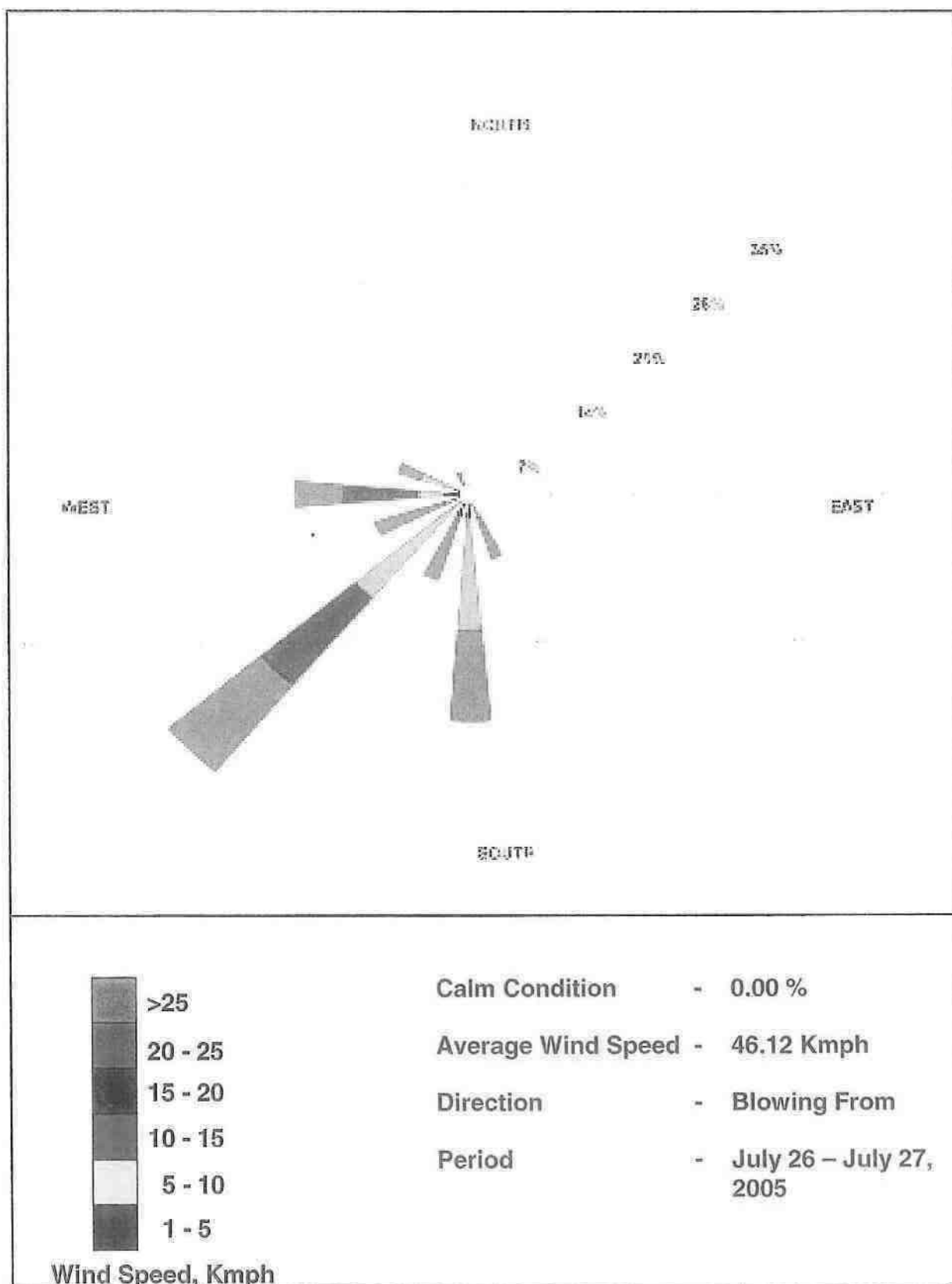


Fig. 3.22 Wind rose Pattern at Stone Crushing Units, Trisoolam
(No Crushing Activity, Only Vehicle Traffic/Movement)

The average concentration of TSPM in the downwind direction varied from 250 to 306 $\mu\text{g}/\text{m}^3$ with a mean of 278 $\mu\text{g}/\text{m}^3$.

The overall concentrations of TSPM varied from 509 to 1266 $\mu\text{g}/\text{m}^3$ with a mean of 721 $\mu\text{g}/\text{m}^3$. The highest TSPM average concentrations were found at Subalaxmi BM (1266 $\mu\text{g}/\text{m}^3$) as shown in Table 3.28. The TSPM concentration exceeded the standard of 600 $\mu\text{g}/\text{m}^3$ recommended by CPCB except at Vigneshwara BM.

3.6.2.2 Dust concentration around stone crushing units

Ambient dust monitoring was carried out around stone crushing units at 6 locations in the stone crushing area. Out of 6 ambient air quality monitoring stations, three were chosen in upwind (3 TSPM) and three (2 TSPM, 1 RSPM) in the downwind direction. Air quality monitoring was carried out simultaneously for all the locations for a day. The average concentration of TSPM in the upwind direction varied from 44 to 73 $\mu\text{g}/\text{m}^3$ with a mean of 60 $\mu\text{g}/\text{m}^3$. The average concentration of TSPM in the downwind direction varied from 49 to 84 $\mu\text{g}/\text{m}^3$ with a mean of 67 $\mu\text{g}/\text{m}^3$. The average concentration of RSPM in the downwind direction was 73 $\mu\text{g}/\text{m}^3$. The highest average concentration in ambient air was very high in the downwind direction when compared to the upwind direction, of the order of 1 to 1.5 for TSPM.

The overall concentrations of TSPM varied from 44 to 107 $\mu\text{g}/\text{m}^3$ with a mean of 67 $\mu\text{g}/\text{m}^3$. The TSPM concentration at any location did not exceed the standard of 200 $\mu\text{g}/\text{m}^3$ recommended by the CPCB. (Table 3.29). The concentration of RSPM was 73 $\mu\text{g}/\text{m}^3$ (Table 3.30). The concentrations of RSPM is within the limit of 100 $\mu\text{g}/\text{m}^3$ recommended by the CPCB at all the locations. The spatial distribution of measured concentration when all the crushers in operation are presented in the form of isopleths and surfer as shown in Fig. 3.23 and 3.24. The impact zone for all the crushers in operation is depicted in Fig. 3.25.

3.7 Micrometeorological observations for overall study period

The wind direction and wind speed were recorded on hourly basis during the study period June 26 - August 05, 2005 and presented in the form of a wind rose (Fig. 3.26). The 24 hours wind rose shows that the dominant wind directions were from South West (19%), followed by the West (18.5%), West of South West (14%). The most prevalent wind speed was in the range of 5 - 10 kmph (25%) followed by 10 - 15 (15%) kmph. The calm condition was observed only 0.52% of the time. The average wind speed observed during the above

Table 3.28
TSPM sampling at source
(No crushing activity, only vehicle traffic/ movement)

S. No.	Sampling Location	No. in the map (Fig 3.1)	TSPM ($\mu\text{g}/\text{m}^3$)		
			Min.	Max.	Avg.
1	Vigneshwara BM	1	524	524	524
2	Subalaxmi BM	2	646	1884	1266
3	Rajalaxmi BM	3	526	646	586
4	Ranni Anna Nagar	10	228	790	509

Table 3.29
TSPM sampling in ambient air
(No crushing activity, only vehicle traffic/ movement)

S. No.	Sampling Location	No. in the map (Fig 3.1)	TSPM ($\mu\text{g}/\text{m}^3$)		
			Min.	Max.	Avg.
1	Trisoolam 1	11	24	75	49
2	Trisoolam 2	12	40	46	44
3	Sara Nagar	13	45	80	63
4	Zamin Pallavaram	14	44	102	73
5	Everedy Nagar	15	90	123	106

Table 3.30
Respirable particulate matter and cyclone dust sampling in ambient air
(No crushing activity, only vehicle traffic/ movement)

S. No.	Sampling Location	No. in the map (Fig 3.1)	RSPM ($\mu\text{g}/\text{m}^3$)			Cyclone Dust ($\mu\text{g}/\text{m}^3$)		
			Min.	Max.	Avg.	Min.	Max.	Avg.
1	Kennady Nagar	17	61	86	73	189	497	343

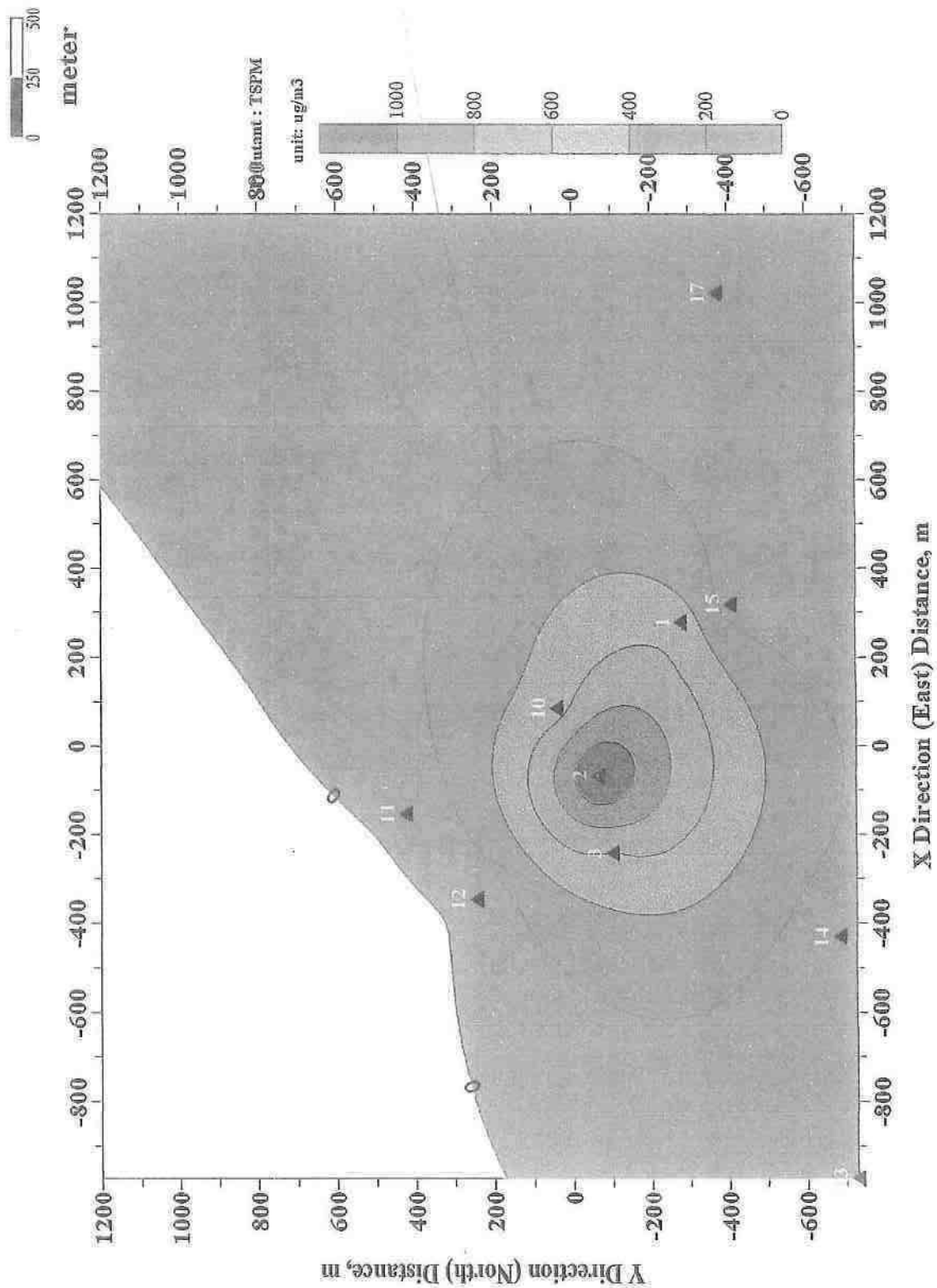


Fig. 3.23 Isopleths showing measured concentration (No crushing activity, only vehicle traffic/movement)

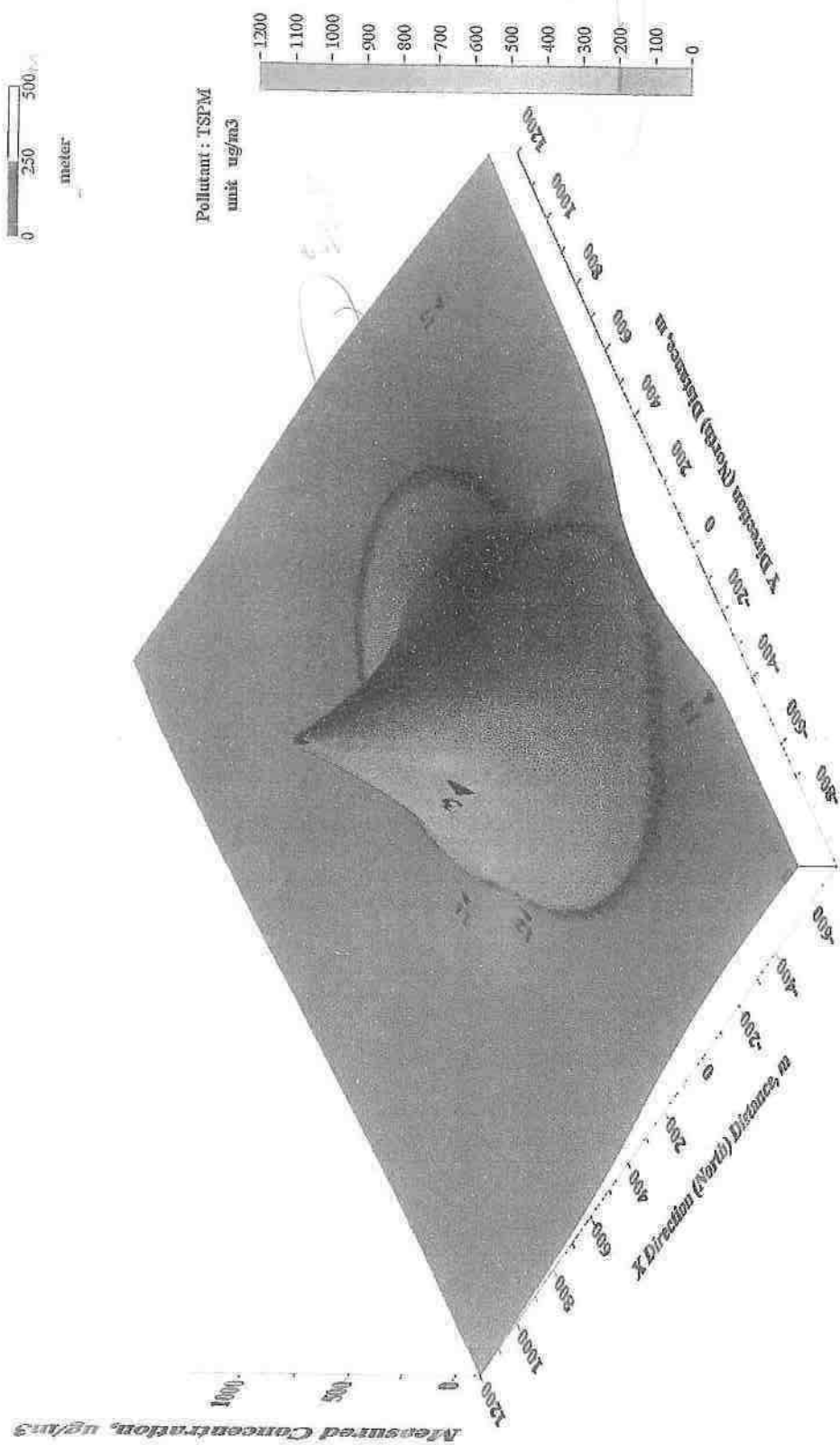


Fig. 3.24 Surfer showing measured concentration (No crushing activity, only vehicle traffic/ movement)

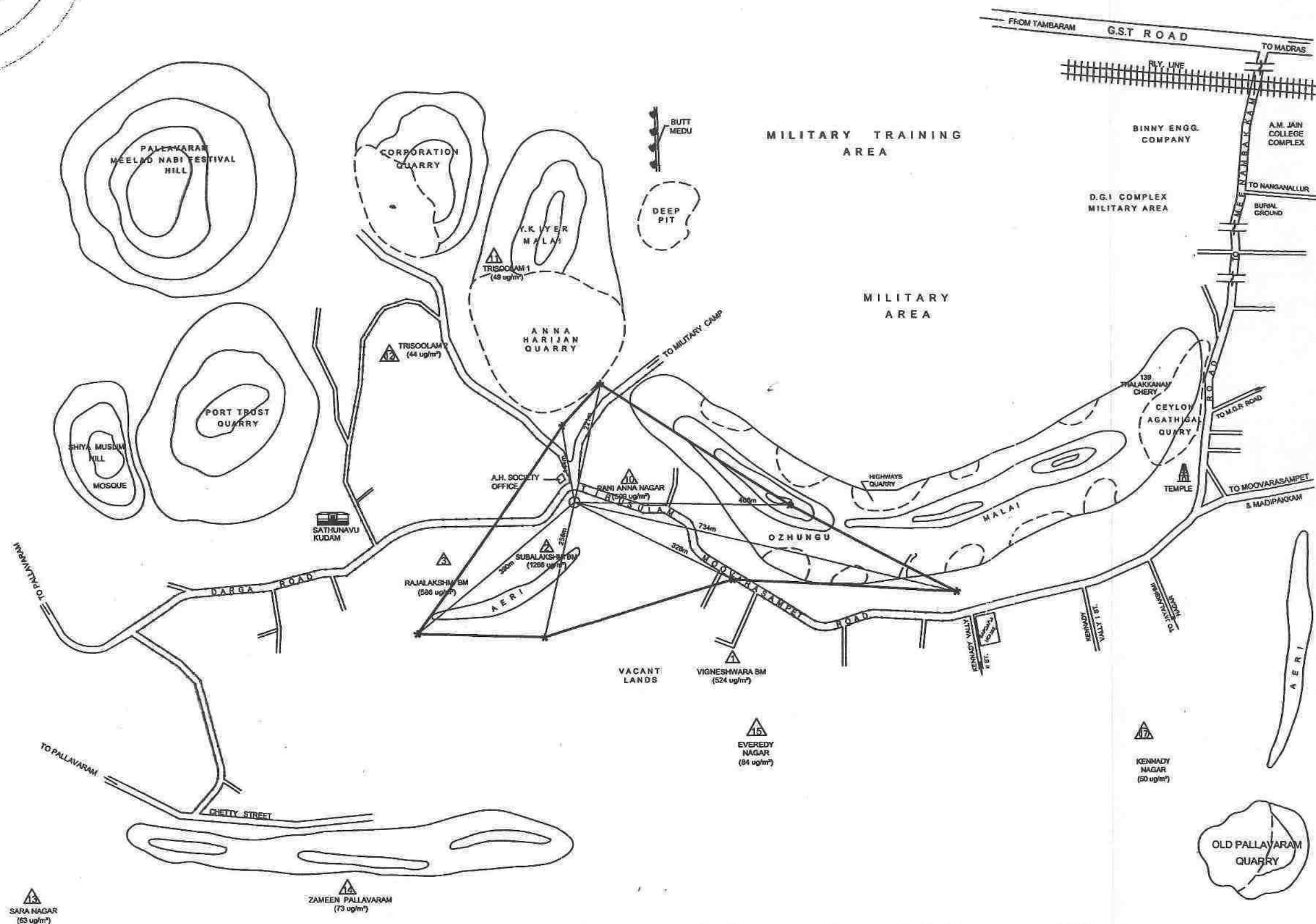
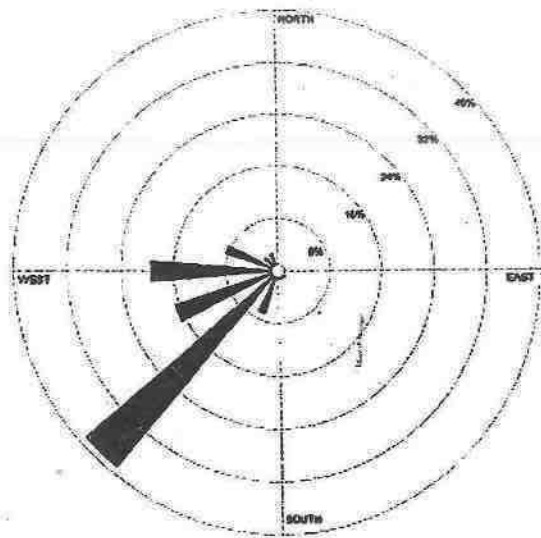


FIG. 3.25 Impact zone for no crushing activity, only vehicles traffic / movement

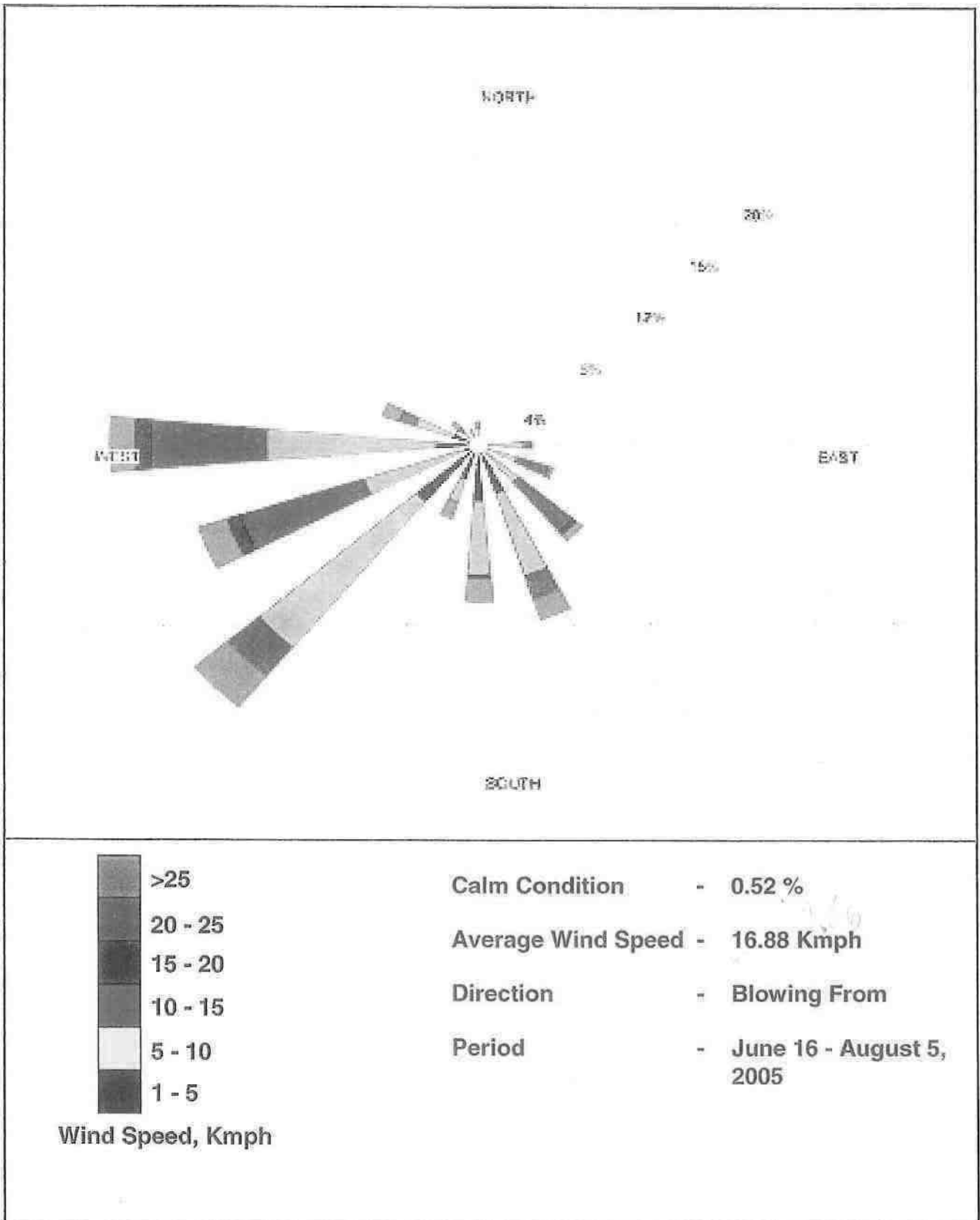


Fig. 3.26 Wind rose Pattern at Stone Crushing Units, Trisoolam
(Overall Study Period)



period was 16.9 kmph. The micrometeorological data recorded at Trisoolam site for the overall period are given in Table 3.31.

3.8 Dust contribution from single and cluster of stone crushing units

The TSPM concentrations of various upwind and downwind locations for different stone crusher working conditions are presented in Table 3.32. The RSPM concentrations of various upwind and downwind locations for different stone crusher working condition are presented in Table 3.33. The incremental increase of TSPM concentrations over the background TSPM, when one crusher is in operation and when all the crushers are in operation are presented in Table 3.34, which is derived from the values presented in Table 3.32.

The incremental increase of RSPM concentrations over the background RSPM, when one crusher is in operation and when all the crushers are in operation are presented in Table 3.35, which is derived from the values presented in Table 3.33.

3.8.1 All crushers running

3.8.1.1 TSPM

The background TSPM concentration varied from 250 to 345 $\mu\text{g}/\text{m}^3$ with a mean of 296 $\mu\text{g}/\text{m}^3$ for source whereas for ambient air TSPM varied from 32 to 84 $\mu\text{g}/\text{m}^3$ with a mean of 61 $\mu\text{g}/\text{m}^3$ (Table 3.32). The incremental increase in average TSPM when all the crushers were in operation varied from 923 to 3454 $\mu\text{g}/\text{m}^3$ with a mean of 2333 $\mu\text{g}/\text{m}^3$ for source whereas TSPM varied from 342 to 667 $\mu\text{g}/\text{m}^3$ with a mean of 458 $\mu\text{g}/\text{m}^3$ for ambient air (Table 3.34).

3.8.1.2 RSPM

The background RSPM concentration varied from 19 to 50 $\mu\text{g}/\text{m}^3$ with a mean of 35 $\mu\text{g}/\text{m}^3$ for ambient air (Table 3.33). The incremental increase in average RSPM when all the crushers were in operation varied from 43 to 203 $\mu\text{g}/\text{m}^3$ with a mean of 123 $\mu\text{g}/\text{m}^3$ for ambient air. The incremental increase in average cyclone dust when all the crushers were in operation varied from 109 to 293 $\mu\text{g}/\text{m}^3$ with a mean of 201 $\mu\text{g}/\text{m}^3$ for ambient air (Table 3.35).

Table 3.31 Summary of meteorological data observed at Trisoolam

S. No	Date	Sun Set	Sun Rise	Wind direction (degree)			Wind Speed (m/s)			Temperature (°C)			Humidity (%)		
				Min.	Max.	Avg.	Min.	Max.	Avg.	Min.	Max.	Avg.	Min.	Max.	Avg.
1	June 16, 2005	5:43	18:36	110	290	161	1.54	4.12	2.31	28.10	36.00	32.14	42	80	61.88
2	June 17, 2005	5:43	18:37	160	270	233	0.51	4.12	2.34	28.00	37.00	32.74	35	70	53.88
3	June 18, 2005	5:43	18:37	230	290	258	1.54	4.63	3.00	27.40	35.90	32.63	39	62	47.92
4	June 19, 2005	5:43	18:37	250	270	264	1.54	3.60	2.26	27.40	35.70	32.53	42	62	48.79
5	June 20, 2005	5:44	18:37	200	250	225	1.54	1.54	1.54	29.80	37.50	32.83	33	79	52.92
6	June 22, 2005	5:44	18:38	110	340	230	1.54	16.46	6.13	29.30	38.40	32.04	32	83	56.10
7	June 23, 2005	5:44	18:38	160	270	228	1.03	7.20	1.95	28.60	37.60	31.87	34	80	60.75
8	June 24, 2005	5:44	18:38	110	270	248	1.54	3.60	2.38	27.90	38.10	32.04	33	82	63.13
9	June 26, 2005	5:44	18:38	110	270	230	4.12	4.12	4.12	28.80	38.10	31.90	32	85	63.42
10	June 27, 2005	5:44	18:38	160	290	204	1.03	2.06	1.54	28.10	37.10	31.16	38	88	68.33
11	June 28, 2005	5:45	18:39	160	290	238	1.03	3.09	1.86	26.40	37.60	31.27	38	91	70.21
12	June 29, 2005	5:45	18:39	140	290	216	0.51	3.09	1.74	26.40	36.90	30.63	41	91	70.92
13	June 30, 2005	5:45	18:39	140	270	210	1.03	3.09	2.08	28.80	37.30	31.19	33	89	67.88
14	July 1, 2005	5:46	18:37	160	270	209	0.51	2.57	1.59	27.90	38.60	32.03	34	89	66.46
15	July 2, 2005	5:47	18:39	140	270	222	0.51	13.38	2.85	26.10	36.70	31.70	35	91	60.21
16	July 3, 2005	5:47	18:37	140	270	214	0.51	3.60	2.16	26.10	34.30	29.88	48	86	65.92
17	July 4, 2005	5:47	18:40	110	270	213	0.51	11.83	2.44	27.40	37.90	30.86	43	89	72.67
18	July 5, 2005	5:47	18:40	90	270	218	0.51	4.12	1.91	28.60	36.00	30.93	34	89	67.58
19	July 6, 2005	5:48	18:40	110	290	223	1.03	12.35	2.25	27.90	35.50	31.47	48	83	68.83
20	July 7, 2005	5:48	18:40	140	270	228	1.03	3.09	1.91	29.20	36.00	31.46	48	88	74.50
21	July 8, 2005	5:48	18:40	110	340	219	0.51	32.92	5.98	27.10	34.20	30.06	55	88	75.46
22	July 9, 2005	5:48	18:40	90	320	214	1.03	32.41	8.81	27.70	285.00	41.11	51	89	75.63
23	July 10, 2005	5:49	18:40	90	270	203	0.51	11.83	2.29	27.20	33.20	29.97	55	88	72.17
24	July 11, 2005	5:49	18:40	110	320	196	1.03	4.12	1.84	26.00	35.60	29.57	47	92	74.67



25	July 12, 2005	5:49	18:40	90	290	180	1.03	5.14	2.23	26.00	29.90	28.05	65	82	73.00
26	July 13, 2005	5:50	18:40	0	270	148	0.00	3.09	1.41	24.20	31.20	27.77	59	93	74.17
27	July 14, 2005	5:50	18:40	0	340	193	0.51	3.09	1.48	27.50	34.30	30.02	48	86	65.83
28	July 15, 2005	5:50	18:40	90	320	185	0.51	4.63	2.01	28.20	33.20	30.09	49	85	66.75
29	July 16, 2005	5:50	18:40	90	320	183	0.51	3.09	1.66	27.30	36.50	31.14	41	89	69.20
30	July 17, 2005	5:51	18:39	110	290	183	0.51	2.57	1.35	28.10	35.20	31.09	42	91	73.50
31	July 18, 2005	5:51	18:39	90	340	193	1.03	33.44	6.99	28.90	34.70	31.20	49	88	72.54
32	July 19, 2005	5:51	18:39	90	340	171	1.54	3.09	2.01	27.20	35.70	31.01	42	85	68.83
33	July 20, 2005	5:52	18:39	90	320	216	0.51	10.29	2.44	28.70	37.60	32.23	31	86	64.38
34	July 21, 2005	5:52	18:39	110	340	242	1.54	33.44	17.58	30.10	37.30	32.05	33	82	60.58
35	July 22, 2005	5:52	18:39	110	270	229	0.51	27.78	8.00	29.10	34.00	31.28	46	79	58.54
36	July 23, 2005	5:52	18:39	140	340	256	1.03	33.44	20.28	26.70	33.10	30.10	42	86	60.21
37	July 24, 2005	5:53	18:38	200	290	253	1.54	33.95	18.97	25.90	33.70	29.46	45	88	65.04
38	July 25, 2005	5:53	18:38	180	270	230	1.03	33.44	9.11	24.60	34.60	29.61	44	94	72.08
39	July 26, 2005	5:53	18:38	160	340	224	1.54	33.44	22.18	24.50	35.40	29.74	40	94	68.25
40	July 27, 2005	5:53	18:38	160	290	228	1.03	23.66	2.85	28.60	33.60	31.09	41	68	55.29
41	July 28, 2005	5:54	18:37	160	290	242	0.51	2.06	1.15	26.60	36.00	30.71	39	89	60.54
42	August 1, 2005	5:54	18:36	160	270	226	1.54	8.74	2.57	27.90	32.40	29.90	52	90	65.67
43	August 2, 2005	5:56	18:36	140	270	241	0.51	3.09	1.91	28.40	32.60	30.47	52	70	59.25
44	August 3, 2005	5:56	18:36	160	290	249	0.51	3.09	1.63	28.20	28.20	28.20	43	89	62.83
45	August 4, 2005	5:55	18:35	140	290	227	1.03	14.40	2.91	27.10	34.7	30.7	42	78	58.96
46	August 5, 2005	5:55	18:35	160	270	218	0.00	7.72	1.80	27.1	36.00	60.43	42	86	62.71

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Table 3.32
Summary of air quality sampling programme results for TSPM (unit: $\mu\text{g}/\text{m}^3$)

S. No.	Sampling Station	Crusher No. in the map (Fig 3.1)	Contribution by					No crusher
			All crushers	35 crushers	18 crushers	9 crushers	Only one crusher	
Source								
1	Vigneshwara BM	1	2962	2050	2014	1003	524	306
2	Subalakshmi BM	2	3735	3071	2845	1574	1266	281
3	Rajalakshmi BM	3	1268			688	586	345
4	Ashok BM	4	2283					
5	Rathna BM	7	4109					
6	Sivakami BM	8	1423					
7	Rani Anna Nagar BM	10	2548	1753	1691	1141	509	250
8	Sivagami Natesan BM	9	3747					
Ambient								
9	Trisoolam-1 BM	11	716	521	418	346	56	49
10	Sara Nagar BM	13	528	126	88	66	65	63
11	Zamin Pallavaram BM	14	430	157	125	123	73	73
12	Everedy Nagar BM	15	426	166	152	107	104	84
13	Trisoolam-2 BM	12			306	178	44	32

Table 3.33
Summary of air quality sampling programme results for RSPM and cyclone dust (unit: $\mu\text{g}/\text{m}^3$)

S. No.	Sampling Station	Crusher No. in the map (Fig 3.1)	Contribution by												Background concentration	
			All crushers		35 crushers		18 crushers		9 crushers		Only one crusher					
Source																
1	Suguna BM	5	654	2180												
2	J R Vimala BM	6	274	608												
Ambient																
3	Trisoolam - 2	12	200	75	155	63										
4	Krishna Nagar	16	91	128	81	117	80	84	56	66	50	43	48			19
5	Kennady Nagar	17	276	343	250	324	165	307	155	291	87	253	73			50

Table 3.34
TSPM contribution of a single crusher and cluster of crushers for Trisoolam area (unit: $\mu\text{g}/\text{m}^3$)

S. No.	Sampling Station	Crusher No. in the map (Fig 3.1)	Contribution by				Only one crusher
			All crushers	35 crushers	18 crushers	9 crushers	
Source							
1	Vigneshwara BM	1	2656	1744	1708	697	218
2	Subalakshmi BM	2	3454	2790	2564	1293	985
3	Rajalakshmi BM	3	923			343	241
4	Rani Anna Nagar	10	2298	1503	1441	891	259
Ambient							
5	Trisoolam -1	11	667	472	369	297	7
6	Trisoolam -2	12			274	146	12
7	Sara Nagar	13	465	63	25	3	2
8	Zamin Pallavaram	14	357	84	52	50	0.11
9	Everdy Nagar	15	342	82	68	23	20

Table 3.35
RSPM and cyclone dust contribution of a single crusher and cluster of crushers for Trisoolam area (unit: $\mu\text{g}/\text{m}^3$)

S. No.	Sampling Station	Crusher No. in the map (Fig 3.1)	Contribution by											
			All crushers		35 crushers		18 crushers		9 crushers		Only one crusher			
			RSPM	Cyclone dust	RSPM	Cyclone dust	RSPM	Cyclone dust	RSPM	Cyclone dust	RSPM	Cyclone dust		
Ambient														
1	Krishna Nagar	16	43	109	33	98	32	65	8	47	2	24		
2	Kennady Nagar	17	203	293	177	274	92	257	82	241	14	203		



3.8.2 Half of the crushers in operation

3.8.2.1 TSPM

The incremental increase in average TSPM when half of the crushers were in operation varied from 1503 to 2790 $\mu\text{g}/\text{m}^3$ with a mean of 2012 $\mu\text{g}/\text{m}^3$ for source whereas TSPM varied from 63 to 472 $\mu\text{g}/\text{m}^3$ with a mean of 175 $\mu\text{g}/\text{m}^3$ for ambient air. (Table 3.34).

3.8.2.2 RSPM

The incremental increase in average RSPM when half of the crushers were in operation varied from 33 to 177 $\mu\text{g}/\text{m}^3$ with a mean of 105 $\mu\text{g}/\text{m}^3$ for ambient air. The incremental increase in average Cyclone dust when half of the crushers were in operation varied from 98 to 274 $\mu\text{g}/\text{m}^3$ with a mean of 186 $\mu\text{g}/\text{m}^3$ for ambient air. (Table 3.35).

3.8.3 1/4th of the crushers in operation

3.8.3.1 TSPM

The incremental increase in average TSPM when 1/4th of the crushers were in operation varied from 1441 to 2564 $\mu\text{g}/\text{m}^3$ with a mean of 1904 $\mu\text{g}/\text{m}^3$ for source whereas TSPM varied from 25 to 369 $\mu\text{g}/\text{m}^3$ with a mean of 158 $\mu\text{g}/\text{m}^3$ for ambient air (Table 3.34).

3.8.3.2 RSPM

The incremental increase in average RSPM when 1/4th of the crushers were in operation varied from 32 to 92 $\mu\text{g}/\text{m}^3$ with a mean of 62 $\mu\text{g}/\text{m}^3$ for ambient air. The incremental increase in average Cyclone dust when 1/4th of the crushers were in operation varied from 65 to 257 $\mu\text{g}/\text{m}^3$ with a mean of 161 $\mu\text{g}/\text{m}^3$ for ambient air. (Table 3.35).

3.8.4 1/8th of the crusher in operation

3.8.4.1 TSPM

The incremental increase in average TSPM when 1/8th of the crushers were in operation varied from 343 to 1293 $\mu\text{g}/\text{m}^3$ with a mean of 1056 $\mu\text{g}/\text{m}^3$ for source whereas TSPM varied from 3 to 297 $\mu\text{g}/\text{m}^3$ with a mean of 104 $\mu\text{g}/\text{m}^3$ for ambient air. (Table 3.34).

3.8.4.2 RSPM

The incremental increase in average RSPM when 1/8th of the crushers were in operation varied from 8 to 82 $\mu\text{g}/\text{m}^3$ with a mean of 45 $\mu\text{g}/\text{m}^3$ for ambient air. The incremental increase in average Cyclone dust when 1/8th of the crushers were in operation varied from 47 to 241 $\mu\text{g}/\text{m}^3$ with a mean of 144 $\mu\text{g}/\text{m}^3$ for ambient air. (Table 3.35).



3.8.5 Only one crusher in operation

3.8.5.1 TSPM

The incremental increase in average TSPM when only one crusher, Rajalakshmi (40) was in operation varied from 218 to 985 $\mu\text{g}/\text{m}^3$ with a mean of 426 $\mu\text{g}/\text{m}^3$ for source whereas RSPM varied from 1 to 20 $\mu\text{g}/\text{m}^3$ with a mean of 8 $\mu\text{g}/\text{m}^3$ for ambient air. (Table 3.34).

3.8.5.2 RSPM

The incremental increase in average RSPM when only one crusher was in operation varied from 2 to 14 $\mu\text{g}/\text{m}^3$ with a mean of 8 $\mu\text{g}/\text{m}^3$ for ambient air. The incremental increase in average cyclone dust when only one crusher was in operation varied from 24 to 203 $\mu\text{g}/\text{m}^3$ with a mean of 114 $\mu\text{g}/\text{m}^3$ for ambient air. (Table 3.35).



CHAPTER 4

PARTICLE SIZE ANALYSIS

4.1 Preamble

The size distribution of particulate matter in air determines its potential for adverse effects on health and visibility. The aerodynamic size of the particle dictates whether it falls rapidly to the ground or remains suspended to enter the human respiratory system. Again depending upon size and chemical nature, the particle may be filtered out in the upper nasal system, settle in the tracheo bronchial system; penetrate into the alveoli suspended to be expired.

Atmospheric particle size distribution shows multimodal pattern due in a large part to the mechanism of their generation. The modes are usually grouped into two broad classifications for air pollution purposes fine and coarse. Fine particles are considered to be those smaller than $2.5 \mu\text{m}$ in diameter. The fine (respirable) particles can penetrate into the pulmonary region of the respiratory system. Coarse particles are principally formed by mechanical, grinding or other dispersive forces. Their size ranges more than $10 \mu\text{m}$ in diameter, depending upon the dispersive forces and atmospheric conditions. The fine stage has an upper cut off particles point of $2.5 \mu\text{m}$, the coarse (inhalable) stage has an upper cut-off particles point of either 10 or $15 \mu\text{m}$ depending upon design. Present tendencies are to standardize on the $10 \mu\text{m}$ cut-off point as the respirable particulates.

Dust particles emitted from a given source are dispersed into the atmosphere where the small particles settle under gravity at near distance from the source. Particles larger than $30 \mu\text{m}$ are usually deposited within short distance from the source and small particles of size in the range of $10 - 15 \mu\text{m}$ stays for a longer time in the atmosphere. Particle size analysis plays an important role in the characterization of dust emission from the stone crushing operation and estimation of percentage of air borne particle which is transported over longer distance from the source causing environmental health effects. The most important particle properties related to atmospheric transport are size, shape and size distribution. Physical properties such as density and moisture also play an important role in the transport.

Emphasis is usually given to dust emission in the inhalable size range ($< 10 \mu\text{m}$). Fine inhalable dust particles $\leq 2.5 \mu\text{m}$ enter human respiratory system causing more damage than



that of coarse inhalable particles of the size range 2.5 to 10 μm . Hence it is necessary to carry out particle size analysis for the size distribution of suspended particulates.

Particle size analysis was carried out by using CILAS 1180 model Particle Size Analyzer using laser diffraction. Of the many particle size measuring methods, laser diffraction technique has distinctive features such as simplified operation, excellent repeatability and short measuring time. The result of measurements is printed out automatically within 3 minutes after the measurement is started.

4.2 Particle size distribution of source dust

Particle size analysis was carried out for dust samples collected at the stone crushing unit, and the results are presented in the form of a cumulative distribution graph. The cumulative distribution graph shows the percentage of particles (number) less than the particle size of interest and the differential distribution graph indicate the percentage of particles in the specified size range.

4.2.1 Ratna BM

The respirable particulate matter (PM_{10}), which is defined as the particles with an aerodynamic diameter not greater than 10 μm , was found to be 36.6 %, and the fine inhalable particulate matter or $\text{PM}_{2.5}$, the particles with an aerodynamic diameter $\leq 2.5 \mu\text{m}$, was found to be 14.3 % as shown in Table 4.1 and Fig 4.1.

4.2.2 Subalakshmi BM

The respirable particulate matter (PM_{10}), was found to be 42.2 % and the fine inhalable particulate matter or $\text{PM}_{2.5}$, was found to be 14.6 %. The fine inhalable particulate concentration ($\text{PM}_{2.5}$) near the source, is presented in Table 4.2 and Fig 4.2.

4.3 Particle size distribution of ambient air dust

4.3.1 Trisoolam area

The particle size distribution of ambient air dust was carried out to quantify the fraction of particles transported from the crusher to the receiver. The results of the analysis are given in Table 4.3 and Fig. 4.3, which show that the percentage of particulate fractions $\text{PM}_{2.5}$, PM_{10} , PM_{15} , and PM_{30} are 25.3, 60.5, 72.8 and 91 % respectively. The higher percentage of finer particles collected was due to the fact that the larger size particles were settling near the source, and the finer particles were able to remain in the air for a much longer time. The settleable particulate matter with an aerodynamic diameter greater than 15 μm that would deposit or settle near the sources is 72.8 %. The differential distribution



Table 4.1
Particle size analysis at source: Rathna BM

S. No.	Diameter, x μm	Cumulative, Q_3 %	Differential, q_3 %
1	0.04	0.10	0.03
2	0.07	0.40	0.05
3	0.10	0.66	0.07
4	0.20	1.95	0.18
5	0.30	3.63	0.39
6	0.40	4.51	0.29
7	0.50	4.72	0.09
8	0.60	4.82	0.05
9	0.70	4.97	0.09
10	0.80	5.25	0.20
11	0.90	5.59	0.27
12	1.00	5.97	0.34
13	1.10	6.39	0.42
14	1.20	6.83	0.48
15	1.30	7.29	0.54
16	1.40	7.78	0.63
17	1.60	8.81	0.73
18	1.80	9.90	0.88
19	2.00	11.00	0.99
20	2.20	12.11	1.10
21	2.40	13.20	1.19
22	2.60	14.25	1.24
23	3.00	16.19	1.28
24	4.00	20.16	1.31
25	5.00	23.43	1.39
26	6.00	26.41	1.55
27	6.50	27.84	1.69
28	7.00	29.23	1.78
29	7.50	30.58	1.85
30	8.00	31.87	1.89
31	8.50	33.10	1.92
32	9.00	34.29	1.97
33	10.00	36.55	2.03
34	11.00	38.71	2.15



35	12.00	40.79	2.26
36	13.00	42.84	2.43
37	14.00	44.86	2.58
38	15.00	46.87	2.76
39	16.00	48.89	2.97
40	17.00	50.90	3.14
41	18.00	52.88	3.28
42	19.00	54.86	3.47
43	20.00	56.79	3.56
44	22.00	60.51	3.70
45	25.00	65.62	3.79
46	28.00	70.23	3.85
47	32.00	75.80	3.95
48	36.00	80.74	3.97
49	38.00	82.98	3.92
50	40.00	85.04	3.80
51	45.00	89.49	3.58
52	50.00	92.96	3.12
53	53.00	94.61	2.68
54	56.00	95.95	2.31
55	63.00	98.07	1.71
56	71.00	99.32	0.99
57	75.00	99.62	0.52
58	80.00	99.84	0.32
59	85.00	99.95	0.17
60	90.00	100.00	0.08
61	95.00	100.00	0.00

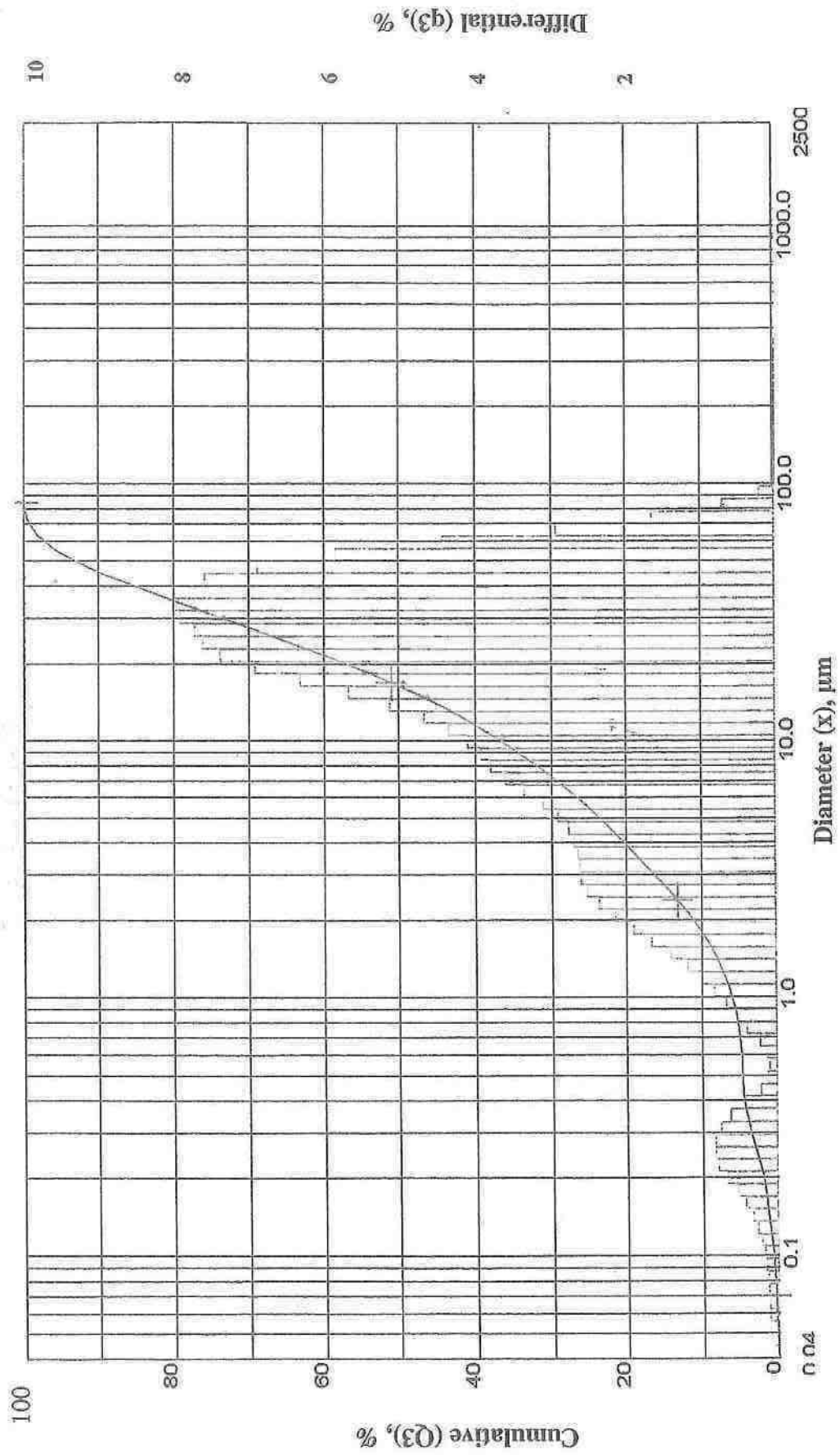


Fig 4.1 Cumulative and Differential Distribution graph for the Source (Ratna crusher)

Table 4.2
Particle size analysis at source: Subha Lakshmi BM

S. No.	Diameter, x μm	Cumulative Q_3 %	Differential q_3 %
1	0.04	0.08	0.03
2	0.07	0.25	0.03
3	0.10	0.39	0.04
4	0.20	0.81	0.06
5	0.30	1.27	0.11
6	0.40	1.69	0.14
7	0.50	2.09	0.17
8	0.60	2.53	0.23
9	0.70	3.04	0.31
10	0.80	3.63	0.42
11	0.90	4.25	0.50
12	1.00	4.89	0.57
13	1.10	5.53	0.63
14	1.20	6.18	0.70
15	1.30	6.83	0.76
16	1.40	7.48	0.83
17	1.60	8.75	0.90
18	1.80	10.00	1.00
19	2.00	11.21	1.08
20	2.20	12.39	1.17
21	2.40	13.54	1.24
22	2.60	14.65	1.31
23	3.00	16.78	1.40
24	4.00	21.61	1.58
25	5.00	25.81	1.77
26	6.00	29.57	1.94
27	6.50	31.32	2.06
28	7.00	33.00	2.13
29	7.50	34.63	2.22
30	8.00	36.21	2.30
31	8.50	37.75	2.39
32	9.00	39.25	2.47
33	10.00	42.15	2.59
34	11.00	44.91	2.73
35	12.00	47.56	2.87
36	13.00	50.09	2.98
37	14.00	52.51	3.07
38	15.00	54.82	3.15
39	16.00	57.03	3.22



40	17.00	59.14	3.28
41	18.00	61.17	3.34
42	19.00	63.11	3.38
43	20.00	64.97	3.41
44	22.00	68.47	3.46
45	25.00	73.20	3.48
46	28.00	77.46	3.54
47	32.00	82.60	3.62
48	36.00	87.10	3.60
49	38.00	89.07	3.43
50	40.00	90.84	3.25
51	45.00	94.44	2.88
52	50.00	96.93	2.23
53	53.00	97.97	1.68
54	56.00	98.75	1.33
55	63.00	99.68	0.74
56	71.00	100.00	0.25
57	75.00	100.00	0.00

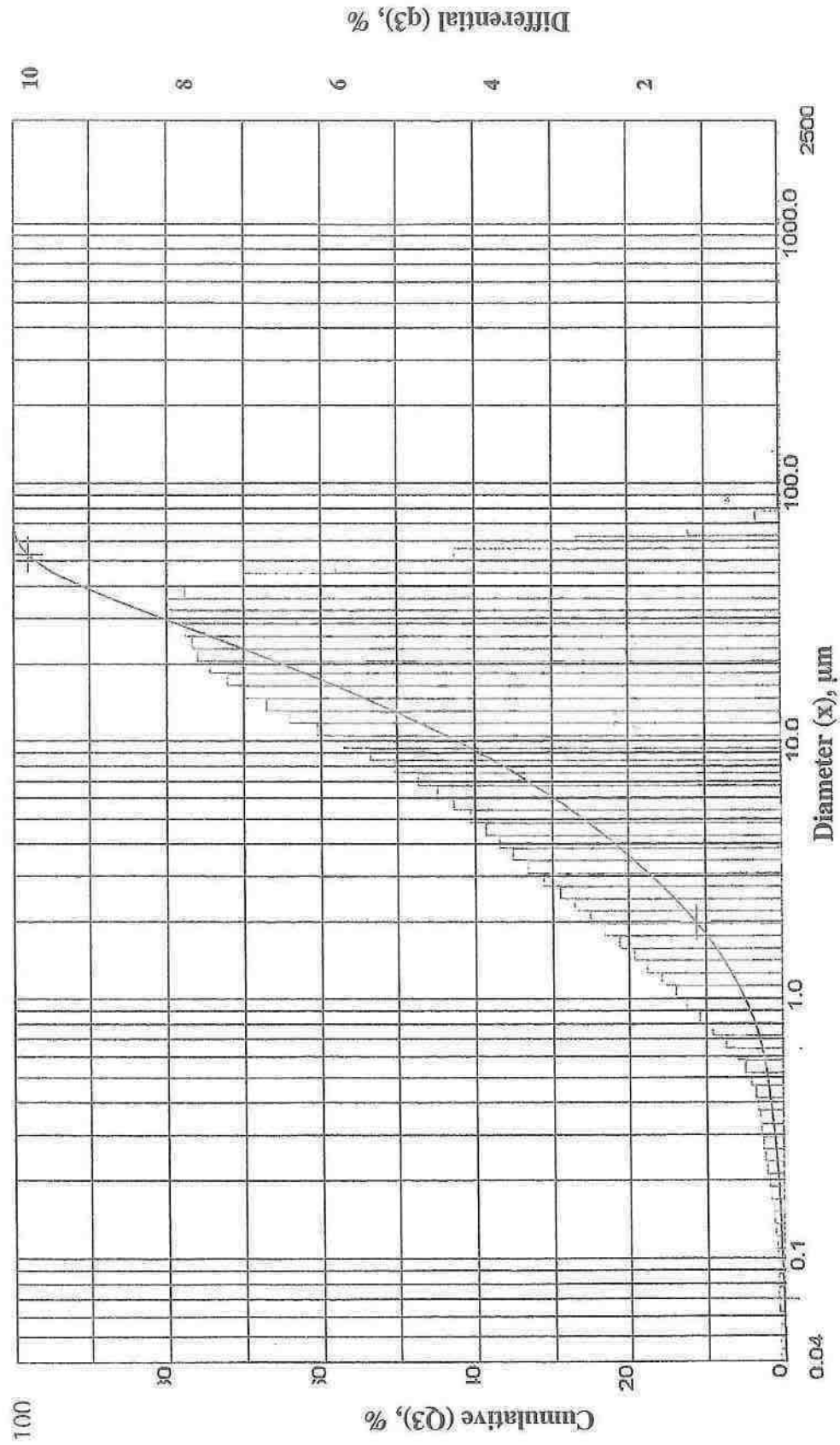


Fig. 4.2 Cumulative and Differential Distribution Graph for the Source (Subha Lakshmi Crusher)



Table 4.3
Particle size analysis in ambient air: Trisoolam area

S. No.	Diameter (x) μm	Cumulative (Q ₃) %	Differential (q ₃) %
1	0.04	0.02	0.01
2	0.07	0.21	0.03
3	0.10	0.44	0.06
4	0.2	1.30	0.12
5	0.3	2.21	0.22
6	0.4	2.98	0.26
7	0.5	3.68	0.31
8	0.6	4.48	0.43
9	0.7	5.43	0.61
10	0.8	6.56	0.83
11	0.9	7.79	1.03
12	1.0	9.07	1.20
13	1.1	10.40	1.38
14	1.2	11.73	1.51
15	1.3	13.03	1.60
16	1.4	14.28	1.66
17	1.6	16.62	1.73
18	1.8	18.72	1.76
19	2.0	20.61	1.77
20	2.2	22.30	1.75
21	2.4	23.85	1.76
22	2.6	25.31	1.80
23	3.0	28.50	1.89
24	4.0	34.47	2.20
25	5.0	40.36	2.60
26	6.0	45.51	2.79
27	6.5	47.80	2.82
28	7.0	49.94	2.85
29	7.5	51.95	2.87
30	8.0	53.85	2.90
31	8.5	55.64	2.91
32	9.0	57.34	2.93
33	10.0	60.49	2.95
34	11.0	63.37	2.98
35	12.0	66.00	2.98
36	13.0	68.45	3.02
37	14.0	70.72	3.02
38	15.0	72.84	3.03
39	16.0	74.83	3.04



40	17.0	76.68	3.01
41	18.0	78.39	2.95
42	19.0	79.98	2.90
43	20.0	81.43	2.79
44	22.0	83.95	2.61
45	25	86.82	2.22
46	28	88.90	1.81
47	32	90.99	1.54
48	36	92.64	1.38
49	38	93.36	1.31
50	40	94.03	1.29
51	45	95.52	1.25
52	50	96.79	1.19
53	53	97.43	1.08
54	56	97.98	0.99
55	63	98.95	0.81
56	71	99.59	0.53
57	75	99.76	0.31
58	80	99.89	0.20
59	85	99.96	0.11
60	90	100.00	0.07
61	95	100.00	0.00

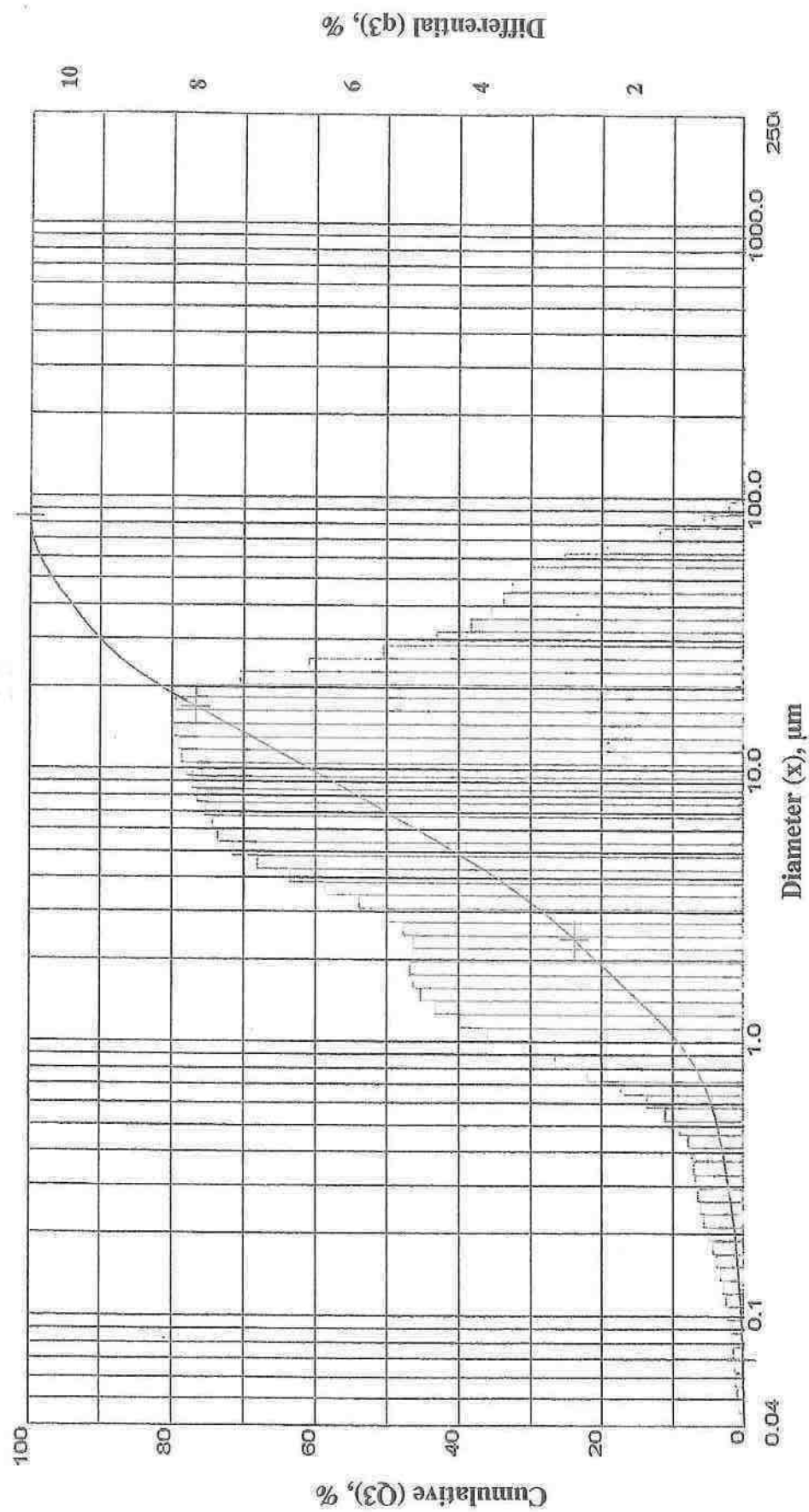


Fig. 4.3 Cumulative and Differential Distribution graph for Ambient Air (Trisoolam)



graphs show that maximum percentages (11%) of particles are in the range of $3 - 5 \mu\text{m}$ (Fig. 4.3).

4.4 Fine respirable particulate matter ($\text{PM}_{2.5}$) at source and ambient air

Ambient air quality monitoring network consisting of 17 locations was designed based on prevailing wind pattern, stone crusher location and their geometry, of which, 10 were deployed at source (TSPM 8, RSPM 2) and seven in ambient air (TSPM 4, RSPM 3). During the same period micro-meteorological data were also collected at 3 identified locations, one inside stone crushing area near Subramaniam BM and two in the residential area viz., Trisoolam- 2 and Kennedy valley. The distance and direction of ambient air quality monitoring stations with reference to stone crushers are given in Table 3.3. Out of 10 source air quality monitoring stations, eight were chosen in the upwind direction and two in the downwind direction. Ambient dust monitoring was carried out around stone crushing units at 7 locations in the stone crushing area. Out of 7 ambient air quality monitoring stations, four were chosen in the upwind direction and three in the downwind direction. The measured concentration of fine respirable particulate matter $\text{PM}_{2.5}$ at source and ambient air are given in Table 4.4. At source except Suguna BM all the $\text{PM}_{2.5}$ concentrations exceed the standard limit of $65 \mu\text{g}/\text{m}^3$ (EPA Standards). In ambient air except Trisoolam-2 and Krishna Nagar $\text{PM}_{2.5}$ concentration exceeded the limit of $65 \mu\text{g}/\text{m}^3$, in all the stations. Also PM_{10} concentration at source exceeded the standard of $100 \mu\text{g}/\text{m}^3$ in all the locations except Suguna BM and J.R Vimala BM. Also PM_{10} concentration in ambient air exceeded the standard limit of $100 \mu\text{g}/\text{m}^3$ in all the locations except at Zamin Pallavaram, Trisoolam 2, Krishna Nagar and Kennedy Nagar.

4.5 Assessment of occupational exposure level

Occupational exposures to total and respirable dusts were assessed on 72 workers through personal sampling. Eleven locations were identified for personal sampler measurements, one at the center of cluster of stone crushers, eight in the downwind, and two in the upwind directions. The measured total dust and respirable particulate matter at these locations are given in Table 4.5. The respirable particulate matter at these locations varied from 26 to $87 \mu\text{g}/\text{m}^3$, with a mean of $56 \mu\text{g}/\text{m}^3$. The TSPM concentration at these locations varied from 49 to $117 \text{mg}/\text{m}^3$, with a mean of $91 \mu\text{g}/\text{m}^3$. The ratio of respirable particulate matter to total dust varied from 44 to 61 %, with a mean of 57 %. The total dust and respirable particulate matter exposure concentrations at all the stations exceeded the



Table 4.4
Respirable particulate matter PM_{2.5} concentration at source and ambient air

S. No.	Sampling Location	TSPM	PM _{2.5} (%)	Concentration (µg/m ³)
Source				
1	Vigneshwara BM	2962	14.25	424
2	Subalaxmi BM	3735	14.65	557
3	Rajalaxami BM	1268	14.45	179
4	Ashok BM	2282	15.7	363
5	Rathna BM	4109	16.5	678
6	Sivakami BM	1424	17.2	245
7	Sivagami Natesan BM	3747	18.7	701
8	Suguna BM	274	13.9	38
9	JR Vimala BM	654	13.75	90
10	Rani Anna Nagar	2548	23.6	601
Ambient				
10	Trisoolam 1	716	25.3	181
11	Sara Nagar	528	23.4	124
12	Zamin Pallavaram	430	22.4	96
13	Everedy Nagar	426	25.1	107
14	Trisoolam 2	200	25.6	51
15	Krishna Nagar	91	22.3	20
16	Kennady Nagar	276	23.7	65

Table 4.5
Occupational exposure level: dust and respirable particulate matter

S. No.	Sampling location	Total dust (µg/m ³)			RSPM* (µg/m ³)			RSPM* / Total dust
		Min	Max	Avg.	Min	Max	Avg.	
1	Subramanian BM	114	121	117	67	71	70	60
2	Gnanaselvam BM	82	115	112	53	67	61	54
3	Praveena BM	77	115	97	50	67	59	60
4	Sri Ganesh BM	62	114	89	36	67	51	58
5	Vignreshwara BM	115	117	116	67	81	51	44
6	Janakrman BM	62	85	74	21	66	45	61
7	Vijayaram BM	101	115	109	63	65	65	60
8	Dwaraga BM	100	114	107	66	62	62	58
9	Ashok crusher BM	34	63	49	31	26	26	53
10	Swaminathan BM	51	63	58	37	37	35	59
11	Kamatchi BM	63	78	70	44	40	87	57

* 4 µm/cut off point

median ✓



occupational environment standards (12 hours) recommended by the Occupational Safety and Health Administration (15 and 5 mg/m³ for TSPM and RSPM, respectively), the National Institute of Occupational Safety and Health (10 mg/m³ for TSPM) (NTIS 1994), and the American Conference of Governmental Industrial Hygienists (10 mg/m³ for both TSPM and RSPM) and were also in excess of permissible exposure limits prescribed by the Indian Factory Act.



CHAPTER 5

PREDICTION OF FUGITIVE DUST EMISSIONS

Prediction of impacts is an important component in environmental impact assessment process. Several techniques and methodologies are in vogue for predicting the impacts. Such predictions are superimposed over the baseline (pre-project) status of environmental quality to derive the ultimate (post-project) scenario of environmental conditions.

Mathematical models are used to predict the impact of emissions on air quality. The concentrations are estimated from meteorology, source geometry, and receptor location. Many models have been developed to describe the dispersion of pollutants from source and vary in their approach from a Gaussian line source approach to numerical solutions of conservation of pollutant mass equation.

Mathematical models are the best tools to quantitatively describe the cause effect relationship between source of pollution and different components of environment. In the present study, the mathematical models that have been used for predictions of air quality include steady state Gaussian Plume Dispersion Model, FDM, ISCST3 and AERMOD designed for predicting fugitive dust emissions.

5.1 Preamble

Pollutants which are generated from open sources exposed to the air and are not discharged into the atmosphere in a confined flow stream are termed as fugitive dust. The deposition of dust particles is considered as the main mechanism by which air borne pollution is removed from the atmosphere. Dust particles emitted from a given source are dispersed in the atmosphere where the small particles stay in suspension for a long time while the larger particles settle towards the earth under gravity at near distance from the source.

For a given rate of deposition the concentration will be proportional to the wind speed. As a result, the rate of deposition of small particles is inversely proportional to wind speed and directly proportional to particle settling velocities. Hence, the settling velocity of large particles dominates movement by diffusion, and the maximum deposition takes place near a source. Further, the location of maximum deposition of large particles moves nearer towards the source as the wind speed decreases. It may, therefore, be noticed that the

↑ arrange



maximum deposition rates increase more rapidly as the wind speed falls and increase of particle settling velocity is more for larger particles than for smaller particles.

However, particles larger than $20\mu\text{m}$ are usually deposited at their settling velocities within short distance from the source for a wide range of wind speed. The deposition of dust is known to be one of the adverse affects that is associated with dust emission. Investigations of fugitive dust necessitate measuring deposition rates in order to produce clear evidence about the impact of particulate pollution. One of the main objectives of fugitive dust investigation is to quantify the emission of particulates and relate emission to the process rates. Emphasis is usually focused on emission factors of dust in inhalable size range, $< 10\mu\text{m}$, and aerodynamic diameter.

The size of dust particle is an important parameter. The measurements of particle size distribution in particulate polluting source are usually made for some fundamental reasons such as:

1. To complete the characteristic information about a given source
2. To permit assessment of potential health and environmental effect of different sources
3. To obtain a complete quantification and better selection and design of control methods and devices

5.2 Estimation of source strength

One major uncertainty in any air quality investigation centering on fugitive dust is the emission rate. The source strength is the rate of dust emission from a source, e.g. g/min or mass per unit of material. This can be determined by quantifying the amount of dust immediately downwind of the source by means of simultaneous multipoint sampling over the effective cross section of fugitive emission plume.

5.3 Model for fugitive dust prediction

Stone crushing operations are major sources of fugitive dust and have been the subject of great concern in and around Trisoolam area. Modeling stone crusher emissions is an intricate issue since emissions are highly fugitive in nature. Hence, the selected models must be able to integrate the complex changes of fugitive dust emissions in the modeling procedures. The primary use of the model is for the computation of the concentrations and deposition rates resulting from stone crushing operations where fugitive dust is a concern. The model contains no plume rise algorithm and is thus not aimed at handling significant



buoyant forces. It was recognized from the start that ultimate acceptance of the model would hinge on its ability to accurately predict concentrations from the fugitive dust sources.

5.4 Technical description of the models tested

5.4.1 FDM

Fugitive Dust model (FDM) model is designed specially for computation of the impacts of fugitive dust sources. FDM model is a computerized air quality model specifically designed for computing concentration and deposition impacts from fugitive dust sources. The model incorporates a detailed deposition routine based on the equation of Ermak (1997). The model calculates concentration and deposition values for each of the receptor locations.

The source may be point, line or area sources. The model is generally based on the well-known Gaussian plume formulation for computing concentration, but the model has been specifically adapted to incorporate an improved gradient-transfer deposition algorithm. Emission for each source is apportioned by the user into a series of particle size classes. A gravitational velocity and a deposition velocity are calculated by FDM for each class. Concentration and deposition are computed at all selected receptor locations. The model is designed to work with pre-processed meteorological data or with card-image of meteorological data either hourly or in Stability Array (STAR) format.

FDM employs an advanced gradient-transfer particle deposition algorithm. Gravitational settling velocity and deposition velocity are calculated by FDM for each of up to 20 user-specified particle size classes. The source can be of three types: points, lines or areas. The line source and area source algorithms are based on algorithms in the CALINE3 Model (California Department of Transportation, 1979). Emission from all sources may be divided into maximum of 20 particle size classes. One of the unique characteristics of fugitive dust is that often emission rates are a function of the wind speed. The FDM has the capability to directly compute the effect of wind speed on emission rate.

FDM more accurately represents the behavior of particles in the atmosphere. The major advantage of the FDM is the ability to more accurately represent deposition. At receptors very close to the source less deposition occurs. One of the major advantages of the FDM approach is the avoidance of these large over predictions. The improved prediction occurs due to the superior deposition algorithm in the FDM. FDM accurately represents the behavior of particles in the atmosphere. Hence, FDM model was selected for the prediction exercise.



5.4.2 ISCST3 model

Industrial Source Complex Short Term (ISCST3, version 3) model provides options to model emissions from a wide range of sources. The basis of the model is the straight-line, steady-state Gaussian plume equation, which is used with some modifications to model simple point source emissions from stacks, emissions from stacks that experience the effects of aerodynamic downwash due to nearby buildings, isolated vents, multiple vents, storage piles, conveyor belts, and the like. Emission sources are categorized into four basic types of sources, i.e., point sources, volume sources, area sources, and open pit sources. The volume source option and the area source option may also be used to simulate line sources.

ISCST3 model accepts hourly meteorological data records to define the conditions for plume rise, transport, diffusion, and deposition. The model estimates the concentration or deposition value for each source and receptor combination for each hour of input meteorology, and calculates user-selected short-term averages. For deposition values, either the dry deposition flux, the wet deposition flux, or the total deposition flux can be estimated.

The ISCST3 models are based on revisions to the algorithms contained in the ISCST2 models. The ISCST3 models include several new features. A revised area source algorithm and revised dry deposition algorithm have been incorporated in the models. The ISCST3 models also include an algorithm for modeling impacts of particulate emissions from open pit sources, such as surface coal mines. The Short Term model includes a new wet deposition algorithm, and also incorporates the COMPLEX1 screening model algorithms for use with complex and intermediate terrain.

5.4.3 AERMOD

With the exception of treating pollutant deposition, AERMOD serves as a complete replacement for ISC3. AERMOD is a steady-state plume model. In the stable boundary layer (SBL), it assumes the concentration distribution to be Gaussian in both the vertical and horizontal. In the convective boundary layer (CBL), the horizontal distribution is also assumed to be Gaussian, but the vertical distribution is described with a bi-Gaussian probability density function (pdf). Additionally, in the CBL, AERMOD treats "plume lofting," whereby a portion of plume mass, released from a buoyant source, rises to and remains near the top of the boundary layer before becoming mixed into the CBL. For sources in both the CBL and the SBL, AERMOD treats the enhancement of lateral dispersion resulting from plume meander. Using a relatively simple approach, AERMOD incorporates



current concepts about flow and dispersion in complex terrain. Where appropriate the plume is modeled as either impacting and/or following the terrain. This approach has been designed to be physically realistic and simple to implement while avoiding the need to distinguish among simple, intermediate and complex terrain, as required by other regulatory models. As a result, AERMOD removes the need for defining complex terrain regimes. All terrain is handled in a consistent and continuous manner while considering the dividing streamline concept. One of the major improvements that AERMOD brings to applied dispersion modeling is its ability to characterize the PBL through both surface and mixed layer scaling.

5.5 Treatment of deposition

In these models the deposition was considered through two parameters viz., gravitational settling velocity and deposition velocity. The gravitational settling velocity accounts for removal of particulate matter from the atmosphere due to gravity. Since only the larger particles have significant mass to overcome turbulent eddies, this mechanism is significant only for the larger size ranges. The deposition velocity accounts for removal of particulate matter which is in contact with the surface and allows it to be removed by impaction velocity which is significantly different from the gravitational settling velocity, while for larger particles they are roughly the same. Each particle size class is treated separately by the model. The result for different particle size classes is summed at the end to develop a total suspended particulate concentration. Alternatively, the model can compute the deposition rate.

5.6. Averaging period

FDM, ISCST3 and AERMOD are capable of predicting average concentrations of both TSPM and particulate matter $< 10 \mu\text{m}$ for a variety of averaging times. The prediction was carried out for 24 hour averaging period; since National Ambient Air Quality Standards (NAAQS) are for 24 hours for TSP and PM_{10} concentrations. Comparison of model algorithm for FDM, ISCST3 and AERMOD is given Table 5.1.

5.7 Data requirements of the models

5.7.1 FDM

The FDM model requires information on the hourly values for wind speed, wind direction, temperature, atmospheric stability and mixing height. The input file of FDM contains three types of information:



Table 5.1 Comparison of model algorithm for FDM, ISCST3 and AERMOD

Parameter	FDM	ISCST3	AERMOD
Plume Rise	The line source and area source algorithms are based on algorithms in CALINE3 Model (California Department of Transportation, 1979)	Uses Briggs equations with stack-top wind speed and vertical temperature gradient	In stable conditions, uses Briggs equations with winds and temperature gradient at stack top and half-way to final plume rise; in convective conditions, plume rise is superposed on the displacements by random convective velocities
Meteorological data input	One level of data	One level of data	An arbitrarily large number of data levels can be accommodated
Profiling meteorological data	Only wind speed is profiled	Only wind speed is profiled	AERMOD creates profiles of wind, temperature, and turbulence, using all available measurement levels
Use of meteorological data in plume dispersion	Based on algorithms in the CALINE3 Model (California Department of Transportation, 1979)	Stack-top variables for all downwind distances	Variables measured throughout the plume depth (averaged from plume centerline to $2.15 \sigma_z$ below centerline; changes with downwind distance)
Plume dispersion: general treatment	Vertical dispersion based on the methodology developed by Pasquill and Draxler and horizontal dispersion based on Turner. The basic model incorporates a detailed deposition routine based on the equations of Ermak (1977)	Gaussian treatment in horizontal and vertical Directions	Gaussian treatment in horizontal and in vertical for stable conditions; non-Gaussian probability density function in vertical for unstable conditions
Urban treatment	There is no such option	Urban option either on or off; no other specification available; all sources must be modeled either rural or urban	Population is specified, so treatment can consider a variety of urban conditions; sources can individually be modeled rural or urban
Characterization of modeling domain surface characteristics	Choice of stability class, surface roughness length and mixing height	Choice of rural or urban	Selection by direction and month of roughness length, albedo, and Bowen ratio, providing user flexibility to vary surface characteristics
Boundary layer parameters	Wind speed, mixing height, and stability class	Wind speed, mixing height, and stability class	Friction velocity, Monin-Obukhov length, convective velocity scale, mechanical and convective mixing height, sensible heat flux



Parameter	FDM	ISCST3	AERMOD
Mixed layer height	The model generally insensitive to values of mixing height	Holzworth scheme; uses interpolation based upon maximum afternoon mixing height	Has convective and mechanical mixed layer height; convective height based upon hourly accumulation of sensible heat flux
Plume dispersion: plume growth rates	Based upon 6 discrete stability classes only (using the classification scheme of Turner, 1970)	Based upon 6 discrete stability classes only; dispersion curves (Pasquill- Gifford) are based upon surface release experiments e.g., Prairie Grass	Uses profiles of vertical and horizontal turbulence (from measurements and/or PBL theory); variable with height; uses continuous growth functions rather than a discrete (stability-based) formulation
Plume interaction with mixing lid: convective conditions	If plume centerline is above lid, a zero ground-level concentration is assumed	If plume centerline is above lid, a zero ground-level concentration is assumed	Three plume components are considered: a "direct" plume that is advected to the ground in a downdraft, an "indirect" plume caught in an updraft that reaches the lid and eventually is brought to the ground, and a plume that penetrates the mixing lid and disperses more slowly in the stable layer aloft (and which can re-enter the mixed layer and disperse to the ground)
Plume interaction with mixing lid: stable conditions	The mixing lid is ignored (assumed to be infinitely high)	The mixing lid is ignored (assumed to be infinitely high)	A mechanically mixed layer near the ground is considered. Plume reflection from an elevated lid is considered.
Building downwash	cannot include terrain features, and the model can be used only for local scale predictions	Combination of Huber-Snyder and Scire-Schulman algorithms; many discontinuities use default wind profile exponents use default vertical potential temperature gradients	New PRIME downwash algorithm Installed calculate wind profiles (not an option) calculate vertical potential temperature gradients (not an option)



1. Source data, including the geometric information on source locations, sizes and orientations, the emission information and the release heights
2. Particle size distribution
3. Meteorological data
4. Receptor locations - the locations at which concentrations and depositions are to be calculated

The centre co-ordinates and dimensions in the x and y directions, rotation angle and emission rates are required for area sources. Area source need not be square, but rather can be rectangular, up to an aspect ratio of 1 to 5 (ratio of width to length). Area source with the length greater than five times the width must be divided in a series of area sources, or modeled as a line source. The model divides the area source into a series of line sources perpendicular to the wind direction. The model computes concentrations from the area sources by first rotating the coordinate system so that, the receptor and the x - axis are aligned with the wind direction. The area source is divided into a series of line sources oriented perpendicular to the wind direction.

5.7.2 ISCST3 model

There are two basic types of inputs that are needed to run the ISCST3 models. They are (1) The input run stream file, (2) The meteorological data file. The runstream setup file contains the selected modeling options, as well as source location and parameter data, receptor locations; meteorological data file specifications, and output options. The ISCST3 models offer various options for file formats of the meteorological data. A third type of input may also be used by the models when implementing the dry deposition and depletion algorithm. The user may optionally specify a file of gridded terrain elevations that are used to integrate the amount of plume material that has been depleted through dry deposition processes along the path of the plume from the source to the receptor. The user also has the option of specifying a separate file of hourly emission rates for the ISCST3 model.

The input run stream file contains the user-specified options for running the ISCST3 model, includes the source parameter data and source group information, defines the receptor locations, specifies the location and parameters regarding the meteorological data, and specifies the output options. The input meteorological data is read into the models from a separate data file.

5.7.3 AERMOD

One of the basic inputs to AERMOD is the run stream setup file which contains the selected modeling options, as well as source location and parameter data, receptor locations, meteorological data file specifications, and output options. Another basic type of input data needed to run the model is the meteorological data. AERMOD requires two types of meteorological data. One file consists of surface scalar parameters, and the other file consists of vertical profiles of meteorological data. AERMOD constructs vertical profiles of required meteorological variables based on measurements and extrapolations of those measurements using similarity (scaling) relationships. Vertical profiles of wind speed, wind direction, turbulence, temperature, and temperature gradient are estimated using all available meteorological observations. AERMOD is designed to run with a minimum of observed meteorological parameters. AERMOD requires only a single surface measurement of wind speed, wind direction and ambient temperature. Like ISC3, AERMOD also needs observed cloud cover.

5.8 Data used for model prediction

Modeling was carried out to assess the contribution from the stone crushers on the surrounding areas. Prediction was carried out in five phases: 1. with all the crushers running, 2. with half of the crushers running, 3. with quarter of the crushers running, 4. with 1/8 of the crushers running, 5. with only one crusher running. The input data requirement for the FDM, ISCST3 and AERMOD can be broadly classified into the following categories:

1. Emission rate
2. Particle size distribution of dust (Particle diameter and their fraction)
3. Meteorology
4. Source-receptor geometry
5. Treatment for deposition (surface roughness, Monin-obukhov length, friction velocity, precipitation, heat flux, convective velocity scale, bowen ratio, albedo etc.)
6. Scavenging effect (for ISCST3 and AERMOD models)

Input data structure of FDM, ISCST3, and AERMOD model used for fugitive dust prediction is given in **Table 5.2**.

Table 5.2
Input data structure of FDM, ISCST3 and AERMOD used for fugitive dust prediction

Data	FDM	ISCST3	AERMOD
Input option	Area source, plotter file option, long-term output option, period average, concentration and deposition, number of sources, receptor particle class, hourly meteorological data, length of time, surface roughness height, scaling factor and density of particulate matter	Area source, terrain nature urban option, concentration and deposition (wet or dry deposition), toxics nature, decay coefficient, particle diameter, particle density, mass fraction, flagpole option, scavenging coefficient for liquid and ice	Area source, terrain nature, urban option, concentration and deposition (wet or dry deposition), toxics, particle diameter, particle density, flagpole option
Diameter of the particle	Twenty class	Twenty class	Twenty class
Mass fraction of the particle	Twenty class	Twenty class	Twenty class
Particle density	Single class	Twenty class	Twenty class
Receptor coordinates	x, y, z coordinates in meter (Only irregular rectangular coordinates)	x, y, z coordinates in meter (combination of irregular spaced rectangular and polar coordinates)	x, y, z coordinates in meter (combination of irregular spaced rectangular and polar coordinates)
Source coordinates	x, y, z coordinates in meter Only irregular rectangular coordinates	x, y, z coordinates in meter (combination of irregular spaced rectangular and polar coordinates)	x, y, z coordinates in meter (combination of irregular spaced rectangular and polar coordinates)
Emission rate	height of emission, source width	height of emission, source width	height of emission, source width
	Unit of emission rate g/m ² .sec	Unit of emission rate g/m ² .sec	unit of emission rate g/m ² .sec



Data	FDM	ISCST3	AERMOD
Meteorological data	Wind speed, wind direction stability class, mixing height, ambient temperature	Wind speed, wind direction stability class, mixing height, ambient temperature Additional data as compared to FDM precipitation rate, precipitation code, surface roughness length convective velocity,	Wind speed, wind direction stability class, mixing height, ambient temperature Additional data as compared to FDM Precipitation rate, precipitation code, surface roughness length convective velocity Additional data as compared to ISCST3 convective velocity scale, mechanical and convective mixing height, sensible heat flux, albedo, and bowen ratio, atmospheric pressure, friction velocity, monin-obukhov, humidity
Level of meteorological data	Single internal/external Meteorological data file.	Single external file SURFILE	Two external file SURFILE and PROFILE
Out put option	Plotter file option, top 50 table for long term averages period average concentration in $\mu\text{g}/\text{m}^3$ and deposition rate in $\mu\text{g}/\text{m}^2 \cdot \text{s}$	Tables of period averages by receptor, highest short term values by receptor and overall maximum short term values, external file(s) of threshold violations	Tables of period averages by receptor overall maximum short term values external file(s) of threshold violations file(s) of high values for plotting

5.8.1 Emission rate

Based on the micro-meteorological condition, location, number of stone crushers and their distribution ¹upwind and ²downwind directions were identified for assessing source strength of each crusher. The estimated source strength of each stone crusher working in Trisoolam area by upwind downwind technique was found to be 112 kg/d and this corroborates quite well with the USEPA's emission rate of 2.778 g/s, which is used for modeling the dispersion of dust emissions from stone crushers to the surrounding areas.) 3

5.8.2 Particle size distribution of dust

Particle size distributions of dust emitted from stone crushers were estimated using particle size analyzer viz. CILAS 1180 model Particle Size Analyzer using laser diffraction. Particle size distributions used in the modeling consisted of 20 separate particle size classes: <0.2, 0.2 - 0.5, 0.5 - 0.7, 0.7 - 1, 1 - 1.3, 1.3 - 1.6, 1.6 - 2, 2 - 2.4, 2.4 - 3, 3 - 5, 5 - 7.5, 7.5 - 10, 10 - 12, 12 - 15, 15 - 17, 17 - 20, 20 - 25, 25 - 32, 32 - 50, 50 - 90 μm . The modeling was carried out for both TSPM and PM_{10} .

5.8.3 Meteorology

The degree to which air pollutants emitted from various sources concentrate in a particular area depends largely on meteorological conditions. Atmospheric conditions play a major role in evaluating the intensity of air pollution. Even though the total discharge of pollutants into the atmosphere in a given area remains the same, the degree of air pollution may vary widely because of difference in meteorological conditions. As a result, the air pollution status in any air shed is governed by its meteorological conditions which play a crucial role. Meteorological factors that govern the transportation and dispersion of pollutants are: atmospheric stability or temperature profile, atmospheric dynamics or wind profiles, mixing depth (and ventilation coefficient), topographical effects. The wind and temperature structure of the atmosphere together would give an indication of atmosphere characteristics besides the height and amount of cloud cover. The ability of the atmosphere to resist vertical motions is called atmospheric stability and depends on the vertical profile of the atmosphere.

5.8.3.1 Weather station

One automatic weather station (Davis Inc, USA) and two mechanical wind monitors (Lawrence and Mayo, India) were used for the continuous measurement of surface meteorological data at the site. The sensors of these equipments were kept at about 3m above ground level with free exposure to atmosphere. Also temperature, pressure and humidity were recorded simultaneously using the weather station and handy thermo-hygrograph (Lawrence



& Mayo, India). Plates 1.7 & 1.8 depicts recording of meteorological data at the site. The meteorological data recording was carried out to measure wind speed, wind direction, temperature, humidity and pressure continuously for 24 hours during the period (June 16, 2005 - August 5, 2005). These data were processed and used for modeling of Fugitive dust emissions from stone crushers.

5.8.4 Source-receptor geometry

Dispersion of particulate material is not only dependent on the source strength, location, wind speed, and atmospheric stability, but also depends on the geometry of the source - receptor. Dense grid of 10m x 10m near source and in the down wind direction was selected and a coarse grid of 50m x 50m was selected in the upwind direction and locations away from the stone crushers. In general, the source receptor distances were of the order of 10 meters or more.

5.8.5 Treatment for deposition

ISCST3 dry deposition model, which is used to calculate the amount of material deposited (i.e., the deposition flux) at the surface from a particle plume through dry deposition processes. The Short Term dry deposition model is based on a dry deposition algorithm (Pleim et al., 1984) contained in the Acid Deposition and Oxidant Model (ADOM).

Dry deposition depends mainly on deposition velocities. A resistance method is used to calculate the deposition velocity. The general approach used in the resistance methods for estimating deposition velocity is to include explicit parameterizations of the effects of Brownian motion, inertial impaction, and gravitational settling. The large settling velocities; the deposition velocity approaches the settling velocity. In addition to the mass mean diameters (microns), particle densities (gm/cm^3), and the mass fractions for each particle size category being modeled, the dry deposition model also requires surface roughness length (cm), friction velocity (m/s), and Monin-Obukhov length (m). In ISCST3 wet deposition model scavenging ratio is used to predict wet deposition of particulate matter. A scavenging ratio approach is used to model the deposition of gases and particles through wet removal. In this approach, the flux of material to the surface through wet deposition is the product of a scavenging ratio times the concentration, integrated. The wet deposition algorithm requires precipitation type (liquid or solid) and precipitation rate.



5.8.6 Scavenging Effect

Scavenging effect is used to measure to wet deposition of the gaseous and particulate matter. The scavenging effect measured in terms of scavenging coefficient. The scavenging coefficient depends on the characteristics of the pollutant (e.g., solubility and reactivity for gases, size distribution for particles) as well as the nature of the precipitation (e.g., liquid or frozen). The scavenging coefficient is the function of particle size. A scavenging ratio approach is used to model the deposition of gases and particles through wet removal. In this approach, the flux of material to the surface through wet deposition is the product of a scavenging ratio times the concentration. The scavenging ratio is computed from a scavenging coefficient and a precipitation rate. The scavenging coefficient has units $(\text{s-mm/hr})^{-1}$.

5.9 Model prediction results ✓

The model was processed with emission rates, meteorological data and geometry of the source and receptors. For fugitive dust impacts, results are found very insensitive to values used for mixing height because the emissions are released at or near the ground, and the impacts are generally very close to the source. As a result the emissions have little opportunity to mix vertically to the height of the mixing layer.

Model predictions were computed using daily emission data and on-site meteorology from stone crushing operations at Trisoolam area. (The input data used for model predictions for various sampling conditions are given in Tables 5.3 - 5.7.) The measured & predicted concentrations at selected monitoring locations and predicted depositions are presented in Tables 5.8 - 5.17 and in the form isopleths and surfers as shown in Figures 5.1 - 5.60 for FDM, ISCST3, and AERMOD.)

5.10 Recommended safe distance ✓

Based on the ambient air quality monitoring results and model predicted concentration, impact zones for different crusher operating conditions were drawn. The impact zone was by demarcated by drawing isopleths of concentration $200 \mu\text{g}/\text{m}^3$ for TSPM and $100 \mu\text{g}/\text{m}^3$ for PM_{10} which are the standard limit set by CPCB for 24 hour averaging time. The average safe distances were estimated for single crusher and cluster of crushers using measured and predicted concentrations. The impacts zone drawn using measured concentration at selected ambient air quality monitoring locations and predicted values of FDM, ISCT3 and AERMOD are given in Tables 5.18 - 21.



**Table 5.3 Meteorological data used for FDM, ISCST3, and AERMOD for prediction
(All the crushers in operation)**

S. No.	Hour	Wind Direction (degree)	Wind Speed (m/s)	Stability class	Mixing height (m)	Temp. (°C)	Humidity (%)
1	0 - 1	235	2.22	5	0	26.9	73
2	1 - 2	238	1.38	5	0	27.3	71
3	2 - 3	238	1.38	5	0	27.3	69
4	3 - 4	245	1.90	5	0	27.3	69
5	4 - 5	244	1.38	5	0	27.2	69
6	5 - 6	235	1.15	4	0	27.2	70
7	6 - 7	249	1.31	4	133	27.1	69
8	7 - 8	237	1.03	4	681	27.1	68
9	8 - 9	208	1.46	3	1007	28.0	66
10	9 - 10	219	1.70	2	1275	29.1	58
11	10 - 11	232	2.02	2	1750	30.4	53
12	11 - 12	241	2.22	1	1944	31.9	50
13	12 - 13	221	2.66	1	2139	32.7	47
14	13 - 14	215	2.57	1	4416	33.5	44
15	14 - 15	214	2.29	1	3500	33.5	44
16	15 - 16	223	2.19	2	2667	33.6	47
17	16 - 17	197	2.27	2	2000	32.3	54
18	17 - 18	197	2.34	3	556	29.2	57
19	18 - 19	180	2.85	2	222	30.2	59
20	19 - 20	183	2.43	4	0	30.1	68
21	20 - 21	180	1.64	5	0	29.7	69
22	21 - 22	176	1.59	5	0	29.3	70
23	22 - 23	188	1.64	6	0	28.9	74
24	23 - 24	204	2.62	6	0	28.7	75

Align

**Table 5.4 Meteorological data used for FDM, ISCST3, and AERMOD for prediction
(Half of the crushers in operation)**

S. No.	Hour	Wind Direction (degree)	Wind Speed (m/s)	Stability class	Mixing height (m)	Temp. (° C)	Humidity (%)
1	0 - 1	197	1.25	6	0	28.8	85
2	1 - 2	213	1.62	6	0	28.7	84
3	2 - 3	233	1.40	5	0	28.5	83
4	3 - 4	236	1.25	5	0	28.5	82
5	4 - 5	236	1.25	5	0	28.4	82
6	5 - 6	236	1.25	5	0	28.3	80
7	6 - 7	220	1.47	4	127	28.2	77
8	7 - 8	244	1.62	4	649	28.3	76
9	8 - 9	230	1.76	4	1170	29.4	70
10	9 - 10	247	2.13	3	1240	30.8	63
11	10 - 11	243	2.35	2	1549	32.5	55
12	11 - 12	256	2.65	2	1874	33.7	51
13	12 - 13	244	2.57	2	2244	35.0	47
14	13 - 14	250	2.35	1	3614	35.9	46
15	14 - 15	244	2.35	1	3014	35.7	46
16	15 - 16	250	2.20	2	2164	35.8	45
17	16 - 17	229	1.98	3	1431	35.0	48
18	17 - 18	191	2.06	3	439	33.1	58
19	18 - 19	164	3.75	2	201	32.0	66
20	19 - 20	149	2.72	4	0	31.5	72
21	20 - 21	167	3.17	5	0	31.1	74
22	21 - 22	166	3.09	5	0	30.8	77
23	22 - 23	194	4.85	6	0	29.3	83
24	23 - 24	189	1.18	6	0	29.1	83



**Table 5.5 Meteorological data used for FDM, ISCST3, and AERMOD for prediction
(1/4th of the crushers in operation)**

S. No.	Hour	Wind Direction (degree)	Wind Speed (m/s)	Stability class	Mixing height (m)	Temp. (° C)	Humidity (%)
1	0 - 1	163	5.22	6	0	28.4	81
2	1 - 2	169	4.70	6	0	28.3	81
3	2 - 3	206	6.10	5	0	64.5	80
4	3 - 4	210	5.66	5	0	27.6	80
5	4 - 5	249	4.48	5	0	27.2	81
6	5 - 6	246	4.48	4	0	26.9	83
7	6 - 7	261	2.35	4	127	26.7	85
8	7 - 8	261	1.32	4	431	26.7	84
9	8 - 9	260	1.47	3	575	27.4	79
10	9 - 10	210	1.84	2	1007	28.7	74
11	10 - 11	204	1.98	2	1250	30.1	67
12	11 - 12	185	2.49	2	1398	31.4	62
13	12 - 13	257	2.74	1	1750	32.5	58
14	13 - 14	203	2.57	1	2945	32.9	57
15	14 - 15	181	2.20	2	1998	32.7	59
16	15 - 16	159	2.43	2	1667	32.5	60
17	16 - 17	181	3.31	2	1054	31.8	60
18	17 - 18	171	4.19	3	401	31.6	64
19	18 - 19	147	2.40	4	158	30.6	68
20	19 - 20	120	2.13	5	0	29.3	72
21	20 - 21	150	2.13	5	0	29.0	75
22	21 - 22	139	5.51	5	0	28.9	77
23	22 - 23	150	6.17	6	0	28.6	81
24	23 - 24	163	6.03	6	0	28.4	82



**Table 5.6 Meteorological data used for FDM, ISCST3, and AERMOD for prediction
(1/8th of the crushers in operation)**

S. No.	Hour	Wind Direction (degree)	Wind Speed (m/s)	Stability class	Mixing height (m)	Temp. (° C)	Humidity (%)
1	0 - 1	196	5.35	6	0	30.1	77
2	1 - 2	212	12.24	6	0	29.8	80
3	2 - 3	218	17.08	5	0	29.6	81
4	3 - 4	248	19.14	5	0	29.4	78
5	4 - 5	250	18.31	5	0	29.2	76
6	5 - 6	243	13.76	5	0	29.1	74
7	6 - 7	220	6.17	4	135	28.9	74
8	7 - 8	244	10.29	4	472	28.8	73
9	8 - 9	244	7.41	3	501	29.8	67
10	9 - 10	270	8.23	2	807	31.3	59
11	10 - 11	260	8.33	2	1250	32.6	52
12	11 - 12	262	8.44	2	1530	34.3	47
13	12 - 13	282	2.68	1	1947	35.3	43
14	13 - 14	230	2.96	1	2874	35.6	43
15	14 - 15	194	2.37	2	2174	35.1	47
16	15 - 16	186	2.26	2	1279	34.8	48
17	16 - 17	170	2.26	2	779	33.8	54
18	17 - 18	186	2.26	3	359	33.2	57
19	18 - 19	190	2.06	2	161	32.3	63
20	19 - 20	136	1.95	4	0	31.5	68
21	20 - 21	138	4.32	5	0	31.1	72
22	21 - 22	142	4.84	6	0	30.9	75
23	22 - 23	145	9.00	6	0	30.5	76
24	23 - 24	180	7.92	6	0	30.2	78



**Table 5.7 Meteorological data used for FDM, ISCST3, and AERMOD for prediction
(Only one crusher in operation)**

S. No.	Hour	Wind Direction (degree)	Wind Speed (m/s)	Stability class	Mixing height (m)	Temp. (° C)	Humidity (%)
1	0 - 1	270	22.46	6	0	26.6	81
2	1 - 2	270	21.26	6	0	28.0	76
3	2 - 3	273	22.12	5	0	27.5	79
4	3 - 4	257	22.46	5	0	27.3	78
5	4 - 5	240	16.98	5	0	27.1	77
6	5 - 6	250	14.92	5	0	26.7	79
7	6 - 7	227	15.78	4	101	26.5	80
8	7 - 8	243	22.12	4	254	26.8	78
9	8 - 9	230	22.29	3	359	28.1	71
10	9 - 10	243	21.78	2	501	29.8	63
11	10 - 11	237	22.29	2	869	30.7	58
12	11 - 12	243	22.64	2	1124	31.9	53
13	12 - 13	237	21.44	2	1659	32.6	50
14	13 - 14	243	3.94	1	2784	32.9	48
15	14 - 15	250	2.23	1	1940	32.9	46
16	15 - 16	257	1.71	2	1074	33.2	50
17	16 - 17	250	1.89	3	469	33.2	48
18	17 - 18	240	2.74	3	268	32.6	50
19	18 - 19	243	11.32	4	107	31.3	58
20	19 - 20	210	14.40	5	0	30.8	67
21	20 - 21	203	11.83	5	0	30.1	70
22	21 - 22	280	22.81	5	0	29.9	71
23	22 - 23	257	22.81	6	0	29.4	72
24	23 - 24	267	22.64	6	0	27.4	75

Table 5.8 Model FDM, ISCST3 and AERMOD predicted Vs measured concentration (All the crushers in operation)

S.No.	Sampling locations	Model Coordinates*		Measured Conc. ($\mu\text{g}/\text{m}^3$)	From the periphery				Predicted concentration, $\mu\text{g}/\text{m}^3$					
		x	y		Dir., degree	Dist., m	No in map (Fig. 3.1)	Crusher Name	FDM	ISCST3	AERMOD			
Source														
1	Vigneshwara BM	278	-279	2051	310	26	20	Vigneshwaran BM	685	61	71			
2	Subalaxmi BM	-66	-66	3071	203	38	35	Subha Lakshmi BM	5297	864	555			
3	Rajalaxmi BM	-242	-102	1268	57	26	40	Rajalakshmi BM	9135	2226	1796			
4	Ashok BM	-435	-175	2283	40	30	51	Ashok BM	7844	485	1147			
5	Suguna BM	-407	191	274	10	38	45	Sugana BM	3983	53	962			
6	JR Vimala BM	397	-249	654	214	38	22	J.R Vimala BM	18380	4076	5137			
7	Rathna BM	634	-170	4109	305	23	6	Rathna BM	18688	1067	3339			
8	Sivakami BM	261	-183	1424	220	30	24	Sivagami BM	9015	292	2511			
9	Sivagami Natesan BM	-248	181	3747	110	60	47	Sivagami Natesan BM	4036	146	517			
10	Rani Anna Nagar	85	40	1754	65	94	34	Subramaniam BM	3850	388	617			
Ambient Air														
11	Trisoolam 1	-153	423	417	50	195	48	Sri Ganesh BM	1926	27	333			
12	Trisoolam 2	-347	244	200	30	38	46	Viswanathan BM	7899	162	1384			
13	Sara Nagar	-972	-730	65	196	394	64	Thirumalaiyan BM	0	0	0			
14	Zamin Pallavaram	-430	-686	125	148	428	55	Dwarga BM	10	0	1			
15	Everedy Nagar	318	-408	152	167	124	20	Vigneshwaran BM	257	28	30			
16	Krishna Nagar	1362	-96	81	80	638	2	Praveena BM	718	132	122			
17	Kennady Nagar	1022	-373	165	120	338	3	Thirugnanam BM	1076	96	80			

* Origin (0, 0): Subramaniam BM

Table 5.9 Model FDM, ISCST3 and AERMOD predicted Vs measured concentration
(Half of the crushers in operation)

S.No.	Sampling locations	Model		Measured Conc. ($\mu\text{g}/\text{m}^3$)	From the Periphery				Predicted concentration, $\mu\text{g}/\text{m}^3$		
		Co – ordinates*			Dir., degree	Dist., m	No in map (Fig. 3.1)	Crusher name	FDM	ISCST3	AERMOD
		x	y								
Source											
1	Vigneshwara BM	278	-279	2962	206	75	69	Amman Arul BM	536	25	5011
2	Subalaxmi BM	-66	-66	3735	75	131	37	Abirami BM	6078	342	1844
3	Rani Anna Nagar	85	40	1691	285	131	27	Durga BM	3345	205	881
Ambient air											
4	Trisoolam 1	-153	423	346	56	188	48	Sri Ganesh BM	1929	129	3
5	Trisoolam 2	-347	244	155	206	75	48	Sri Ganesh BM	1712	55	533
6	Sara Nagar	-972	-730	88	197	386	64	Thirumalaiyan BM	1	0	224
7	Zamin Pallavaram	-430	-686	157	148	488	56	Lakshmi BM	2	0	322
8	Everedy Nagar	318	-408	166	167	113	20	Vigneshwaran BM	150	11	1284
9	Krishna Nagar	1362	-96	56	86	638	2	Praveena BM	820	53	0
10	Kennedy Nagar	1022	-373	250	121	349	2	Praveena BM	453	32	0

* Origin (0, 0): Subramaniam BM

Table 5.10 Model FDM, ISCST3 and AERMOD predicted Vs measured concentration
(18 Crushers in Operation)

S.No.	Sampling locations	Model Co - ordinates*		Measured Conc. ($\mu\text{g}/\text{m}^3$)	From the periphery				Predicted concentration, $\mu\text{g}/\text{m}^3$		
		x	y		Dir., degree	Dist., m	No in map (Fig. 3.1)	Crusher name	FDM	ISCST3	AERMOD
Source											
1	Vigneshwara BM	278	-279	2014	262	469	2	Praveena BM	168	41	24
2	Subalaxmi BM	-66	-66	2845	225	56	34	Subramaniam BM	2396	571	1895
3	Rani Anna Nagar	85	40	2548	64	94	34	Subramaniam BM	2220	606	58
Ambient Air											
4	Trisoolam 1	-153	423	716	54	180	48	Sri Ganesh BM	989	87	1
5	Trisoolam 2	-347	244	306	209	75	48	Sri Ganesh BM	5588	746	525
6	Sara Nagar	-972	-730	528	227	694	52	Vijayaram BM	1	0	62
7	Zamin Pallavaram	-430	-686	430	173	458	52	Vijayaram BM	4	0	148
8	Everedy Nagar	318	-408	426	245	454	2	Praveena BM	81	17	30
9	Krishna Nagar	1362	-96	91	262	645	2	Praveena BM	91	32	10
10	Kennady Nagar	1022	-373	276	123	345	2	Praveena BM	74	26	4

* Origin (0, 0): Subramaniam BM

Table 5.11 Model FDM, ISCST3 and AERMOD predicted Vs measured concentration
(9 Crushers in operation)

(9 Crushers in operation)											
S.No.	Sampling locations	Model		Measured Conc. ($\mu\text{g}/\text{m}^3$)	From the periphery			Predicted concentration, $\mu\text{g}/\text{m}^3$			
		Co - ordinates*			Dir., degree	Dist., m	No in map (Fig. 3.1)	Crusher name	FDM	ISCST3	AERMOD
		x	y								
Source											
1	Vigneshwara BM	278	-279	1004	154	56	25	Subam BM	759	63	396
2	Subalaxmi BM	-66	-66	1574	80	225	40	Rajalakshmi BM	215	0	26
3	Rajalaxmi BM	-242	-102	688	258	473	27	Durga BM	73	0	13
4	Rani Anna Nagar	85	40	1141	285	131	27	Durga BM	855	0	105
Ambient air											
5	Trisoolam 1	-153	423	521	313	514	29	Maheshwari BM	270	0	15
6	Trisoolam 2	-347	244	178	288	585	29	Maheshwari BM	96	0	5
7	Sara Nagar	-972	-730	126	250	1331	25	Subam BM	1	0	2
8	Zamin Pallavaram	-430	-686	123	235	806	25	Subam BM	1	0	6
9	Everedy Nagar	318	-408	104	224	169	15	Star BM	52	5	142
10	Krishna Nagar	1362	-96	80	82	788	10	Vasudevan BM	53	14	0
11	Kennady Nagar	1022	-373	155	114	480	10	Vasudevan BM	89	13	0

* Origin (0, 0): Subramaniam BM

Table 5.12 Model FDM, ISCST3 and AERMOD predicted Vs measured concentration
(Only one crusher in operation)

S.No.	Sampling locations	Model		Measured Conc. ($\mu\text{g}/\text{m}^3$)	From the periphery				Predicted concentration, $\mu\text{g}/\text{m}^3$		
		Co - ordinates*			Dir., degree	Dist., m	No in map (Fig. 3.1)	Crusher name	FDM	ISCST3	AERMOD
		x	y								
Source											
1	Vigneshwara BM	278	-279	306	107	570	40	Rajalakshmi BM	17	0	67
2	Subalaxmi BM	-66	-66	281	81	225	40	Rajalakshmi BM	180	0	67
3	Rajalaxmi BM	-242	-102	345	0	0	40	Rajalakshmi BM	6859	0	67
4	Rani Anna Nagar	85	40	250	67	383	40	Rajalakshmi BM	65	0	67
Ambient air											
5	Trisoolam 1	-153	423	56	14	555	40	Rajalakshmi BM	6	0	67
6	Trisoolam 2	-347	244	32	352	368	40	Rajalakshmi BM	3	0	67
7	Sara Nagar	-972	-730	66	230	938	40	Rajalakshmi BM	0	5	72
8	Zamin Pallavaram	-430	-686	73	194	600	40	Rajalakshmi BM	0	2	69
9	Everedy Nagar	318	-408	84	116	656	40	Rajalakshmi BM	6	0	67
10	Krishna Nagar	1362	-96	48	93	1631	40	Rajalakshmi BM	7	0	67
11	Kennady Nagar	1022	-373	87	105	1313	40	Rajalakshmi BM	2	0	67

* Origin (0, 0): Subramaniam BM



Table 5.13 FDM, ISCST3 and AERMOD predicted deposition
(All the crushers in operation)

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S.No.	Sampling locations	Model Co - ordinates*		From the periphery				Predicted deposition			
		x	y	Dir., degree	Dist., m	No in map (Fig. 3.1)	Crusher name	FDM ($\mu\text{g}/\text{m}^2 \cdot \text{sec}$)	ISCST3 ($\mu\text{g}/\text{m}^3$)	AERMOD ($\mu\text{g}/\text{m}^3$)	
Source											
1	Vigneshwara BM	278	-279	310	26	20	Vigneshwaran BM	14	861	5570	
2	Subalaxmi BM	-66	-66	203	38	35	Subha Lakshmi BM	147	12297	7800	
3	Rajalaxmi BM	-242	-102	57	26	40	Rajalakshmi BM	374	32863	29245	
4	Ashok BM	-435	-175	40	30	51	Ashok BM	177	6956	8787	
5	Suguna BM	-407	191	10	38	45	Sugana BM	79	768	4131	
6	JR Vimala BM	397	-249	214	38	22	J.R Vimala BM	779	120561	277741	
7	Rathna BM	634	-170	305	23	6	Rathna BM	552	15292	28089	
8	Sivakami BM	261	-183	220	30	24	Sivagami BM	248	4507	15285	
9	Sivagami Natesan BM	-248	181	110	60	47	Sivagami Natesan BM	89	2161	6184	
10	Rani Anna Nagar	85	40	65	94	34	Subramaniam BM	92	5562	4810	
Ambient Air											
11	Trisoolam 1	-153	423	50	195	48	Sri Ganesh BM	22	397	938	
12	Trisoolam 2	-347	244	30	38	46	Viswanathan BM	225	2387	8839	
13	Sara Nagar	-972	-730	196	394	64	Thirumalaiyan BM	0	0	5	
14	Zamin Pallavaram	-430	-686	148	428	55	Dwarga BM	1	2	41	
15	Everedy Nagar	318	-408	167	124	20	Vigneshwaran BM	6	406	521	
16	Krishna Nagar	1362	-96	80	638	2	Praveena BM	13	1804	1421	
17	Kennady Nagar	1022	-373	120	338	3	Thirugnanam BM	14	1428	1112	

* Origin (0, 0): Subramaniam BM

Table 5.14 FDM, ISCST3 and AERMOD predicted deposition
(Half of the crushers in operation)

S.No.	Sampling locations	Model Co - ordinates*		From the Periphery			Predicted Deposition						
		x	y	Dir., degree	Dist., m	No in map (Fig. 3.1)	Crusher name	FDM ($\mu\text{g}/\text{m}^2 \cdot \text{sec}$)	ISCST3 ($\mu\text{g}/\text{m}^3$)	AERMOD ($\mu\text{g}/\text{m}^3$)			
Source													
1	Vigneshwara BM	278	-279	206	75	69	Amman Arul BM	7	293		17755		
2	Subalaxmi BM	-66	-66	75	131	37	Abirami BM	119	4235		7711		
3	Rani Anna Nagar	85	40	285	131	27	Durga BM	67	2545		3145		
Ambient Air													
4	Trisoolam 1	-153	423	56	188	48	Sri Ganesh BM	34	1422		13		
5	Trisoolam 2	-347	244	206	75	48	Sri Ganesh BM	27	552		1933		
6	Sara Nagar	-972	-730	197	386	64	Thirumalaiyan BM	0	0		400		
7	Zamin Pallavaram	-430	-686	148	488	56	Lakshmi BM	0	0		496		
8	Eveready Nagar	318	-408	167	113	20	Vigneshwaran BM	2	127		2383		
9	Krishna Nagar	1362	-96	86	638	2	Praveena BM	14	635		0		
10	Kennady Nagar	1022	-373	121	349	2	Praveena BM	7	391		0		

* Origin (0, 0): Subramaniam BM.

Table 5.15 FDM, ISCST3 and AERMOD predicted deposition
(18 Crushers in Operation)

S.No.	Sampling locations	Model Co - ordinates*		From the periphery			Predicted deposition			
		x	y	Dir., degree	Dist., m	No in map (Fig. 3.1)	Crusher name	FDM ($\mu\text{g}/\text{m}^2 \cdot \text{sec}$)	ISCST3 ($\mu\text{g}/\text{m}^3$)	AERMOD ($\mu\text{g}/\text{m}^3$)
Source										
1	Vigneshwara BM	278	-279	262	469	2	Praveena BM	2	411	55
2	Subalaxmi BM	-66	-66	225	56	34	Subramaniam BM	46	5499	6428
3	Rani Anna Nagar	85	40	64	94	34	Subramaniam BM	39	6477	66
Ambient air										
4	Trisoolam 1	-153	423	54	180	48	Sri Ganesh BM	12	886	1
5	Trisoolam 2	-347	244	209	75	48	Sri Ganesh BM	134	7793	1791
6	Sara Nagar	-972	-730	227	694	52	Vijayaram BM	0	1	79
7	Zamin Pallavaram	-430	-686	173	458	52	Vijayaram BM	0	0	262
8	Everedy Nagar	318	-408	245	454	2	Praveena BM	1	173	61
9	Krishna Nagar	1362	-96	262	645	2	Praveena BM	1	281	5
10	Kennady Nagar	1022	-373	123	345	2	Praveena BM	1	244	5

* Origin (0, 0): Subramaniam BM

Table 5.16 FDM, ISCST3 and AERMOD predicted deposition
(9 crushers in operation)

S.No.	Sampling locations	Model Co - ordinates*		From the periphery			Predicted deposition			
		x	y	Dir., degree	Dist., m	No in map (Fig. 3.1)	Crusher name	FDM ($\mu\text{g}/\text{m}^2 \cdot \text{sec}$)	ISCST3 ($\mu\text{g}/\text{m}^3$)	AERMOD ($\mu\text{g}/\text{m}^3$)
Source										
1	Vigneshwara BM	278	-279	154	56	25	Subam BM	21	496	3105
2	Subalaxmi BM	-66	-66	80	225	40	Rajalakshmi BM	4	0	387
3	Rajalaxmi BM	-242	-102	258	473	27	Durga BM	1	0	199
4	Rani Anna Nagar	85	40	285	131	27	Durga BM	17	1	1652
Ambient Air										
5	Trisoolam 1	-153	423	313	514	29	Maheshwari BM	4	0	71
6	Trisoolam 2	-347	244	288	585	29	Maheshwari BM	1	0	77
7	Sara Nagar	-972	-730	250	1331	25	Subam BM	0	0	23
8	Zamin Pallavaram	-430	-686	235	806	25	Subam BM	0	0	50
9	Everedy Nagar	318	-408	224	169	15	Star BM	2	39	856
10	Krishna Nagar	1362	-96	82	788	10	Vasudevan BM	1	129	0
11	Kennady Nagar	1022	-373	114	480	10	Vasudevan BM	2	146	1

* Origin (0, 0): Subramaniam BM

**Table 5.17 FDM, ISCST3 and AERMOD predicted deposition
(Only one crusher in operation)**

S.No.	Sampling locations	Model Co - ordinates*		From the periphery				Predicted deposition			
		x	y	Dir., degree	Dist., m	No in map (Fig. 3.1)	Crusher Name	FDM ($\mu\text{g}/\text{m}^2\cdot\text{sec}$)	ISCST3 ($\mu\text{g}/\text{m}^3$)	AERMOD ($\mu\text{g}/\text{m}^3$)	
Source											
1	Vigneshwara BM	278	-279	107	570	40	Rajalakshmi BM	1	3	0	
2	Subalaxmi BM	-66	-66	81	225	40	Rajalakshmi BM	6	114	0	
3	Rajalaxmi BM	-242	-102	0	0	40	Rajalakshmi BM	294	10470	0	
4	Rani Anna Nagar	85	40	67	383	40	Rajalakshmi BM	2	55	0	
Ambient air											
5	Trisoolam 1	-153	423	14	555	40	Rajalakshmi BM	0	5	1	
6	Trisoolam 2	-347	244	352	368	40	Rajalakshmi BM	0	0	7	
7	Sara Nagar	-972	-730	230	938	40	Rajalakshmi BM	0	0	21	
8	Zamin Pallavaram	-430	-686	194	600	40	Rajalakshmi BM	0	0	11	
9	Everedy Nagar	318	-408	116	656	40	Rajalakshmi BM	0	1	0	
10	Krishna Nagar	1362	-96	93	1631	40	Rajalakshmi BM	0	2	0	
11	Kennady Nagar	1022	-373	105	1313	40	Rajalakshmi BM	0	1	0	

* Origin (0, 0): Subramaniam BM

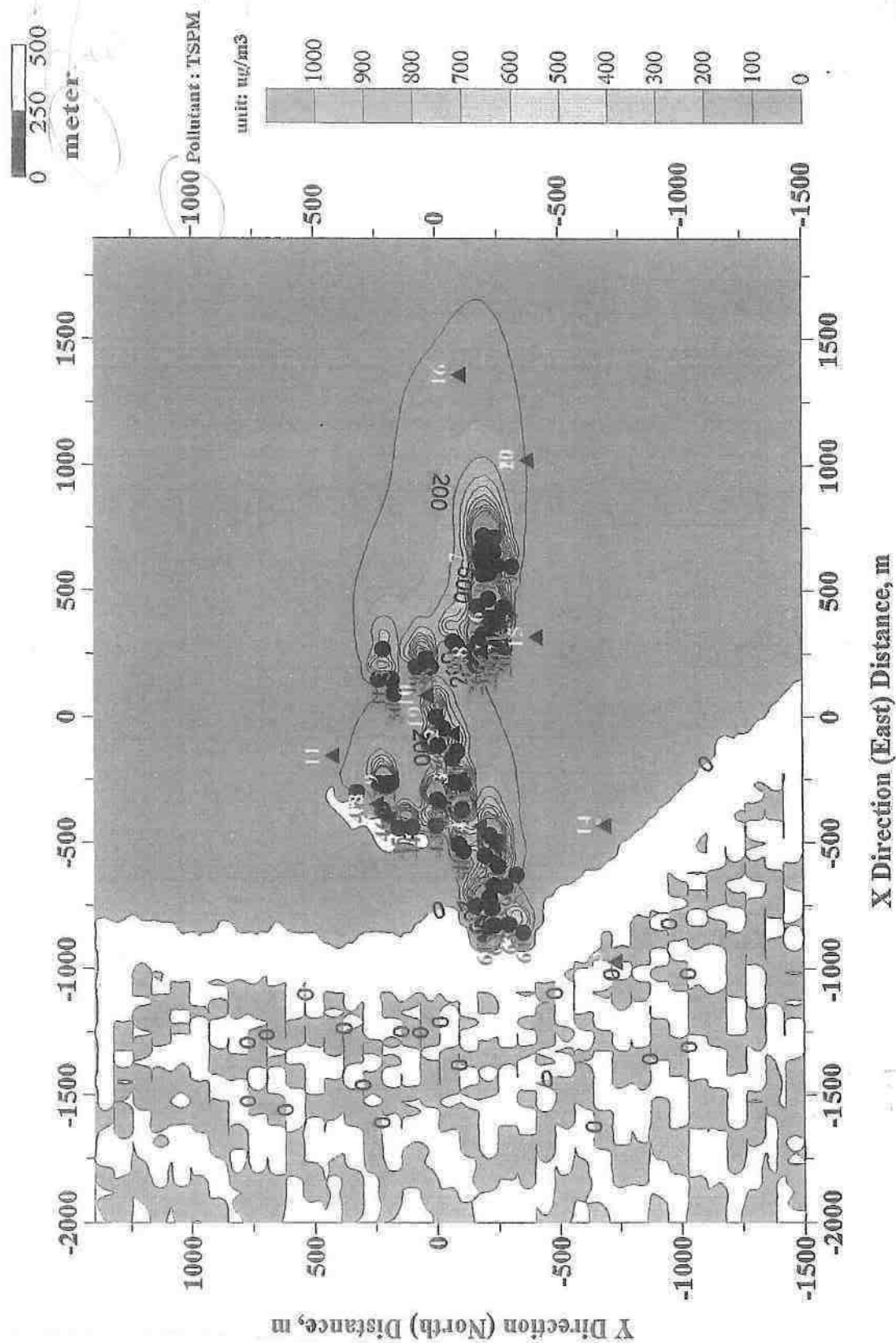


Fig. 5.1 Isopleths showing ISCST3 predicted concentration (all the crushers in operation)

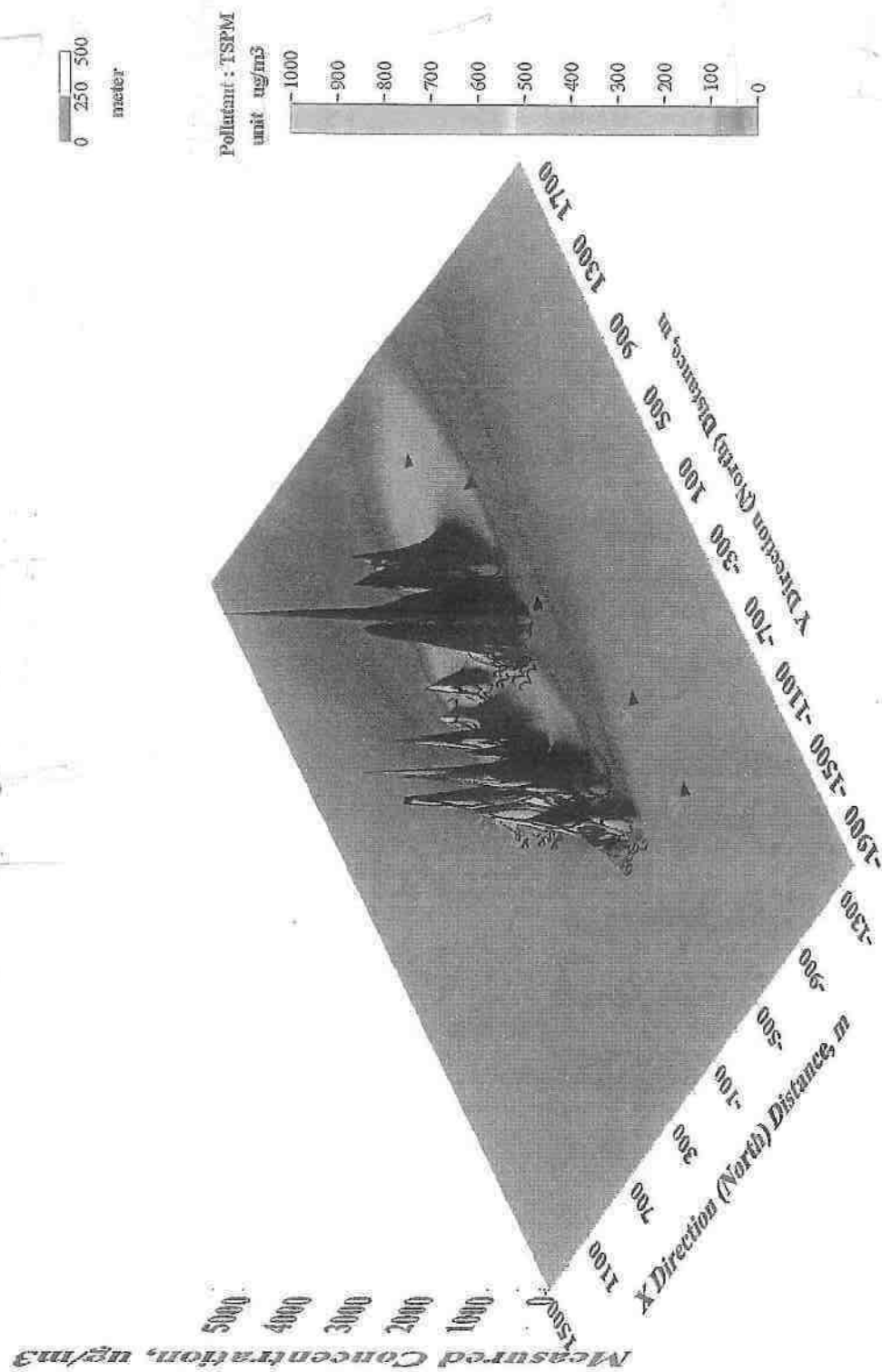


Fig. 5.2 Surfer showing ISCST3 Predicted concentration (all the crushers in operation)

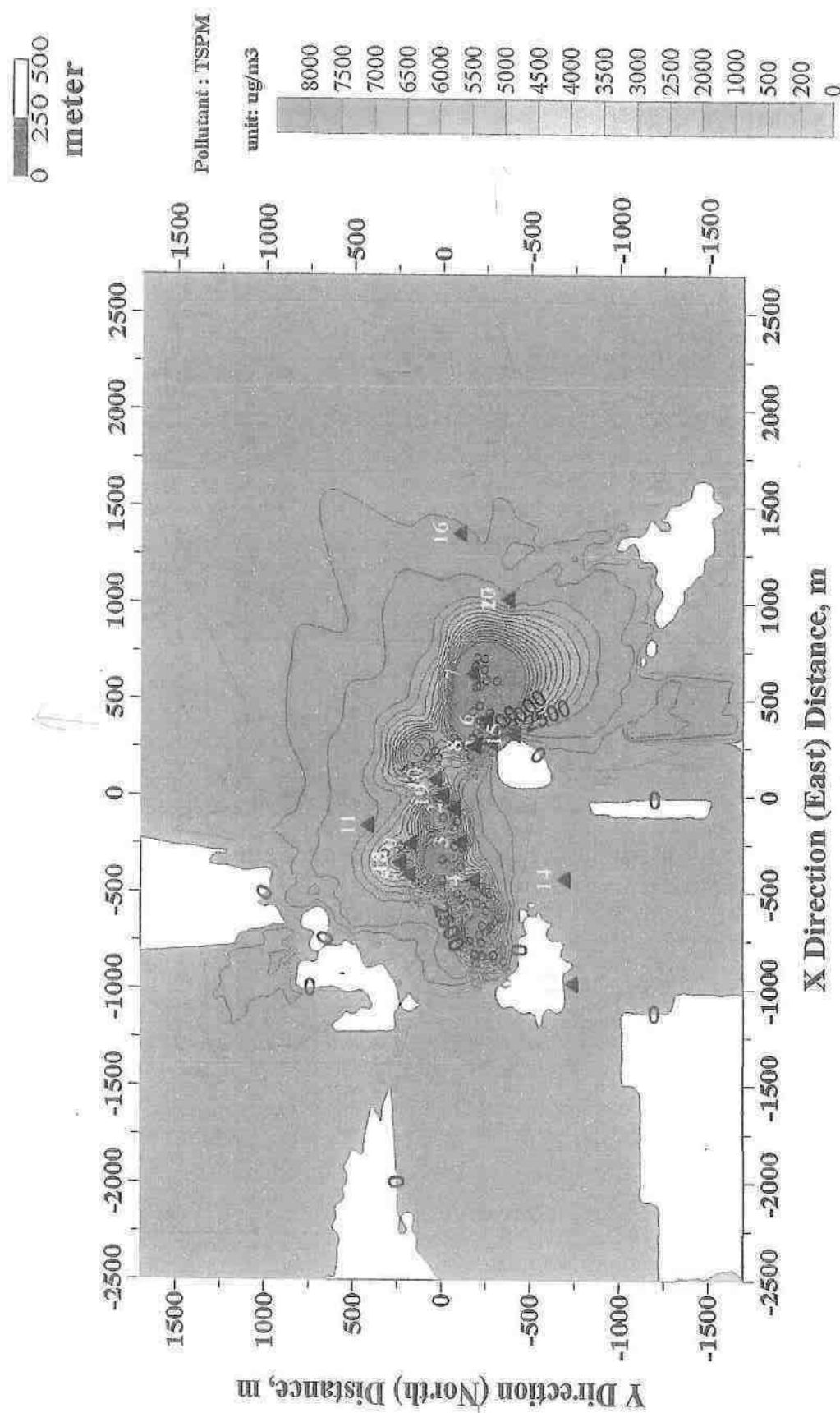


Fig. 5.3 Isopleths showing FDM predicted concentration (all the crushers in operation)

0 250 500
meter

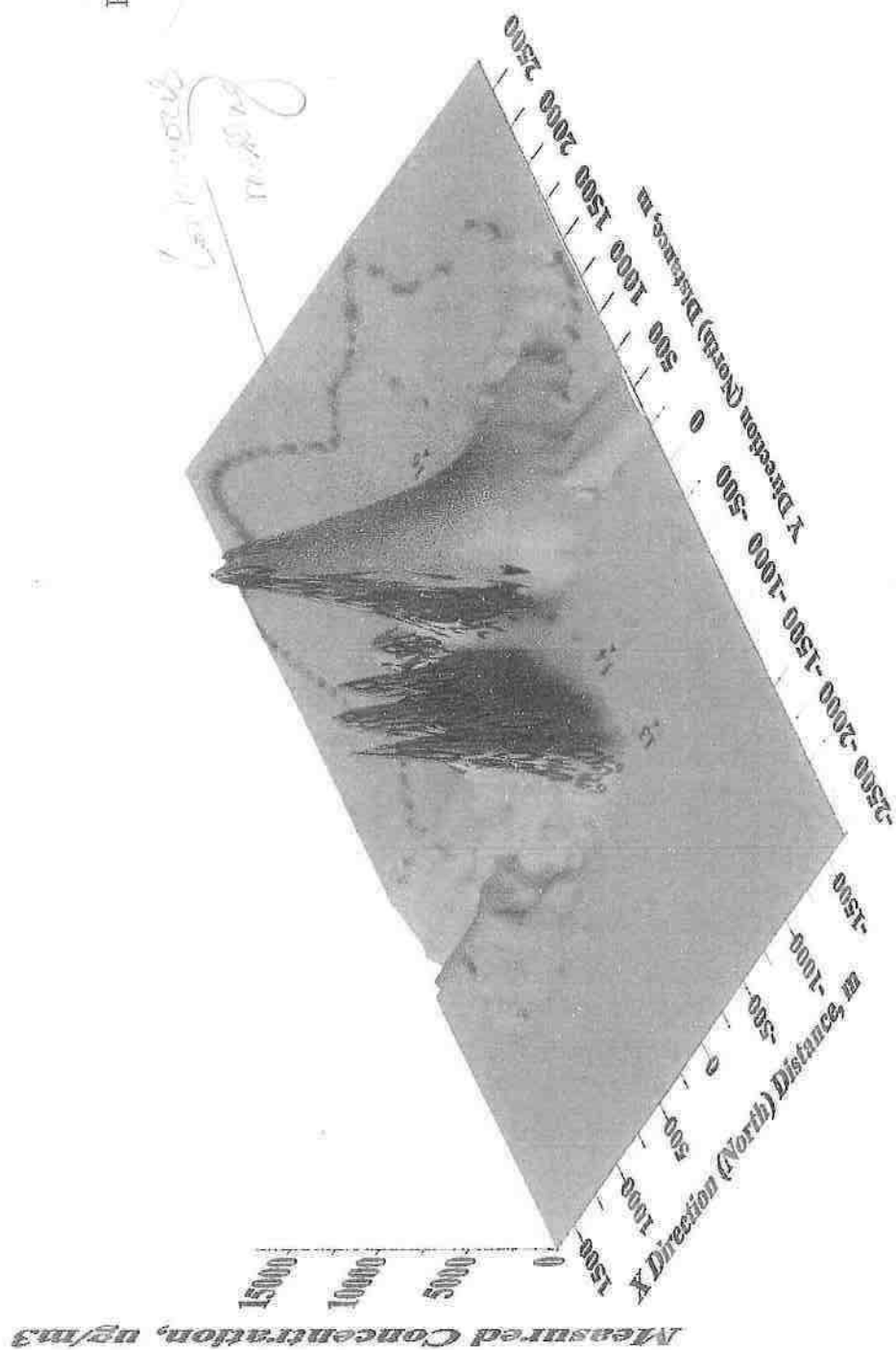


Fig. 5.4 Surfer showing FDM Predicted concentration (all the crushers in operation)

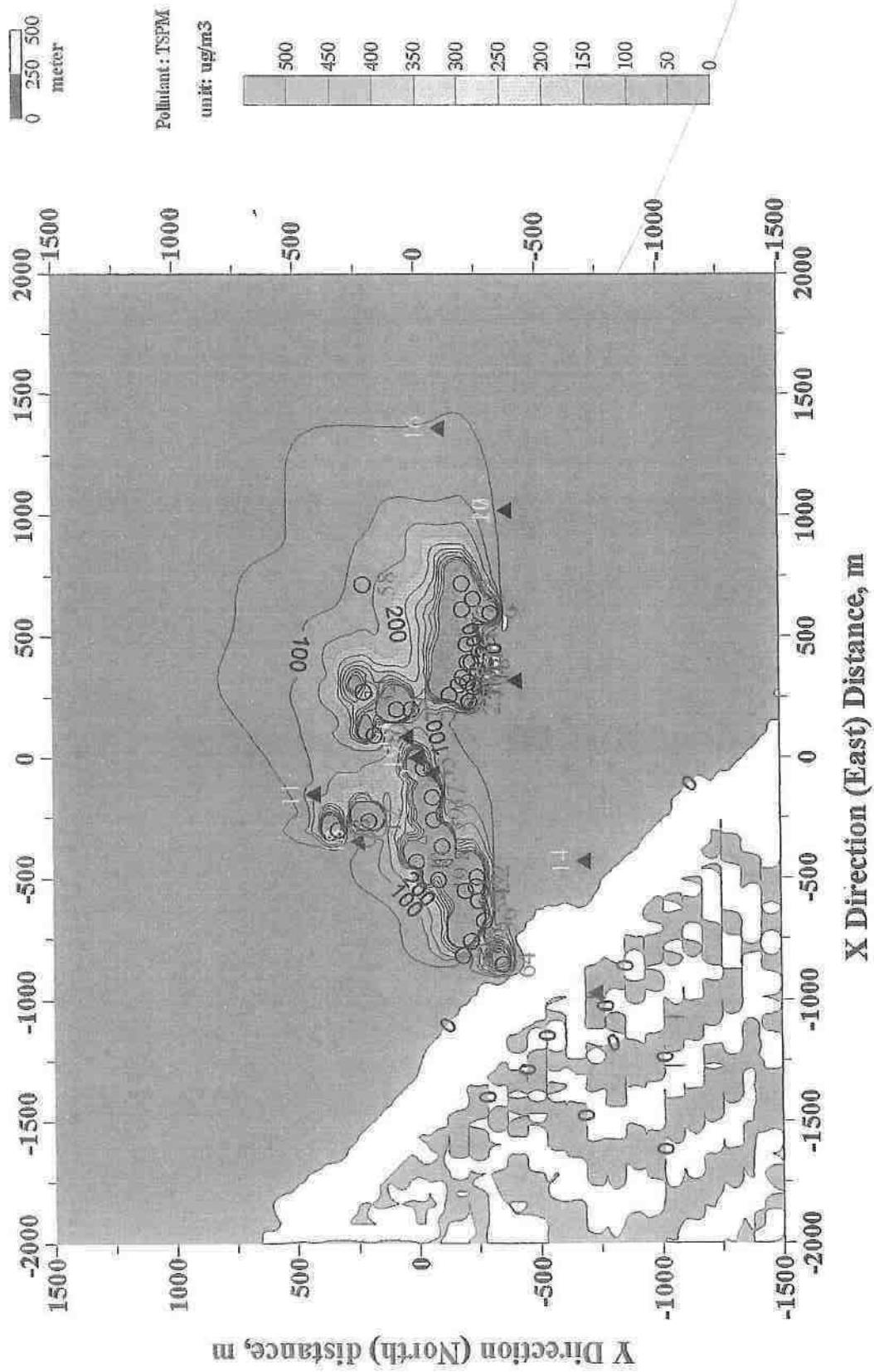


Fig. 5.5 Isopleths showing ISCST3 predicted concentration (half of the crushers in operation)

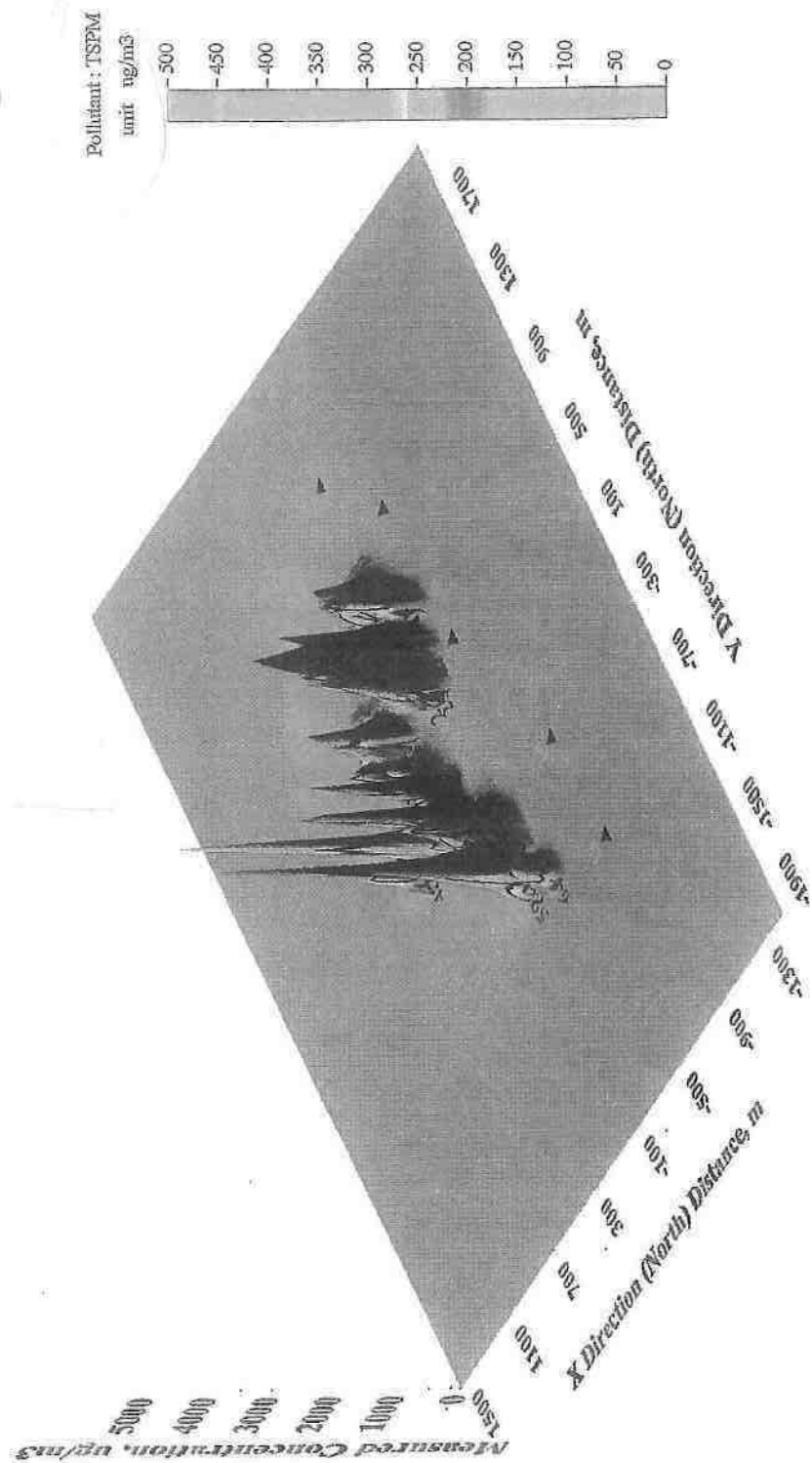
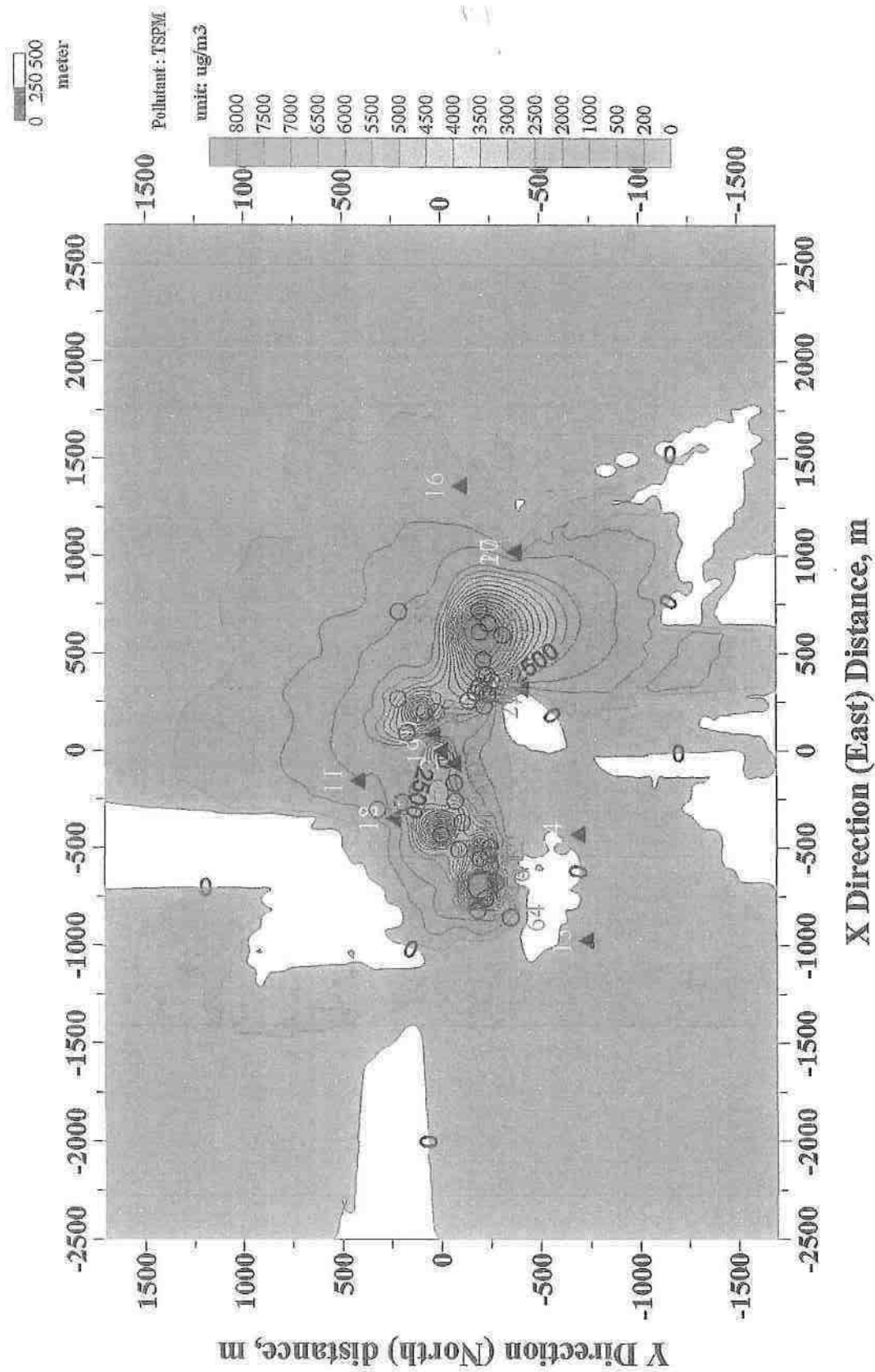


Fig. 5.6 Surfer showing ISCST3 Predicted concentration (half of the crushers in operation)



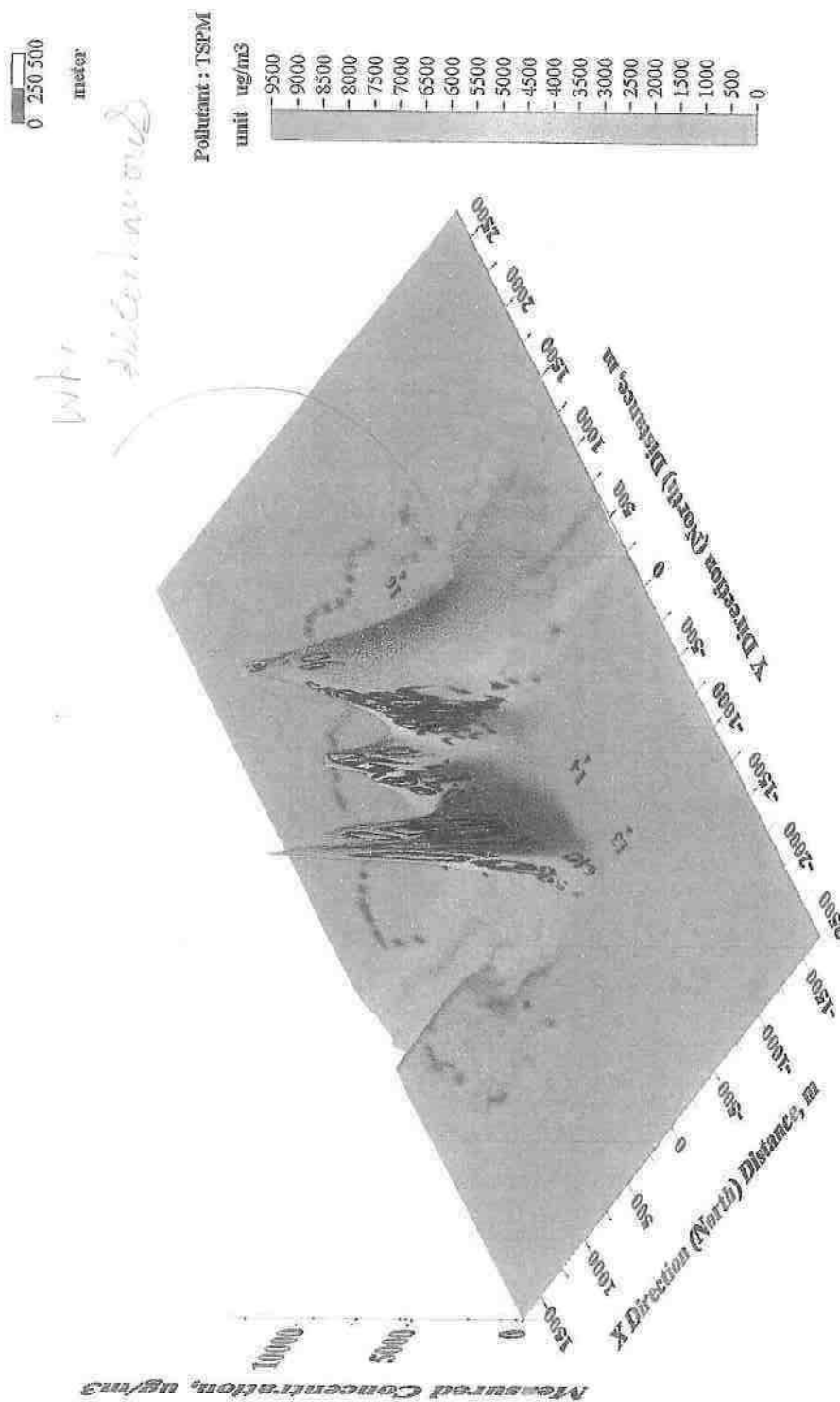


Fig. 5.8 Surfer showing FDM Predicted concentration (half of the crushers in operation)

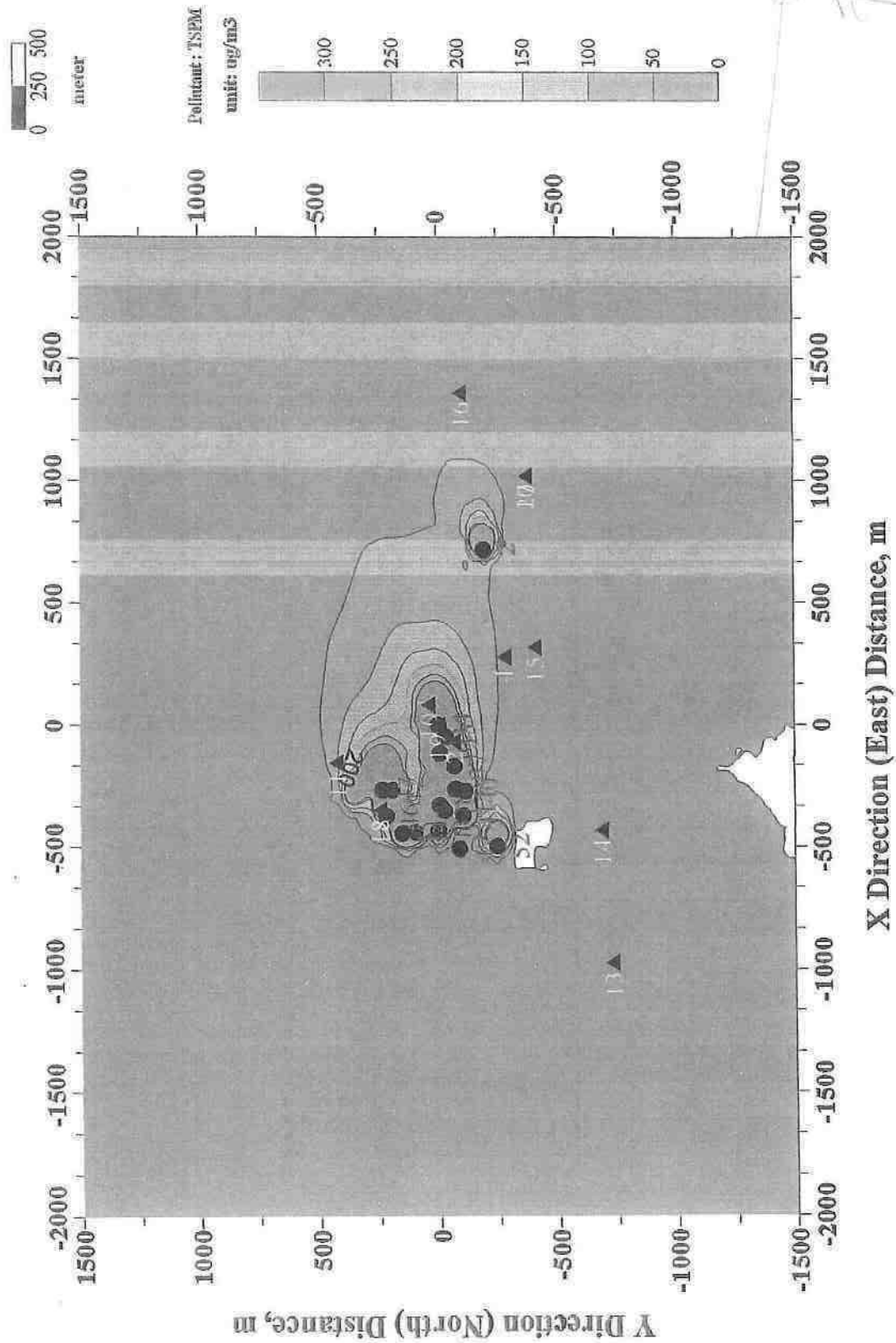


Fig. 5.9 Isopleths showing ISCST3 predicted concentration (1/4th of the crushers in operation)

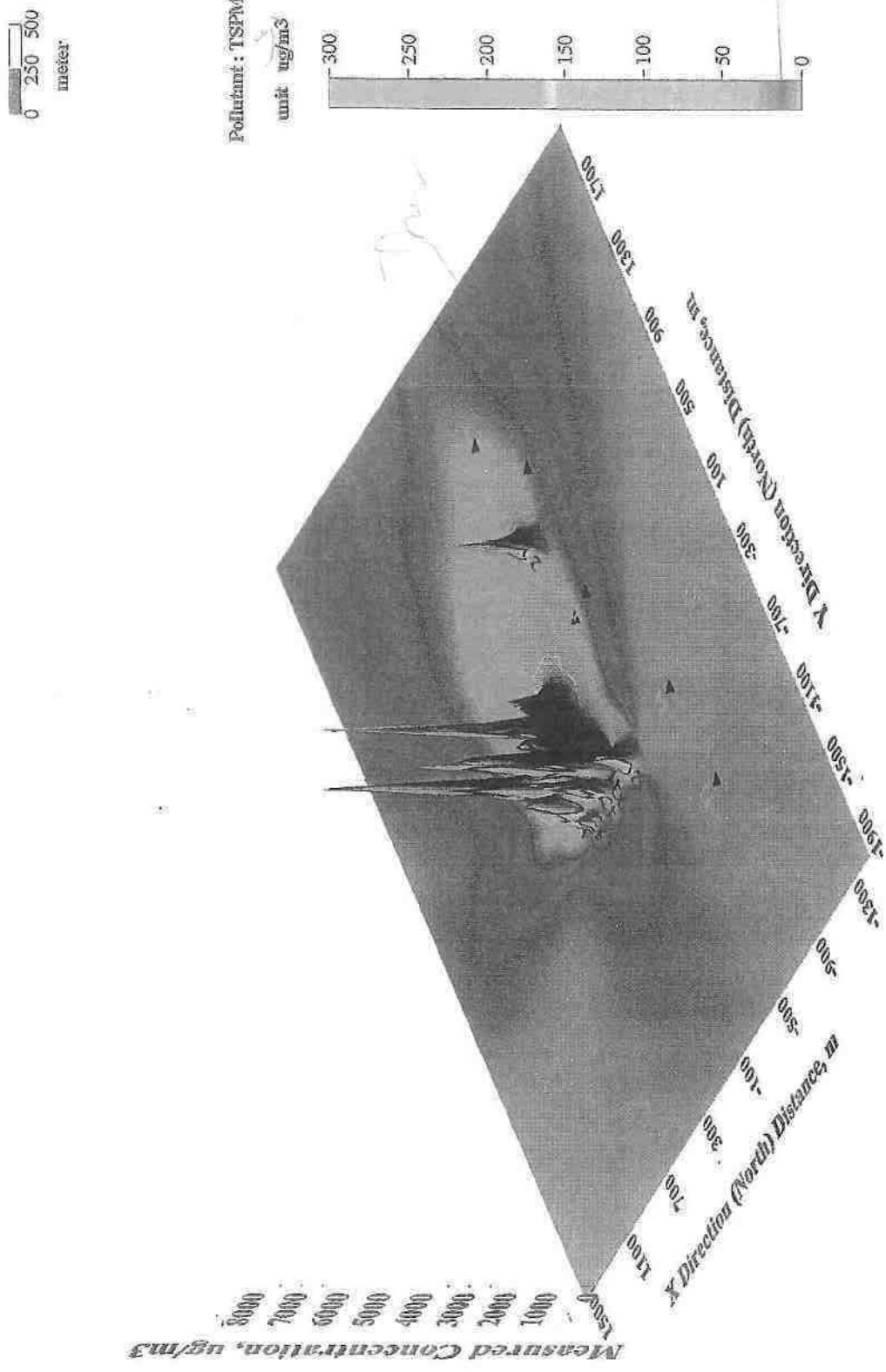


Fig. 5.10 Surfer showing ISCST3 Predicted concentration (1/4th of the crushers in operation)

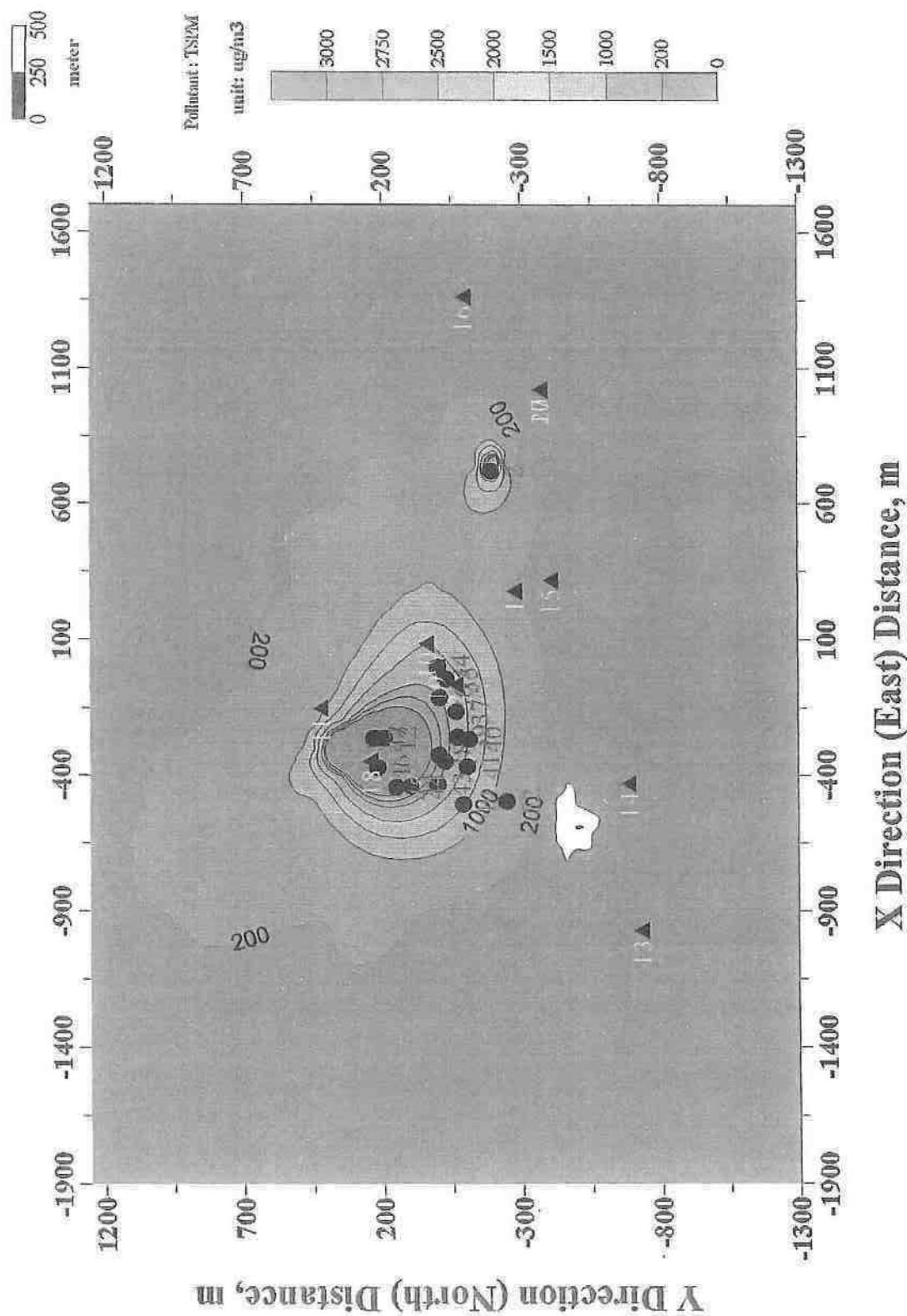


Fig. 5.11 Isopleths showing FDM predicted concentration (1/4th of the crushers in operation)

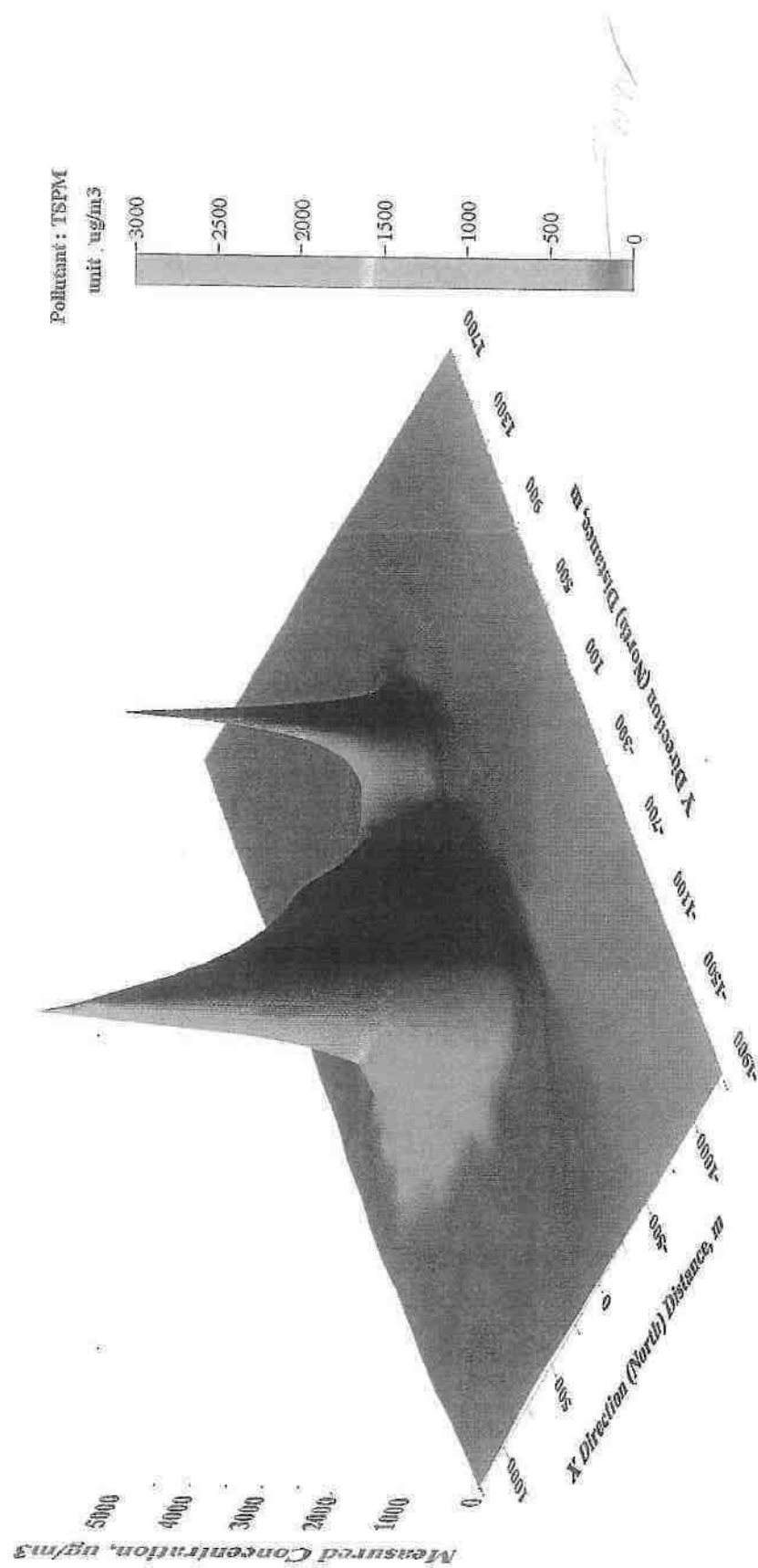


Fig. 5.12 Surfer showing FDM Predicted concentration (1/4th of the crushers in operation)

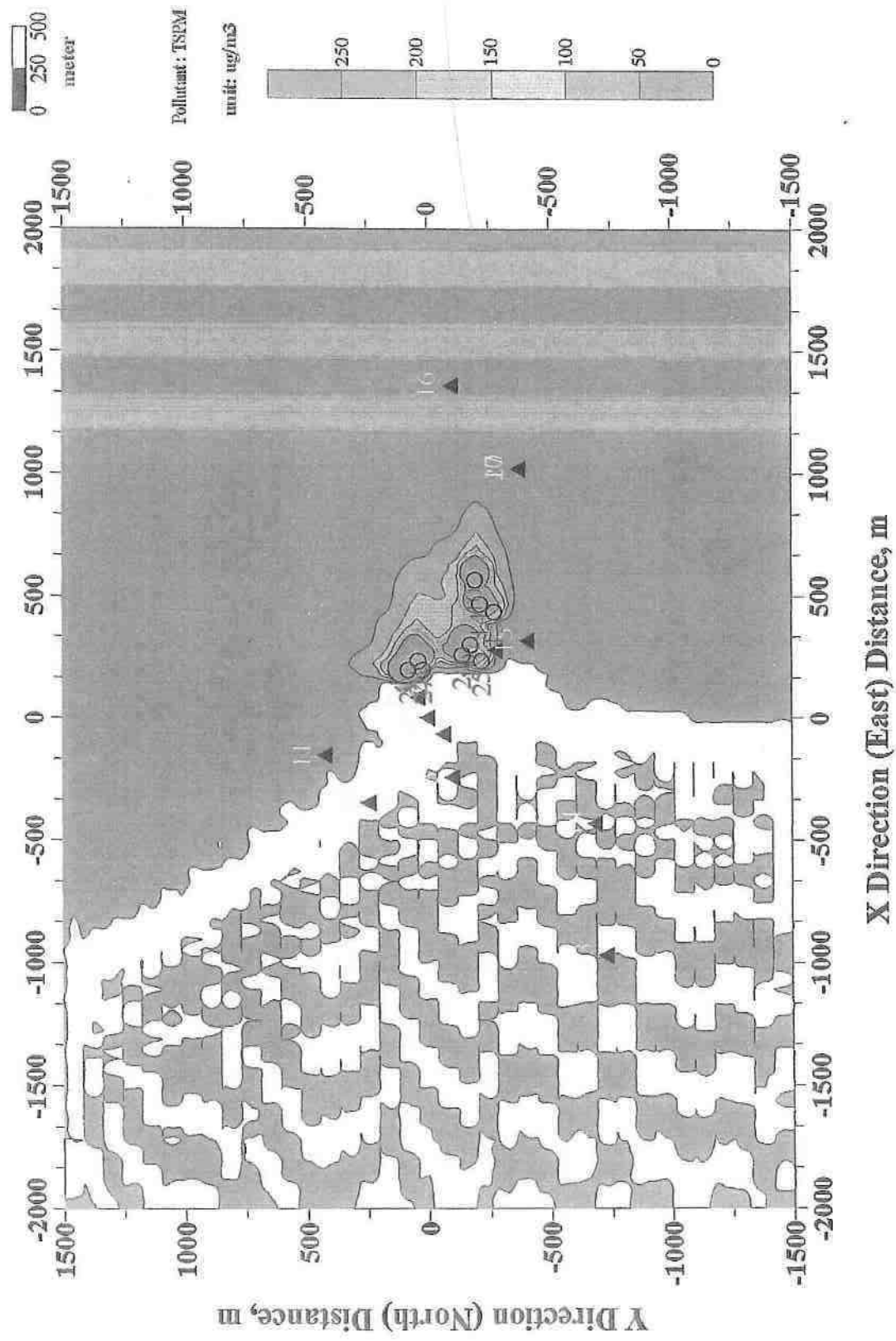


Fig. 5.13 Isopleths showing ISCST3 predicted concentration (1/8th of the crushers in operation)

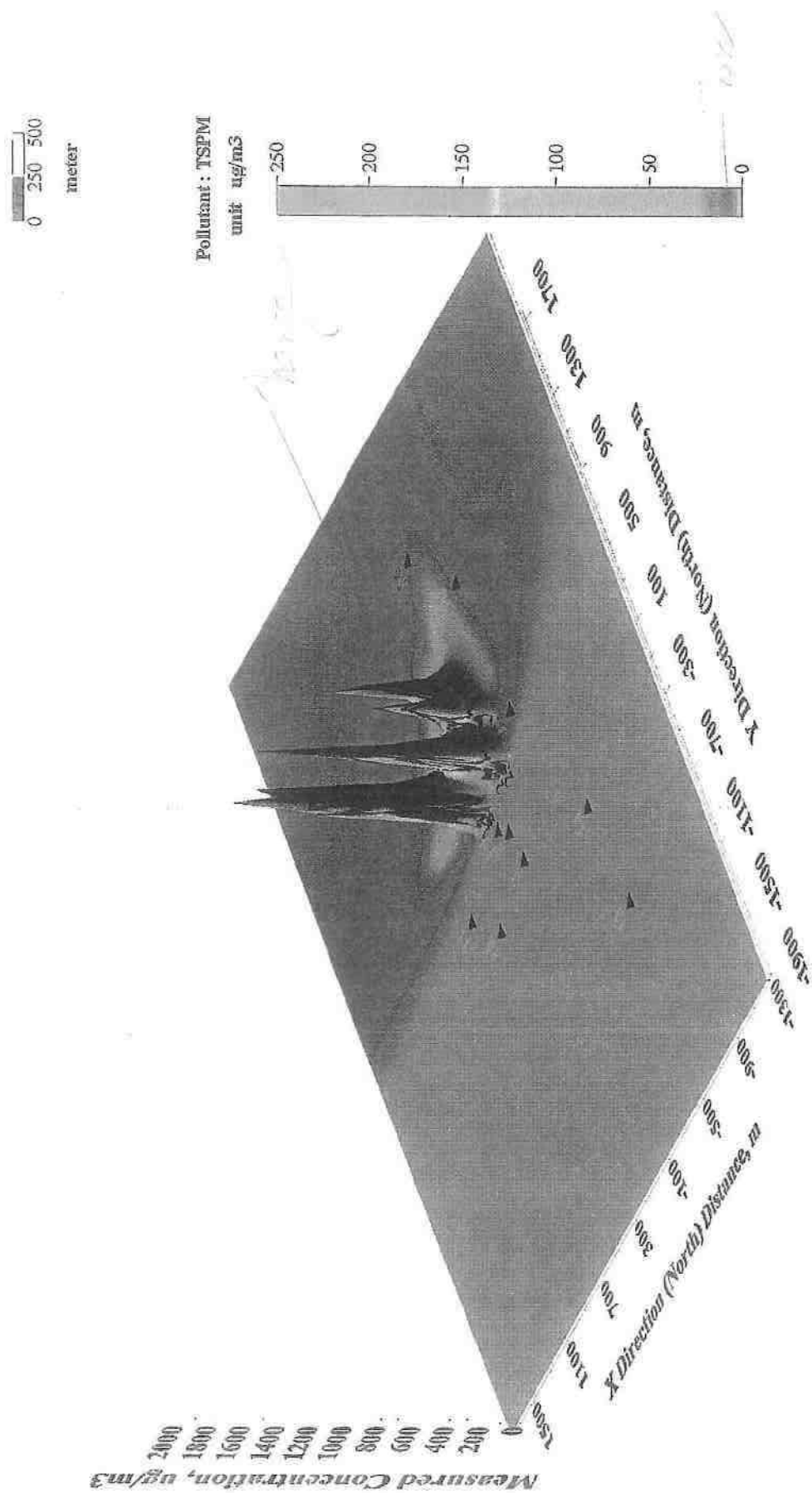


Fig. 5.14 Surfer showing ISCST3 Predicted concentration (1/8th of the crushers in operation)

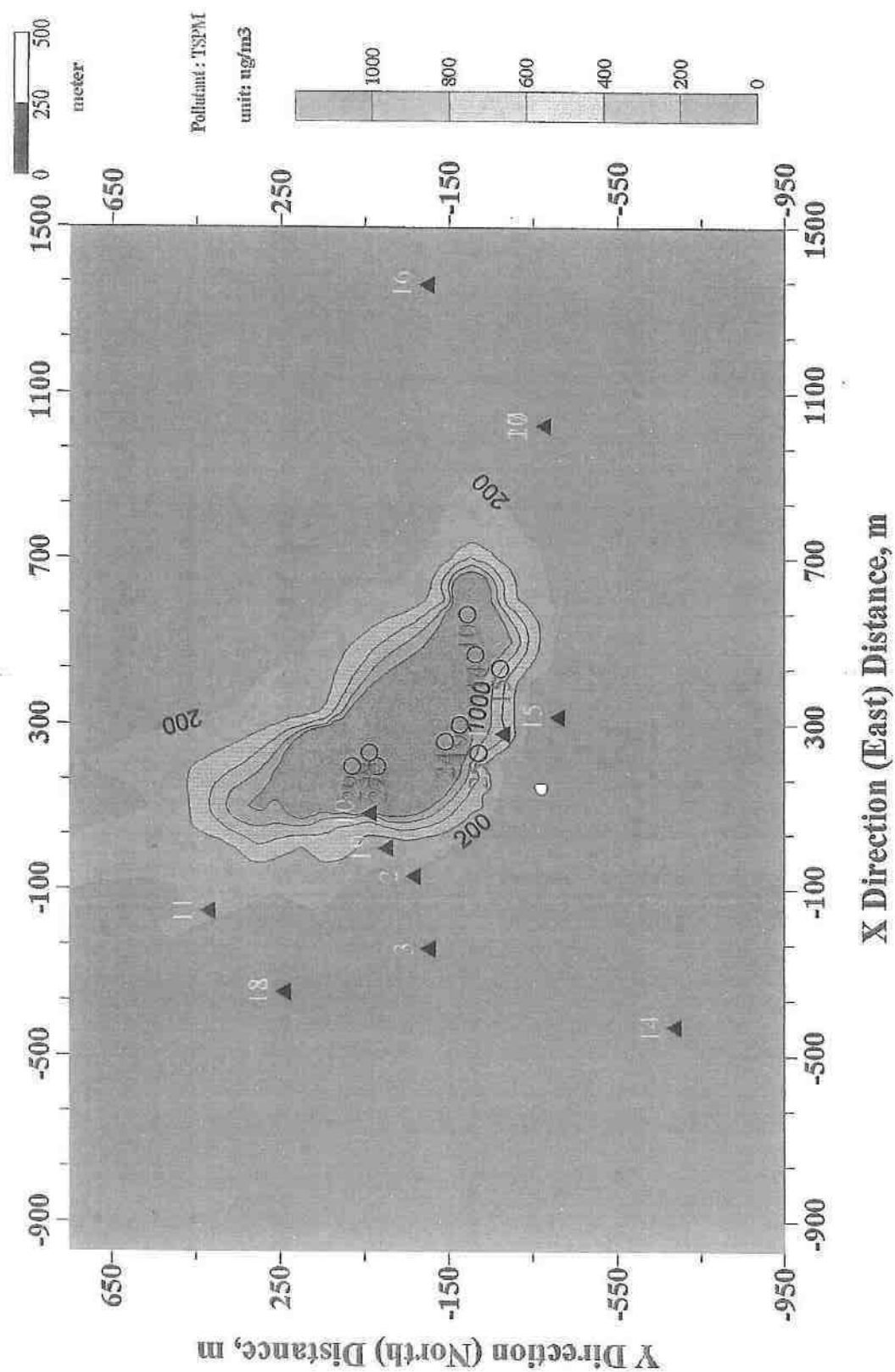


Fig. 5.15 Isopleths showing FDM predicted concentration (1/8th of the crushers in operation)

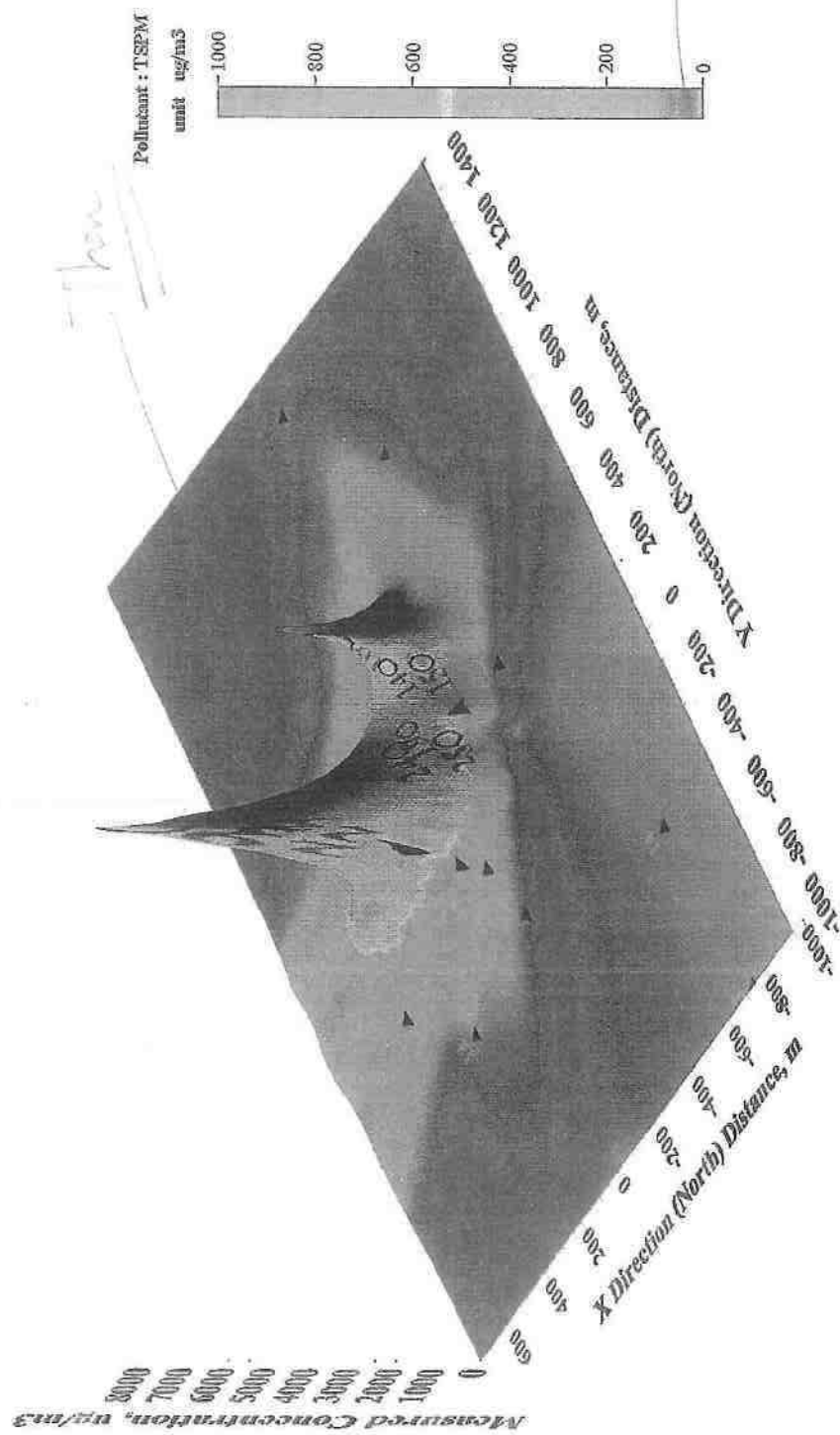


Fig. 5.16 Surfer showing FDM Predicted concentration (1/8th of the crushers in operation)

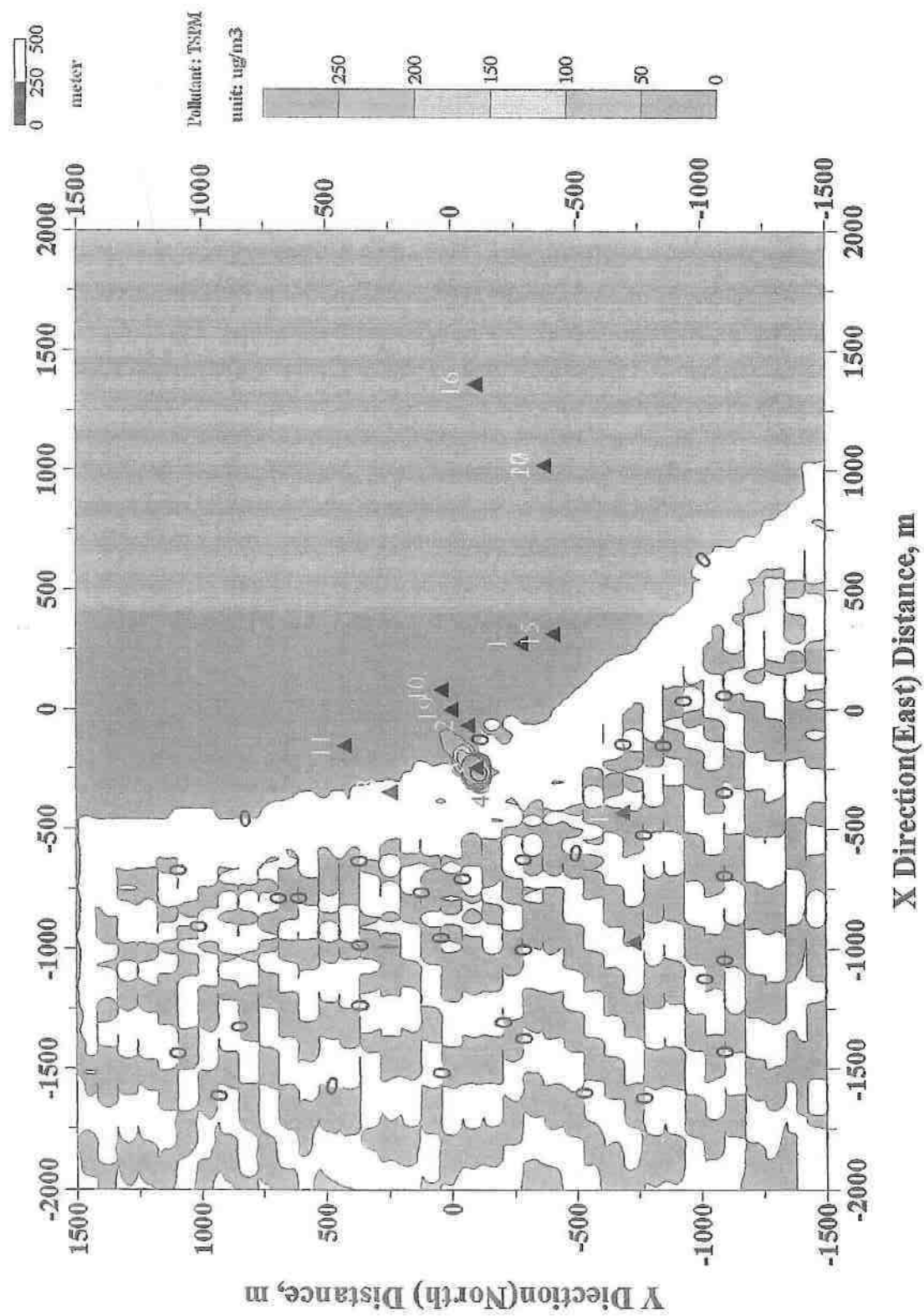


Fig. 5.17 Isopleths showing ISCST3 predicted concentration (only one crusher in operation)

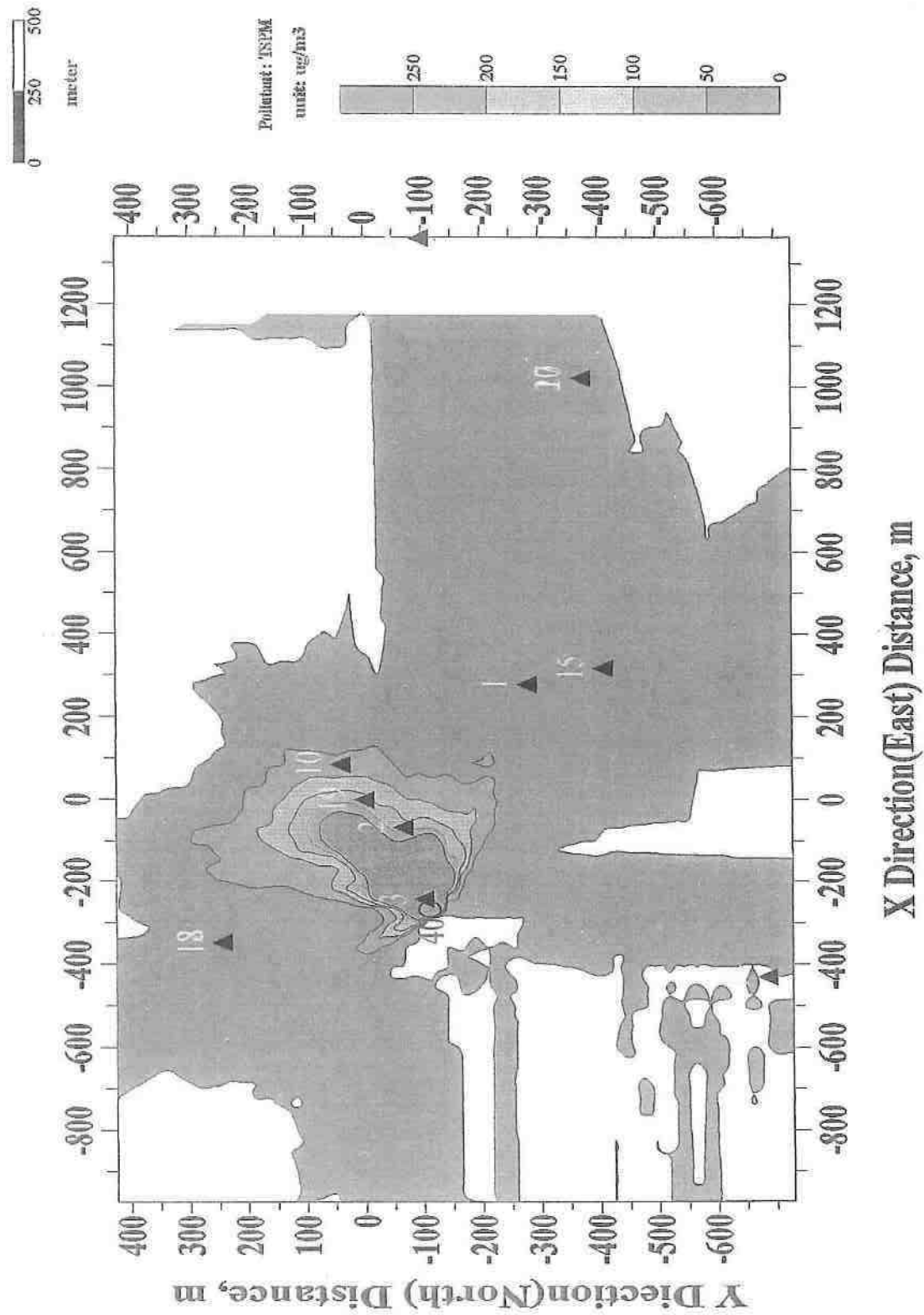


Fig. 5.19 Isopleths showing FDM predicted concentration (only one crusher in operation)

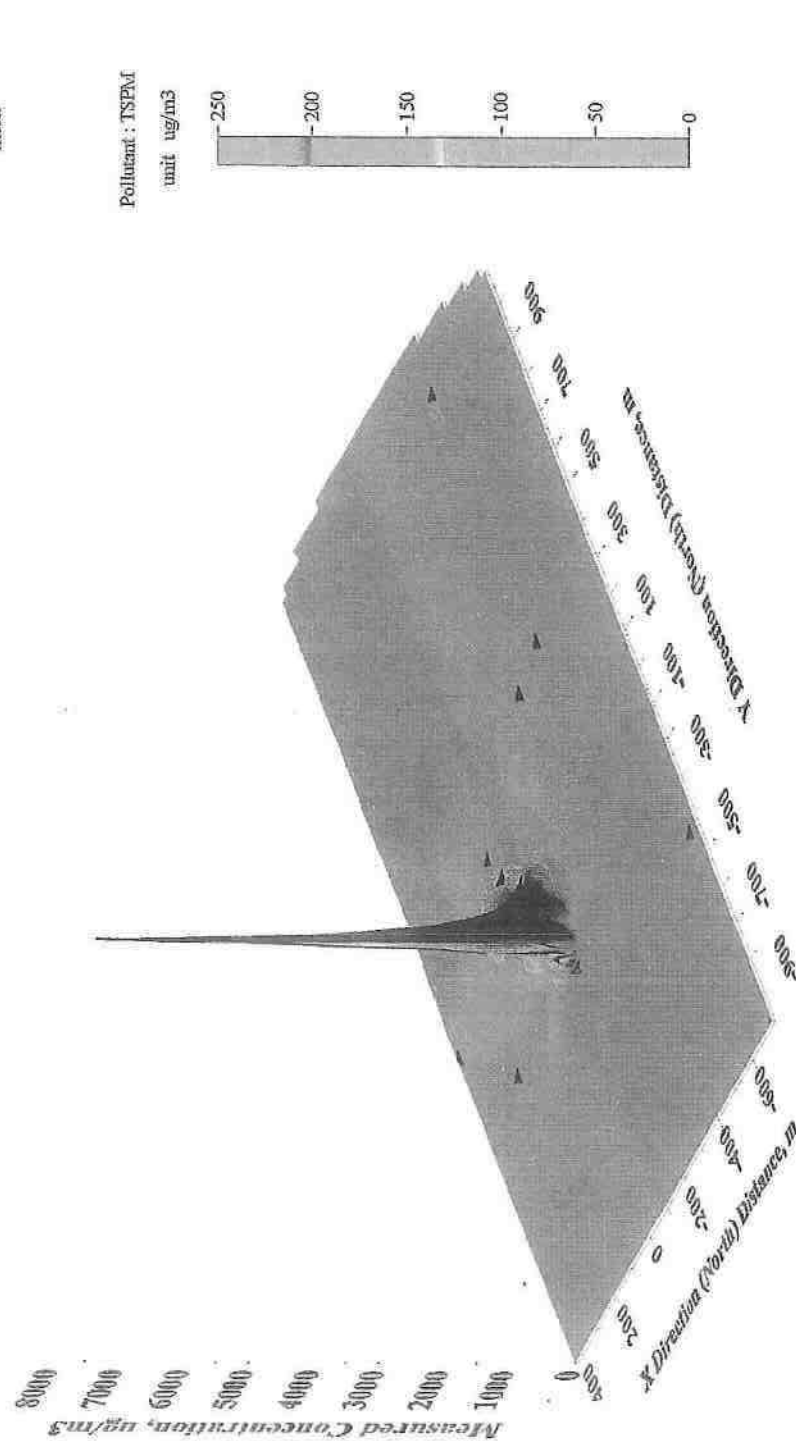


Fig. 5.20 Surfer showing FDM Predicted concentration (only one crusher in operation)

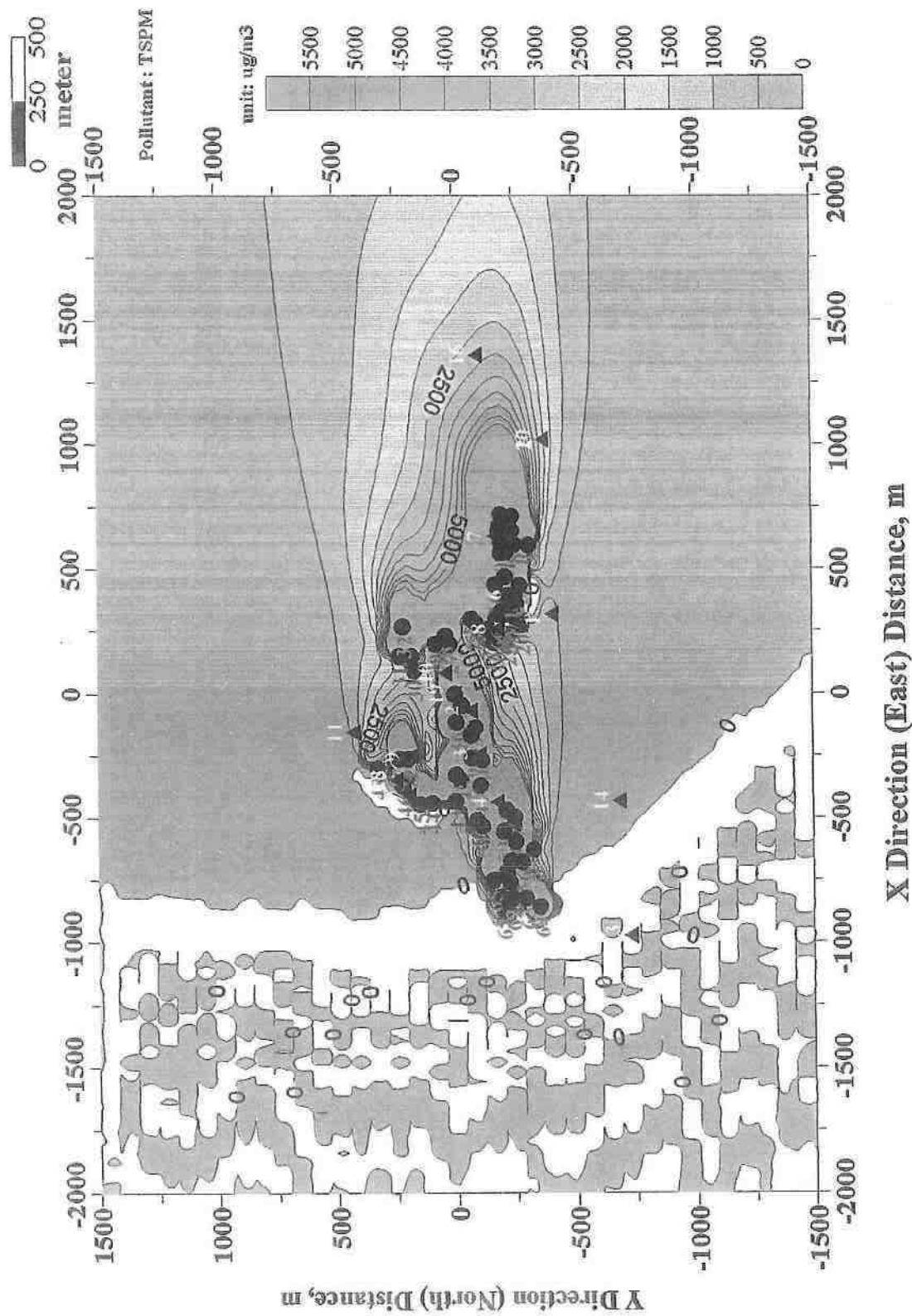


Fig. 5.21 Isopleths showing ISCST3 predicted deposition (all the crushers in operation)

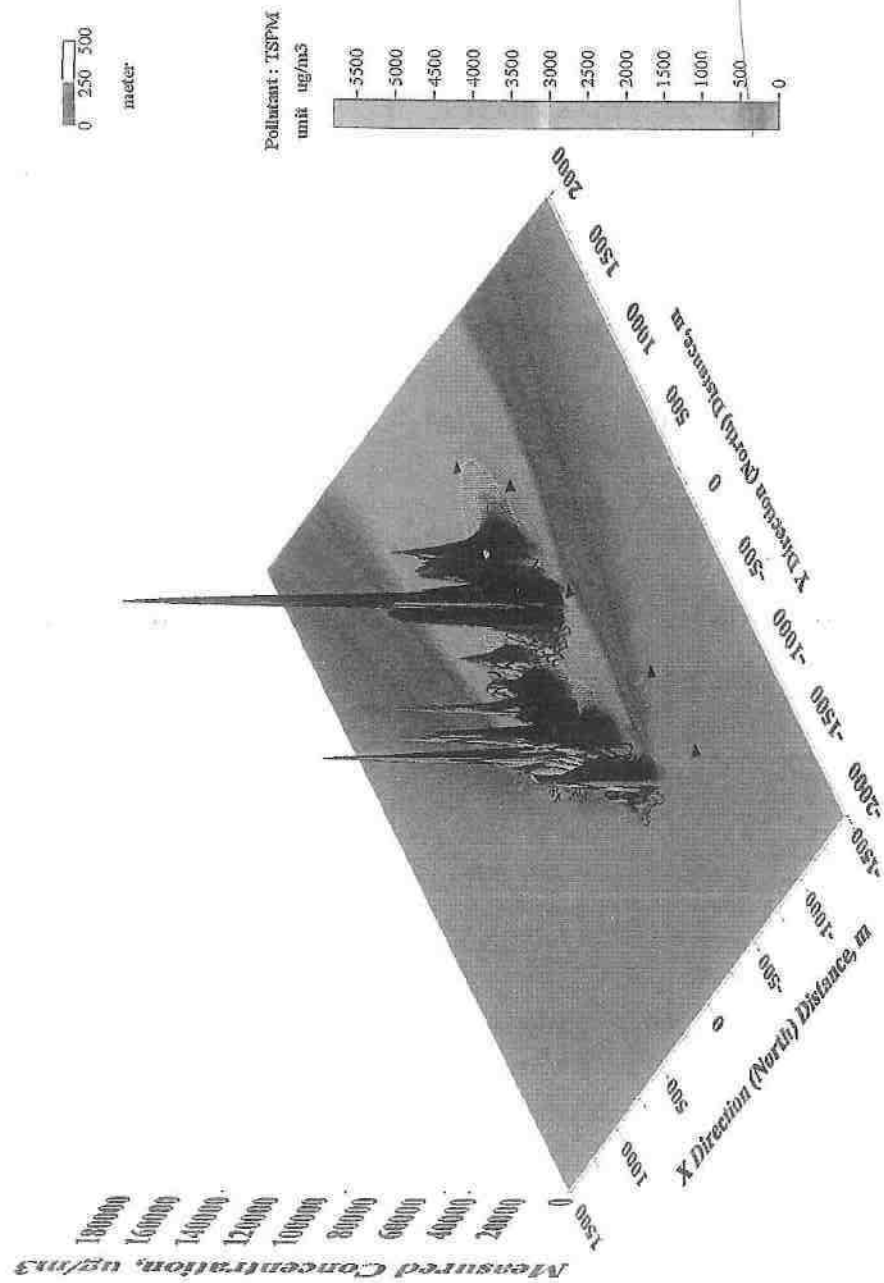


Fig. 5.22 Surfer showing ISCST3 Predicted deposition (all the crushers in operation)

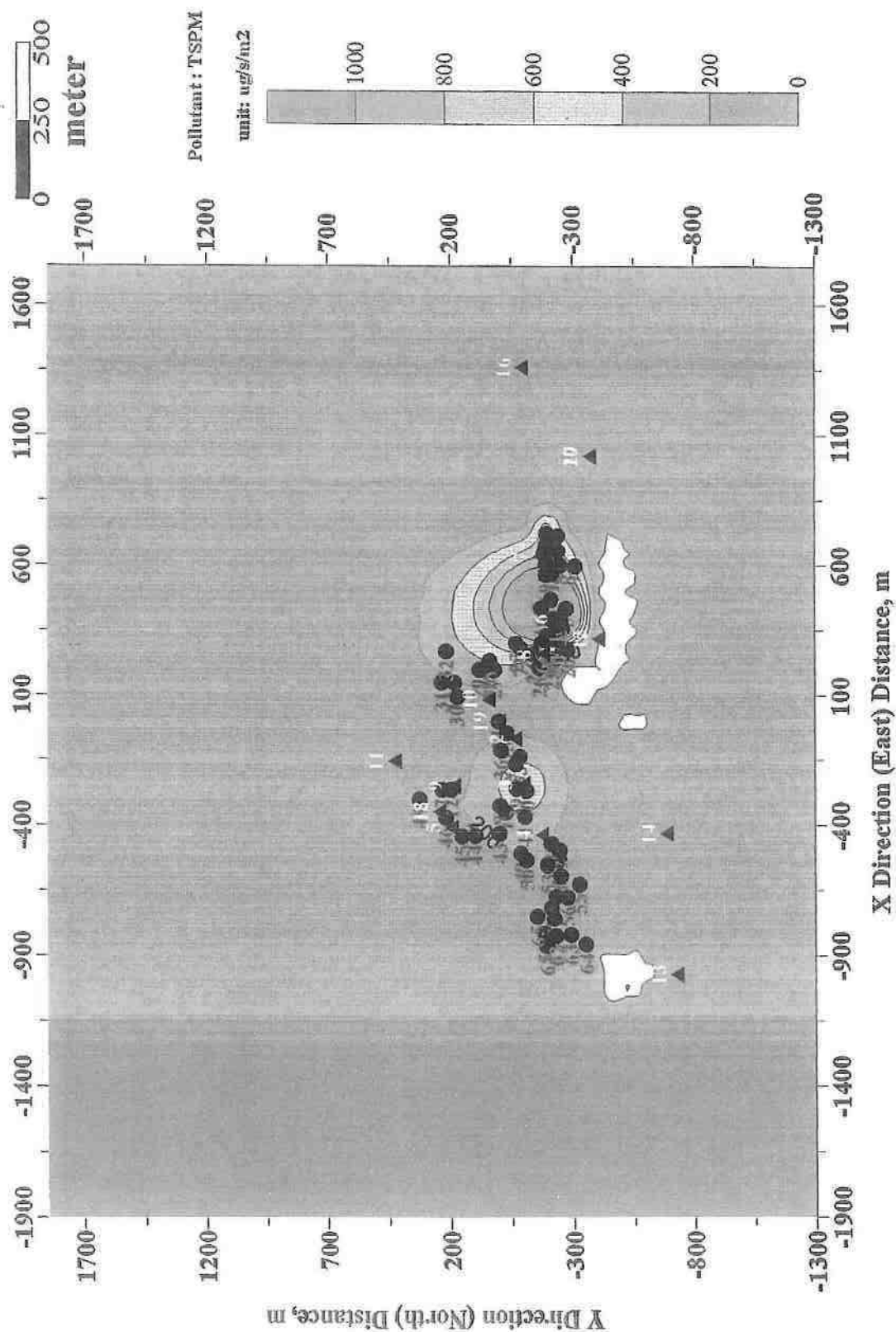


Fig. 5.23 Isopleths showing FDM predicted deposition (all the crushers in operation)

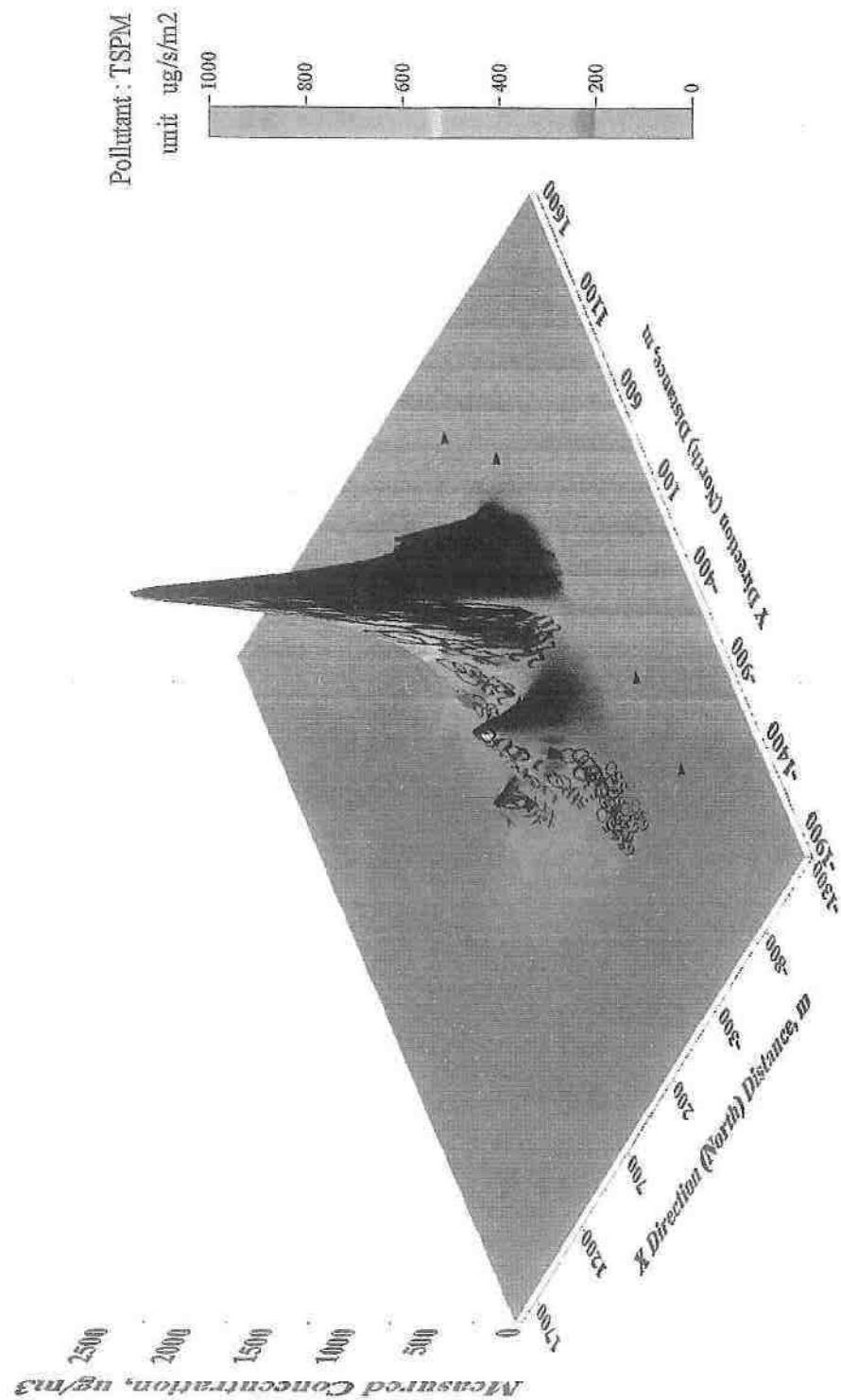


Fig. 5.24 Surfer showing FDM Predicted deposition (all the crushers in operation)

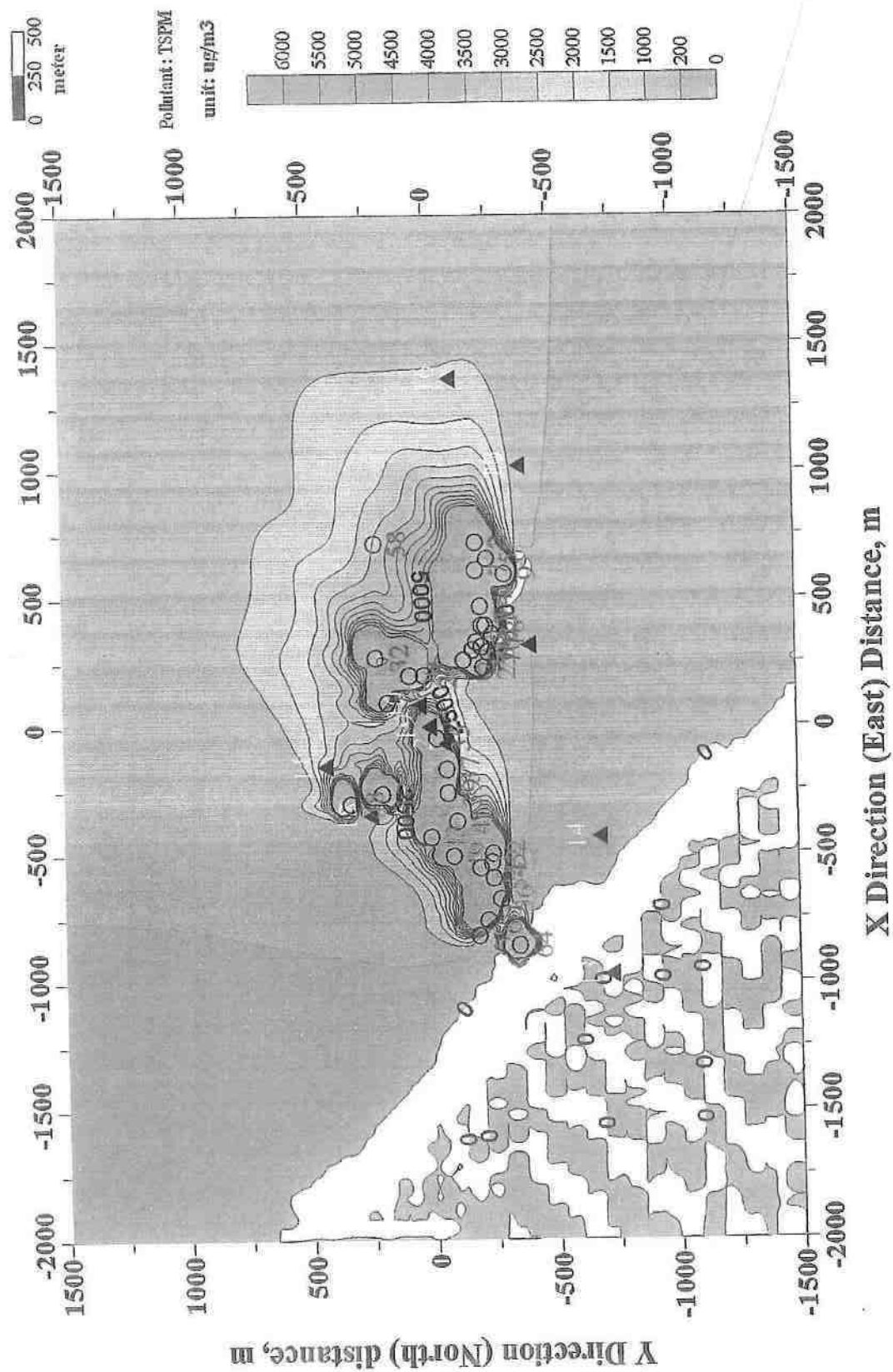


Fig. 5.25 Isopleths showing ISCST3 predicted deposition (half of the crushers in operation)

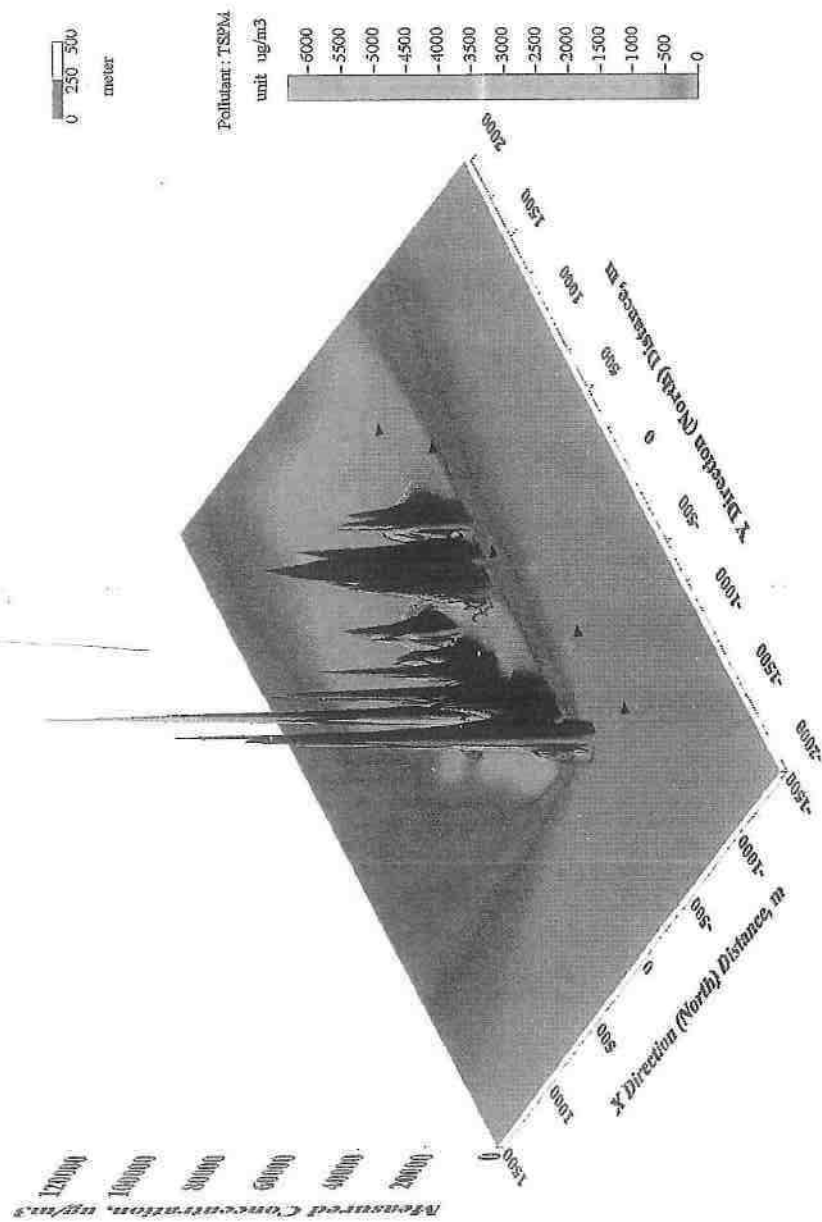


Fig. 5.26 Surfer showing ISCST3 Predicted deposition (half of the crushers in operation)

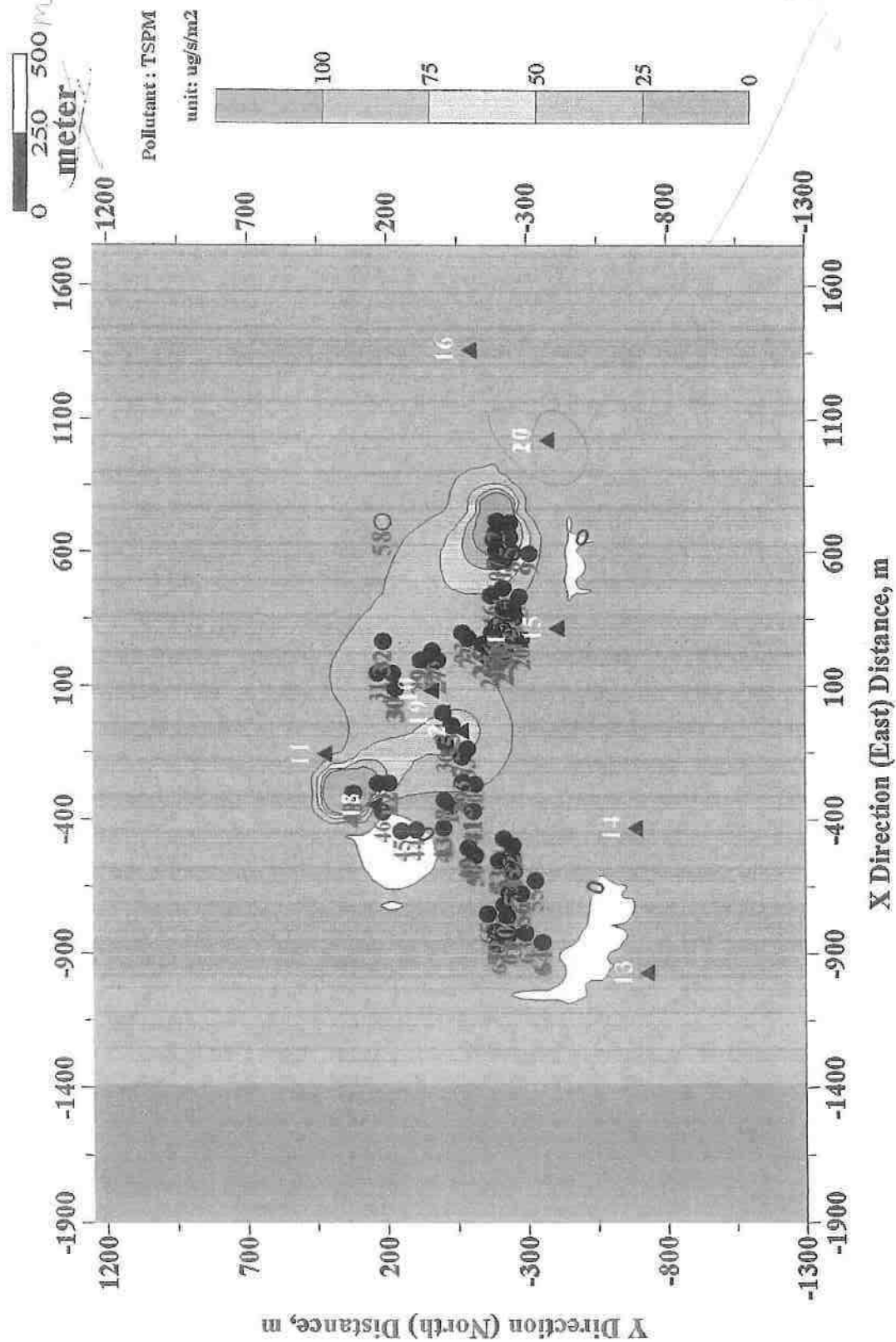


Fig. 5.27 Isopleths showing FDM predicted deposition (half of the the crushers in operation)

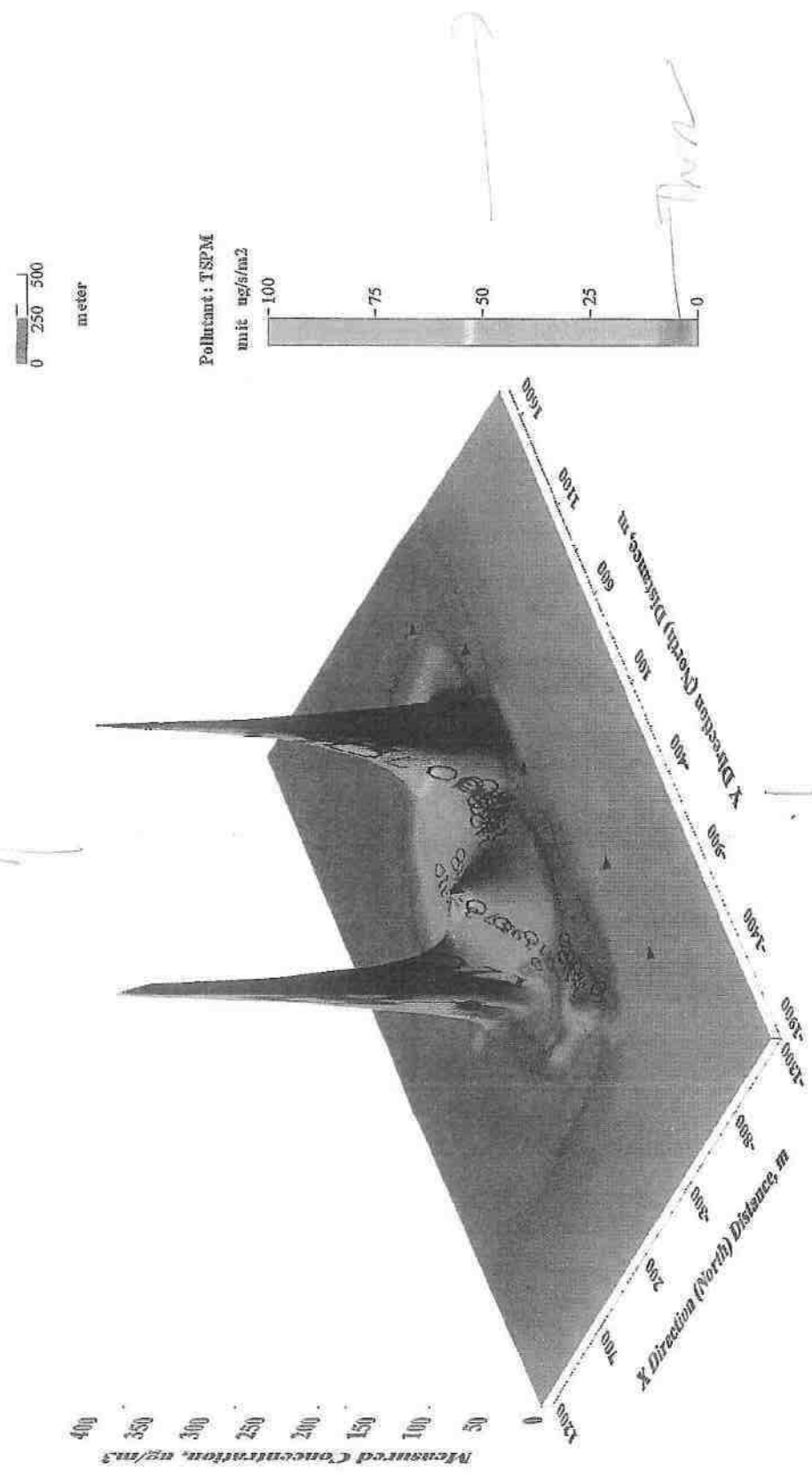


Fig. 5.28 Surfer showing FDM Predicted deposition (half of the crushers in operation)

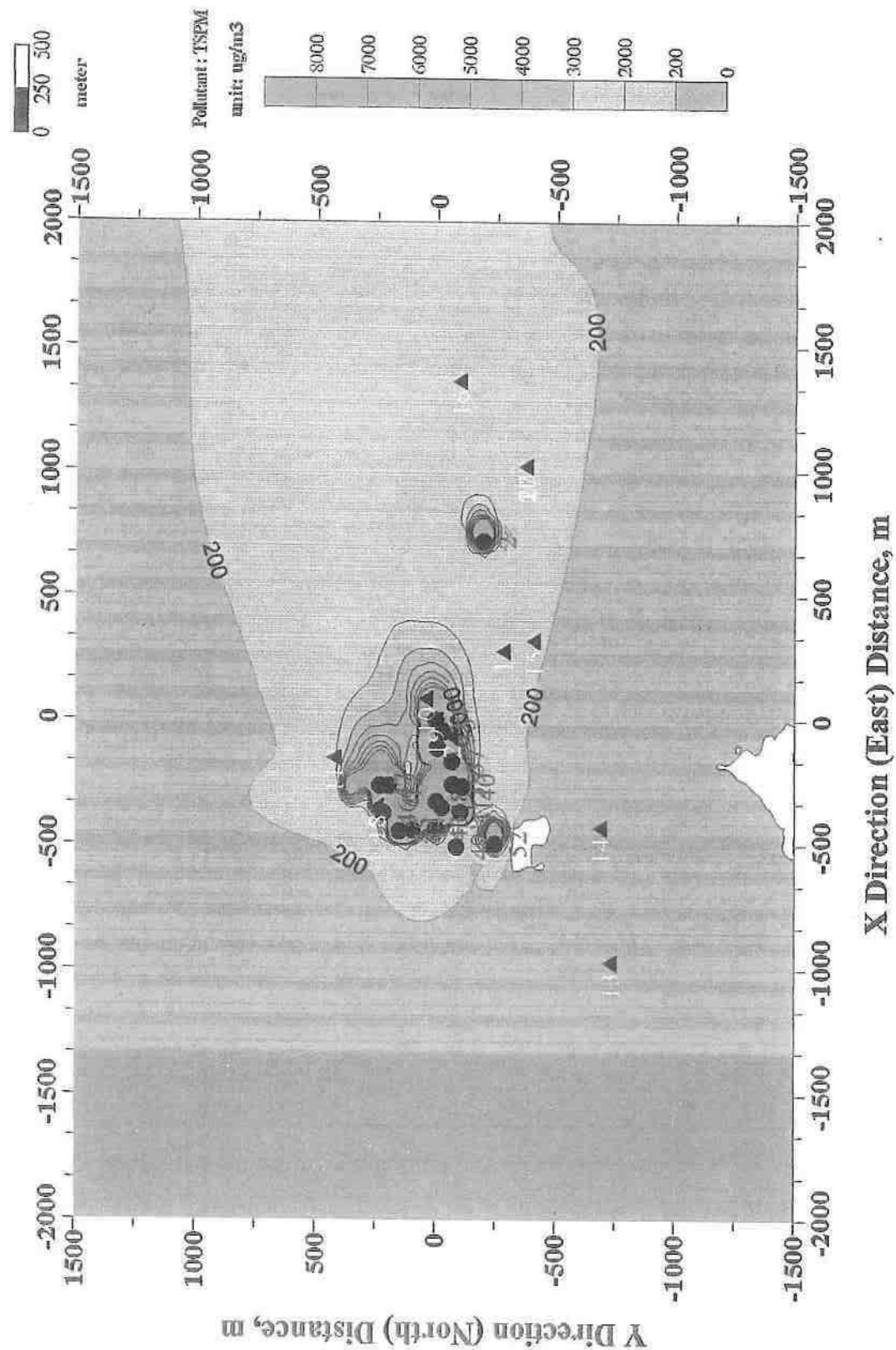


Fig. 5.29 Isopleths showing ISCST3 predicted deposition (1/4th of the crushers in operation)

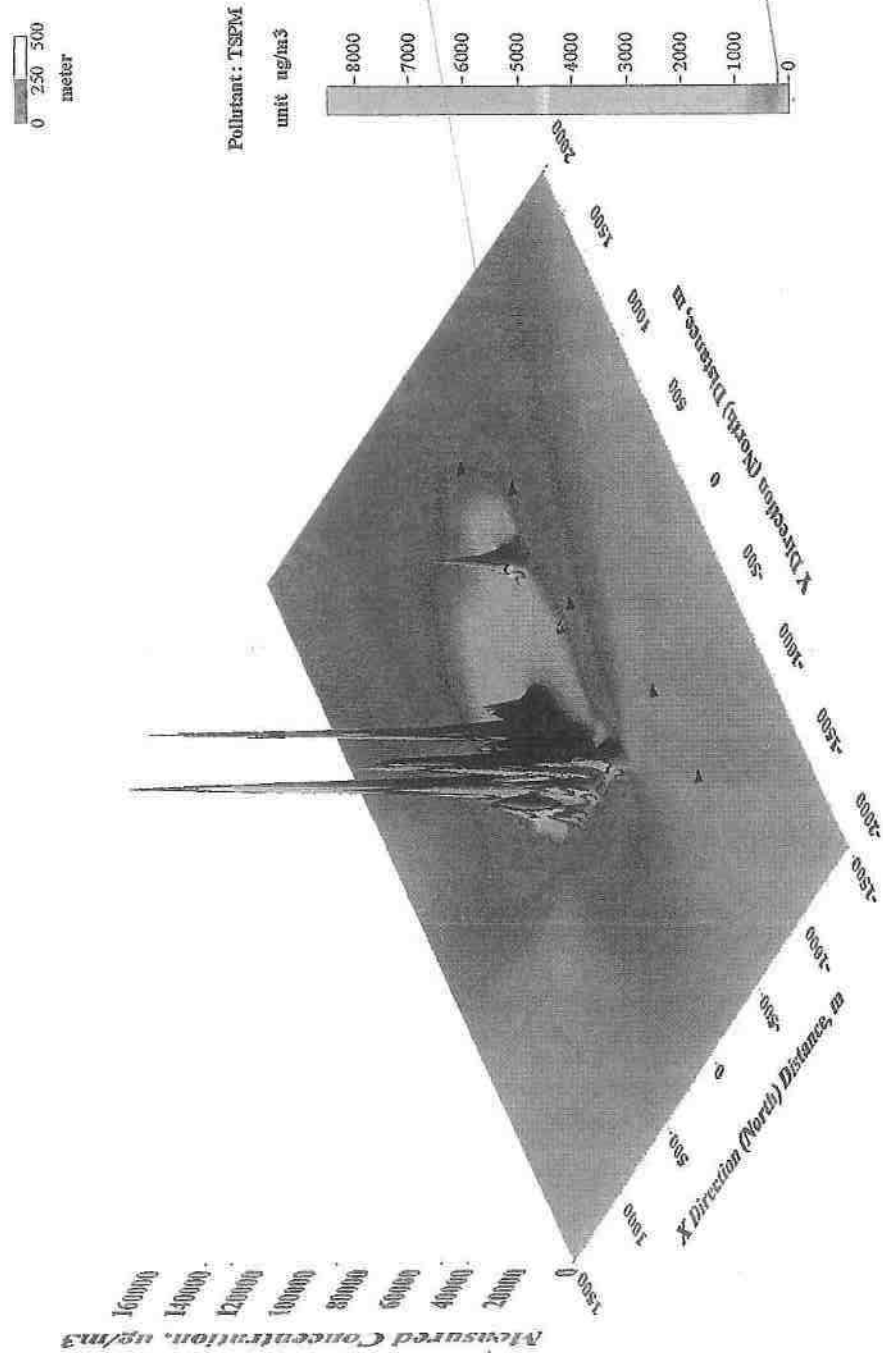


Fig. 5.30 Surfer showing ISCST3 Predicted deposition (1/4th of the crushers in operation)

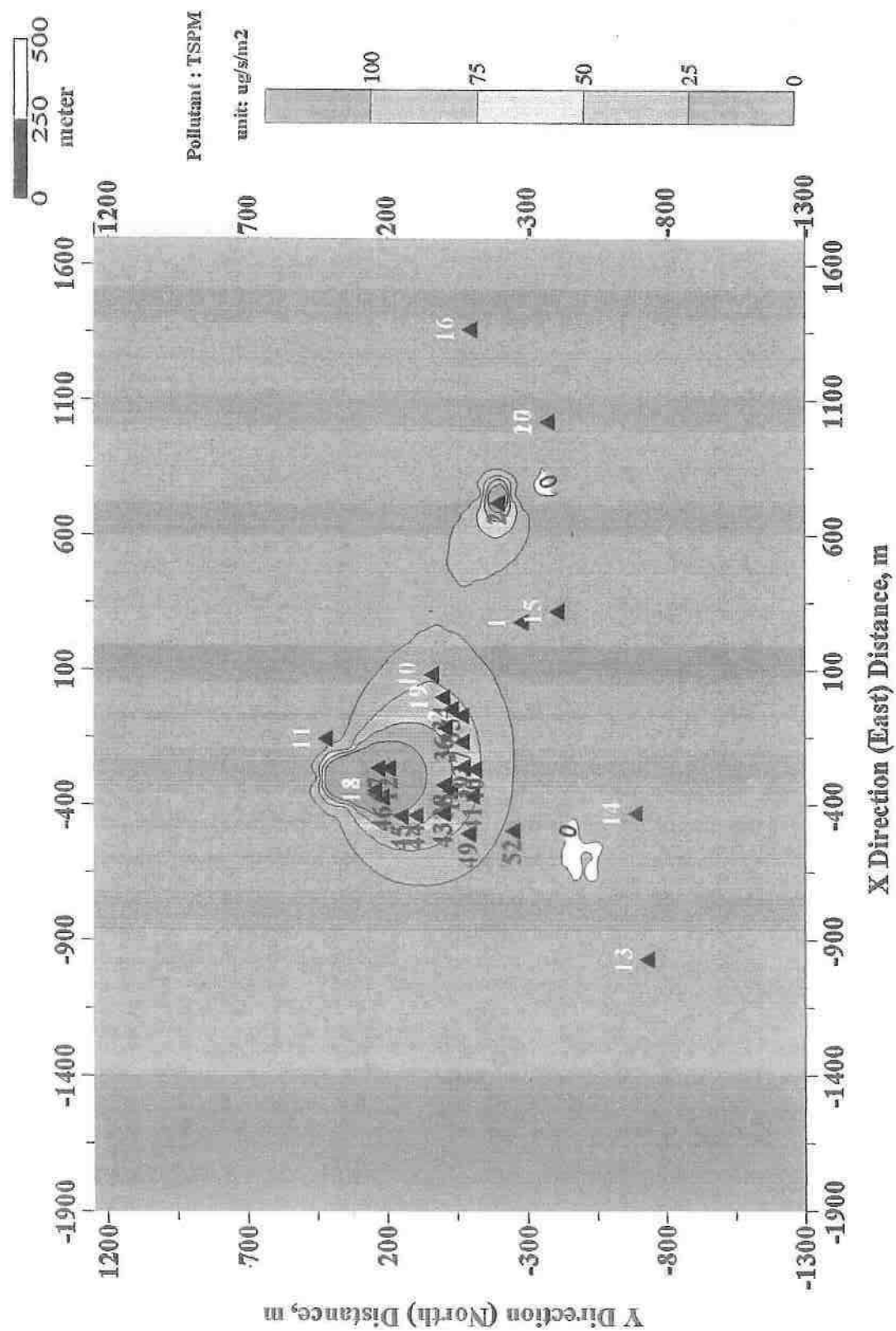


Fig. 5.31 Isopleths showing FDM predicted deposition (1/4th of the crushers in operation)

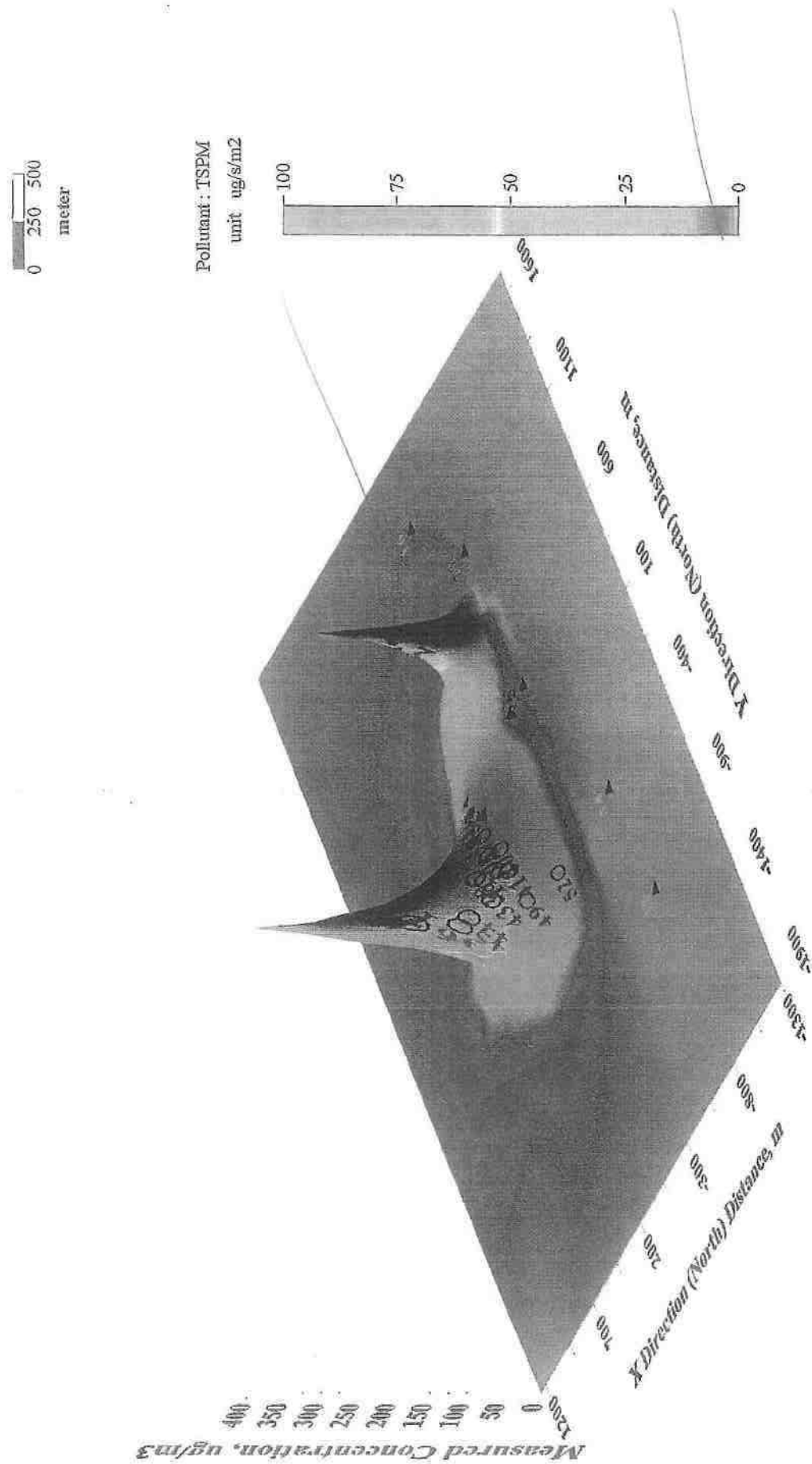


Fig. 5.32 Surfer showing FDM Predicted deposition (1/4th of the crushers in operation)

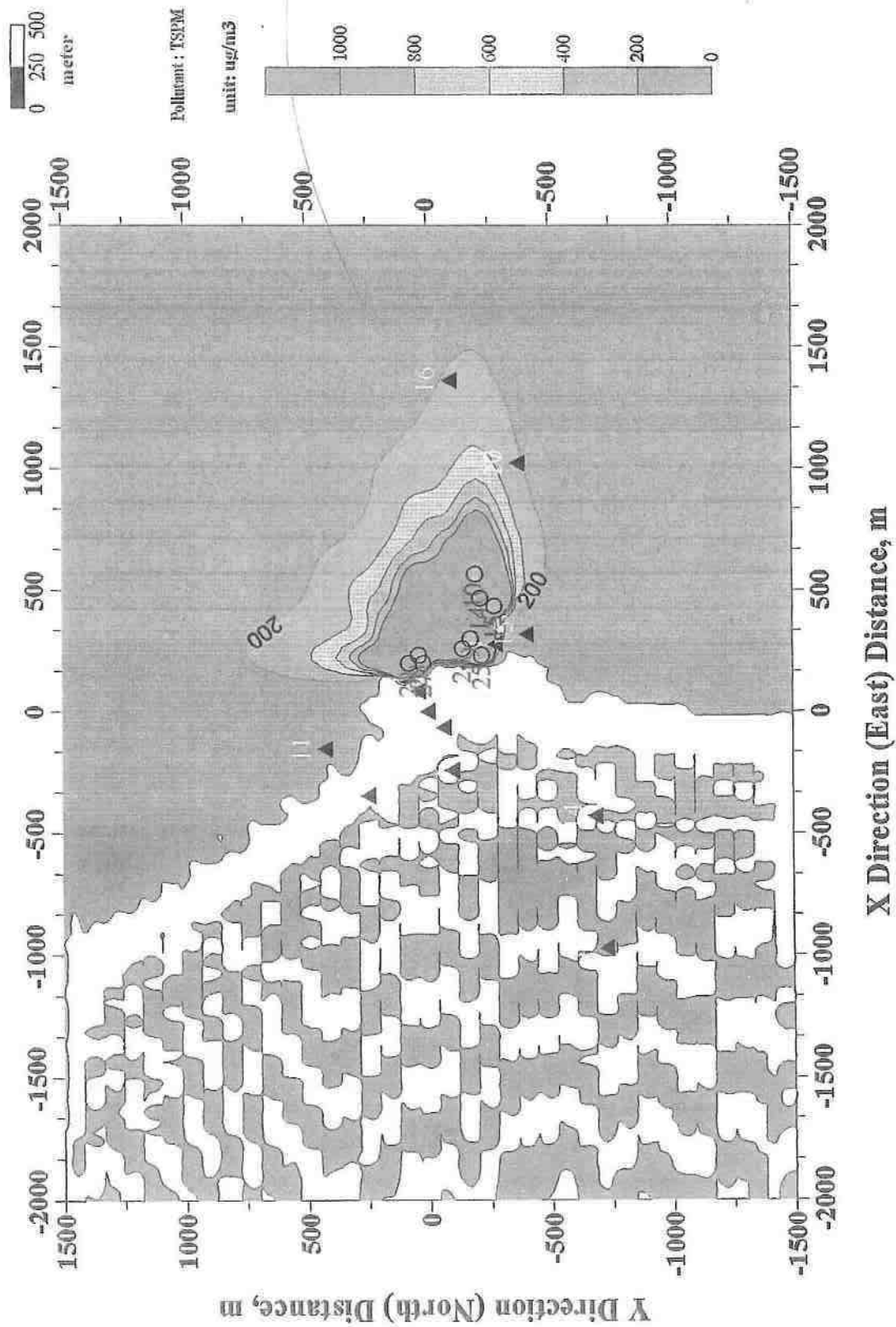


Fig. 5.33 Isopleths showing ISCST3 predicted deposition (1/8th of the crushers in operation)

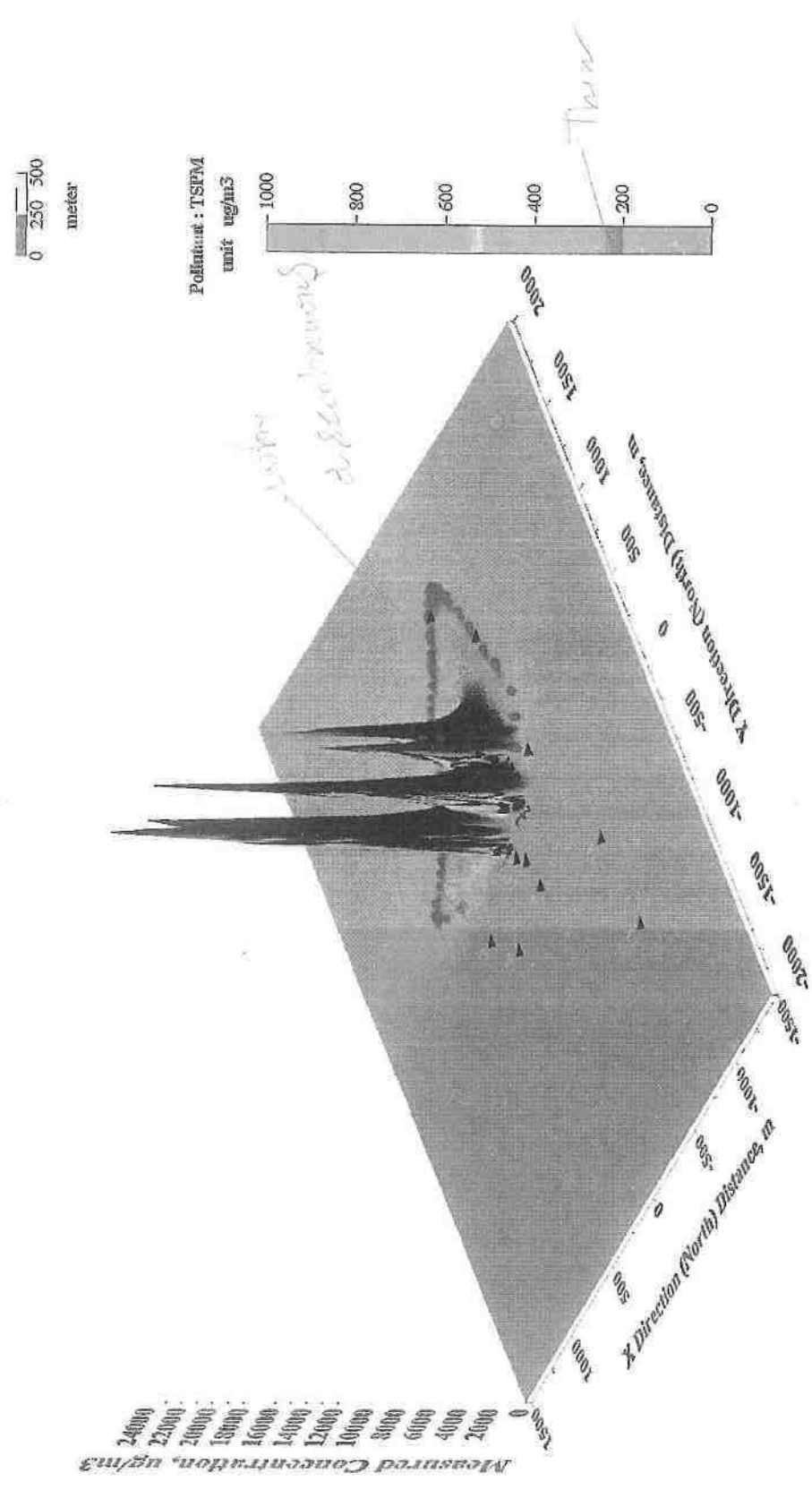


Fig. 5.34 Surfer showing ISCST3 Predicted deposition (1/8th of the crushers in operation)

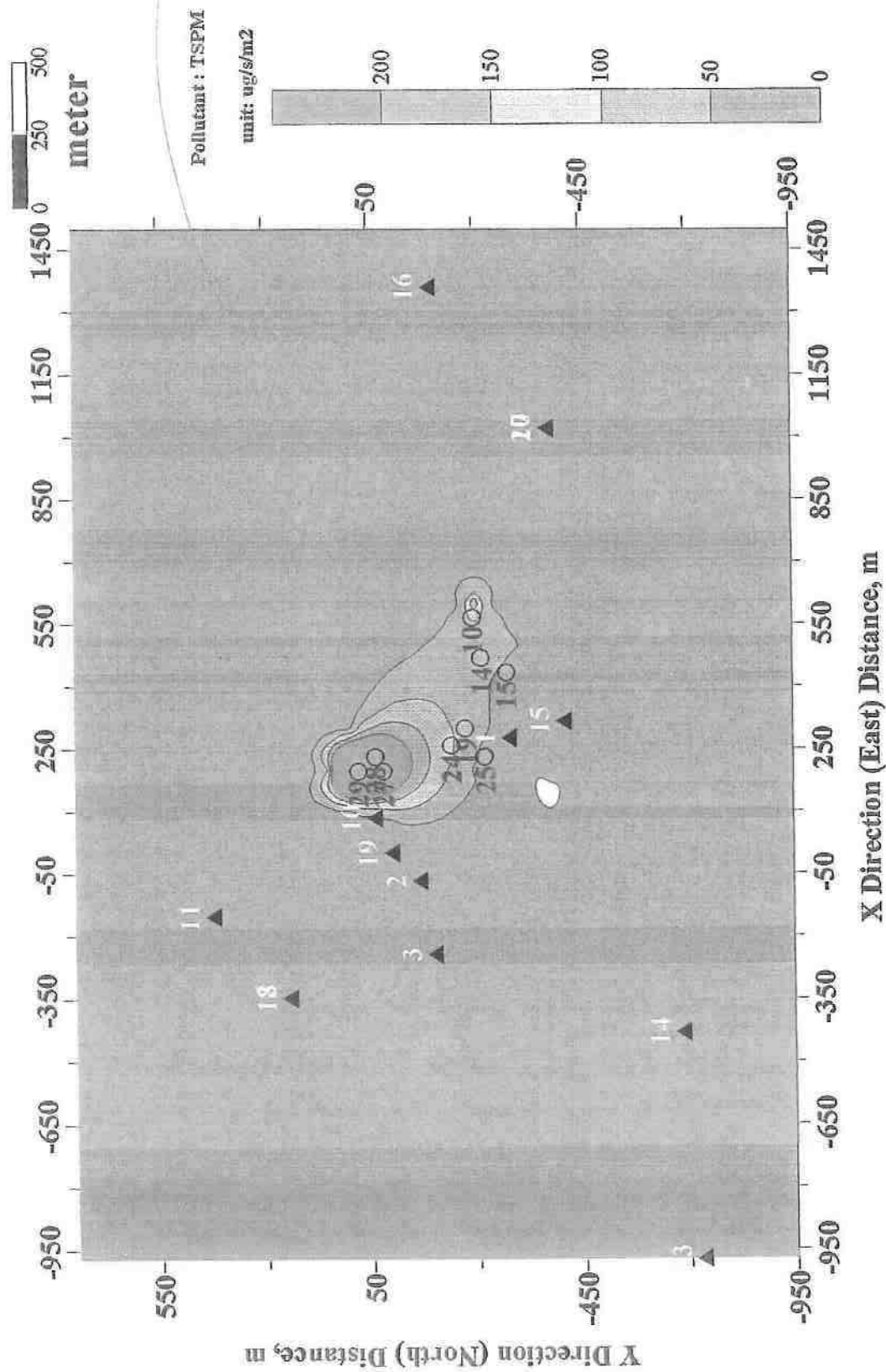


Fig. 5.35 Isopleths showing FDM predicted deposition (1/8th of the crushers in operation)

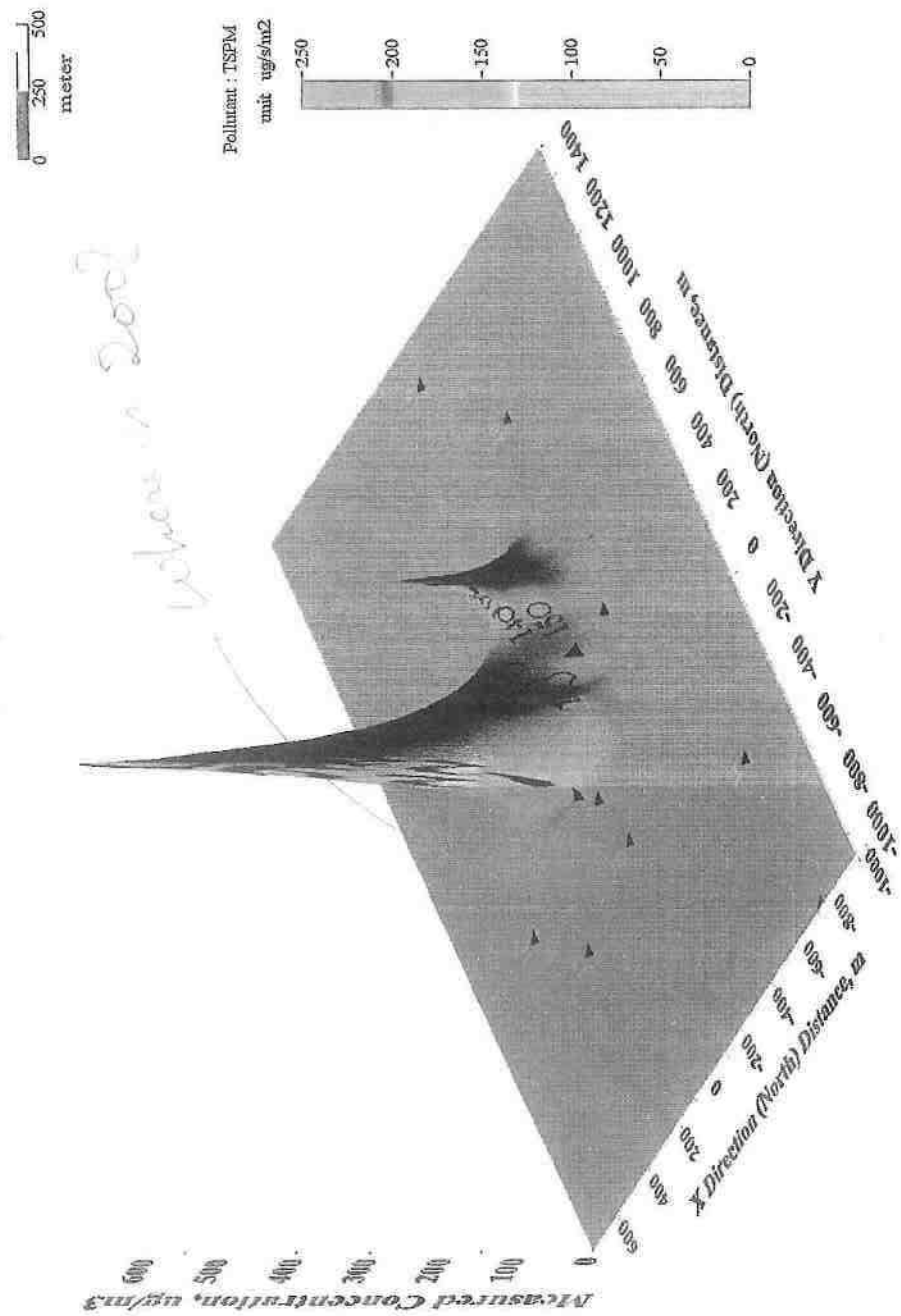


Fig. 5.36 Surfer showing FDM Predicted deposition (1/8th of the crushers in operation)

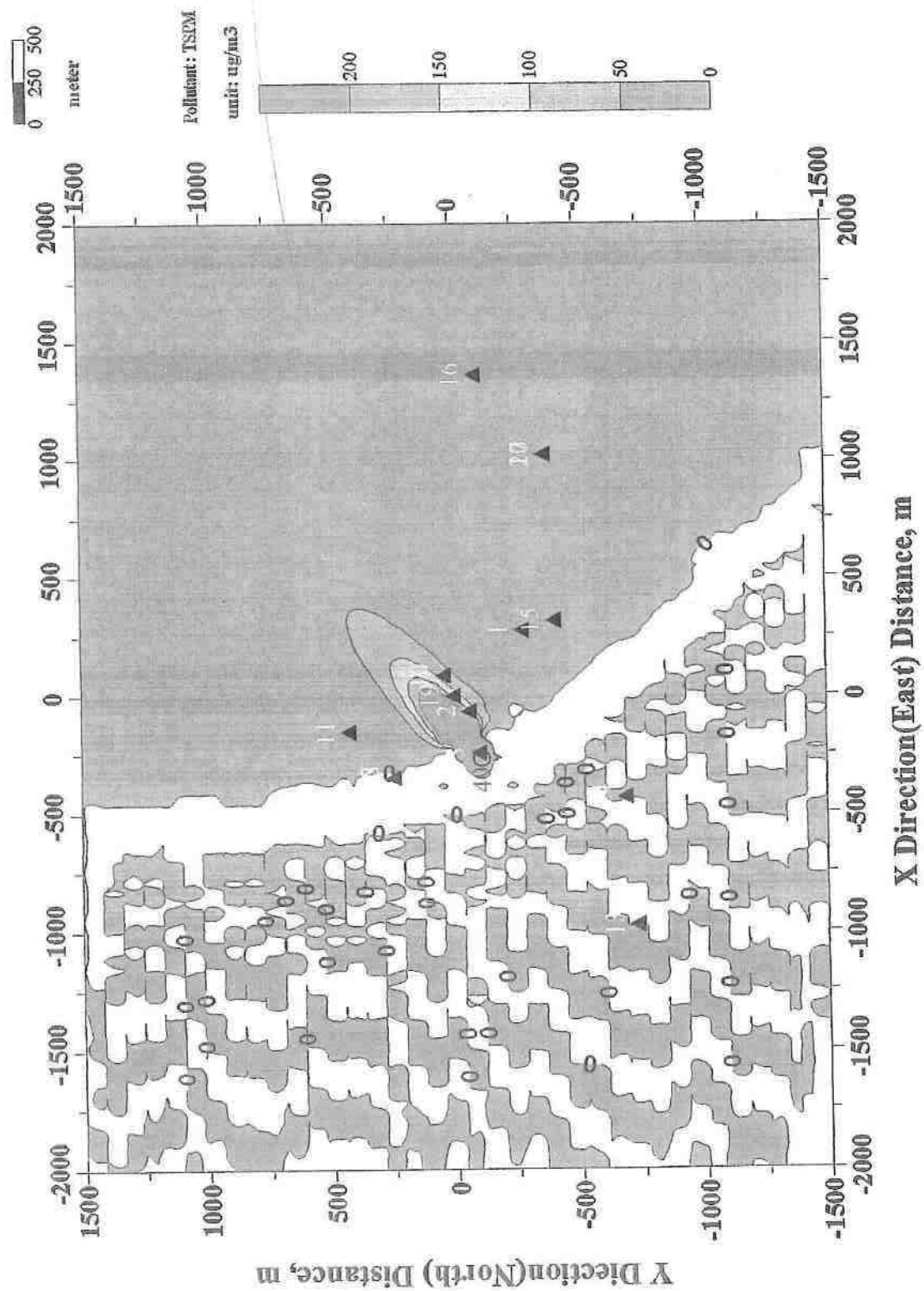


Fig. 5.37 Isopleths showing ISCST3 predicted deposition (only one crusher in operation)

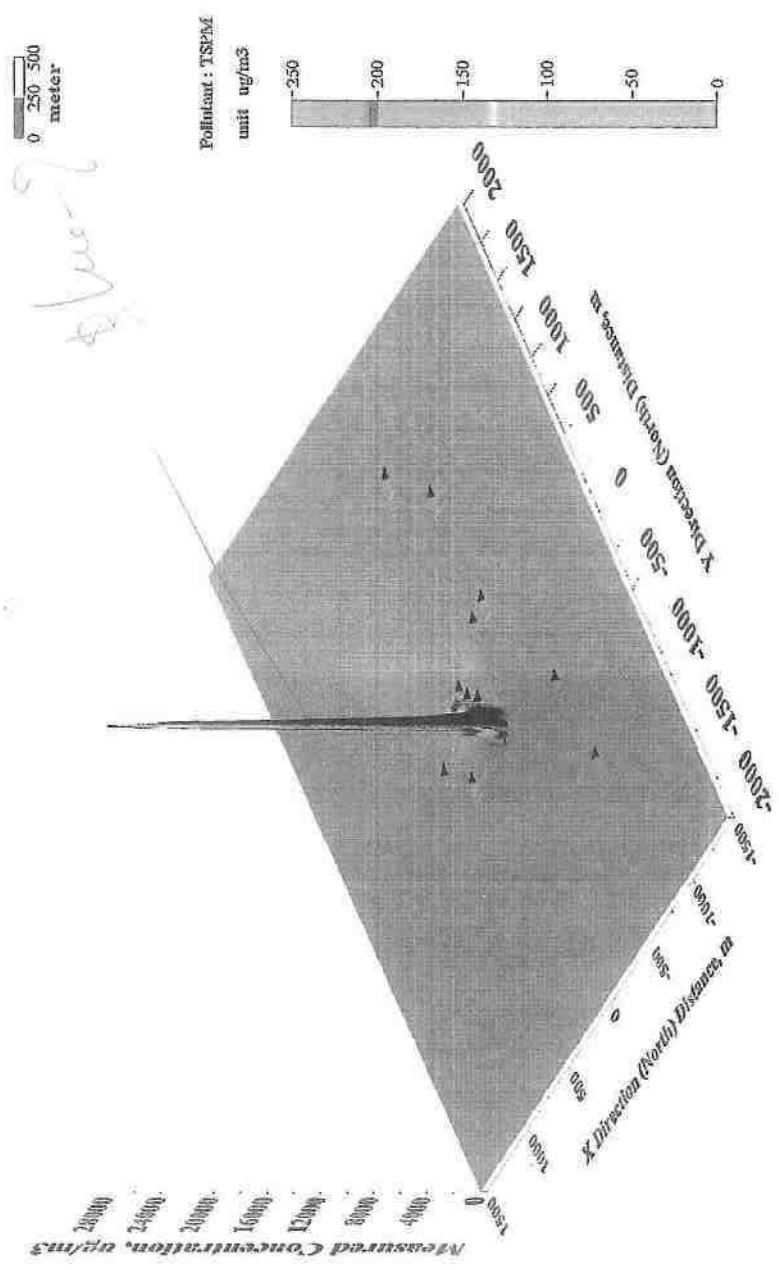


Fig. 5.38 Surfer showing ISCST3 Predicted deposition (only one crusher in operation)

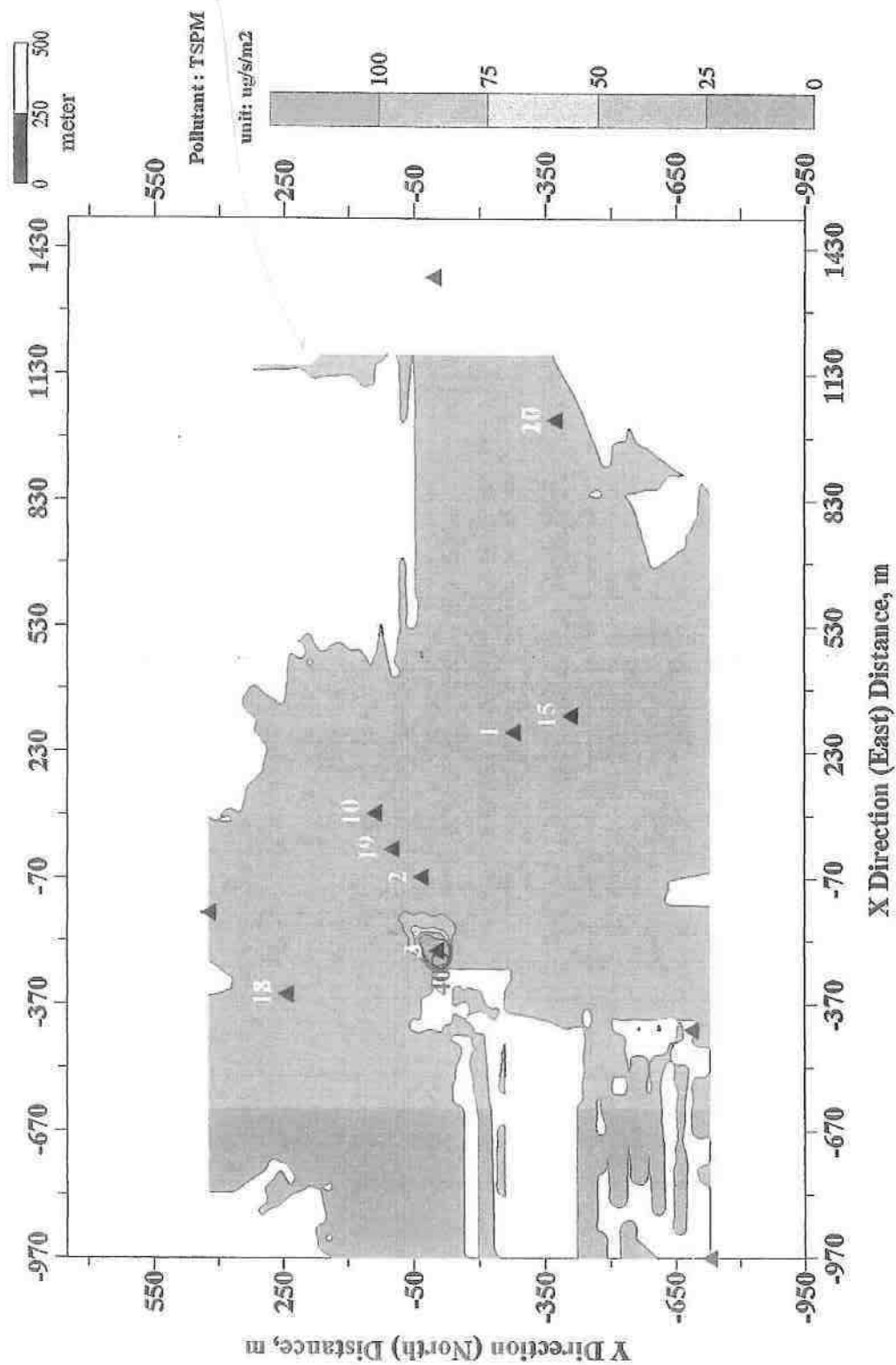


Fig. 5.39 Isopleths showing FDM predicted deposition (only one crusher in operation)

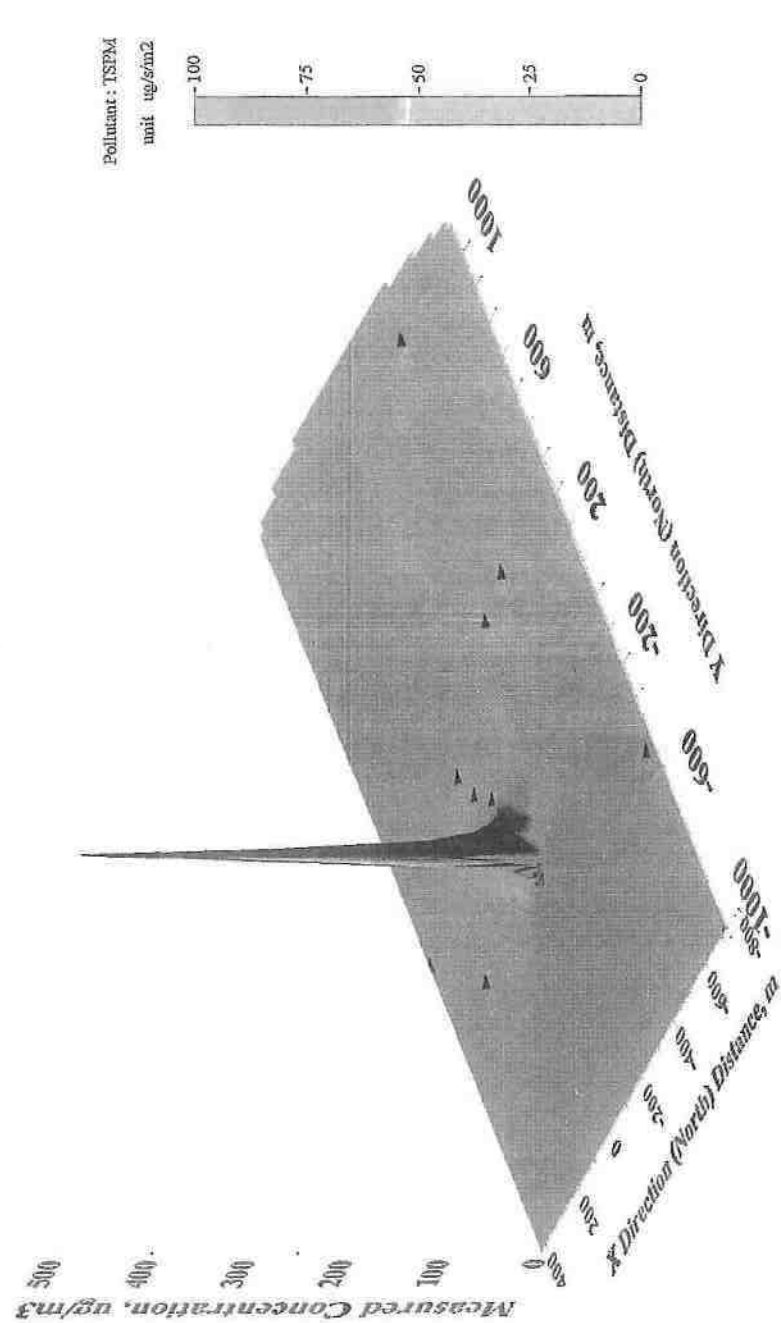


Fig. 5.40 Surfer showing FDM Predicted deposition (only one crusher in operation)

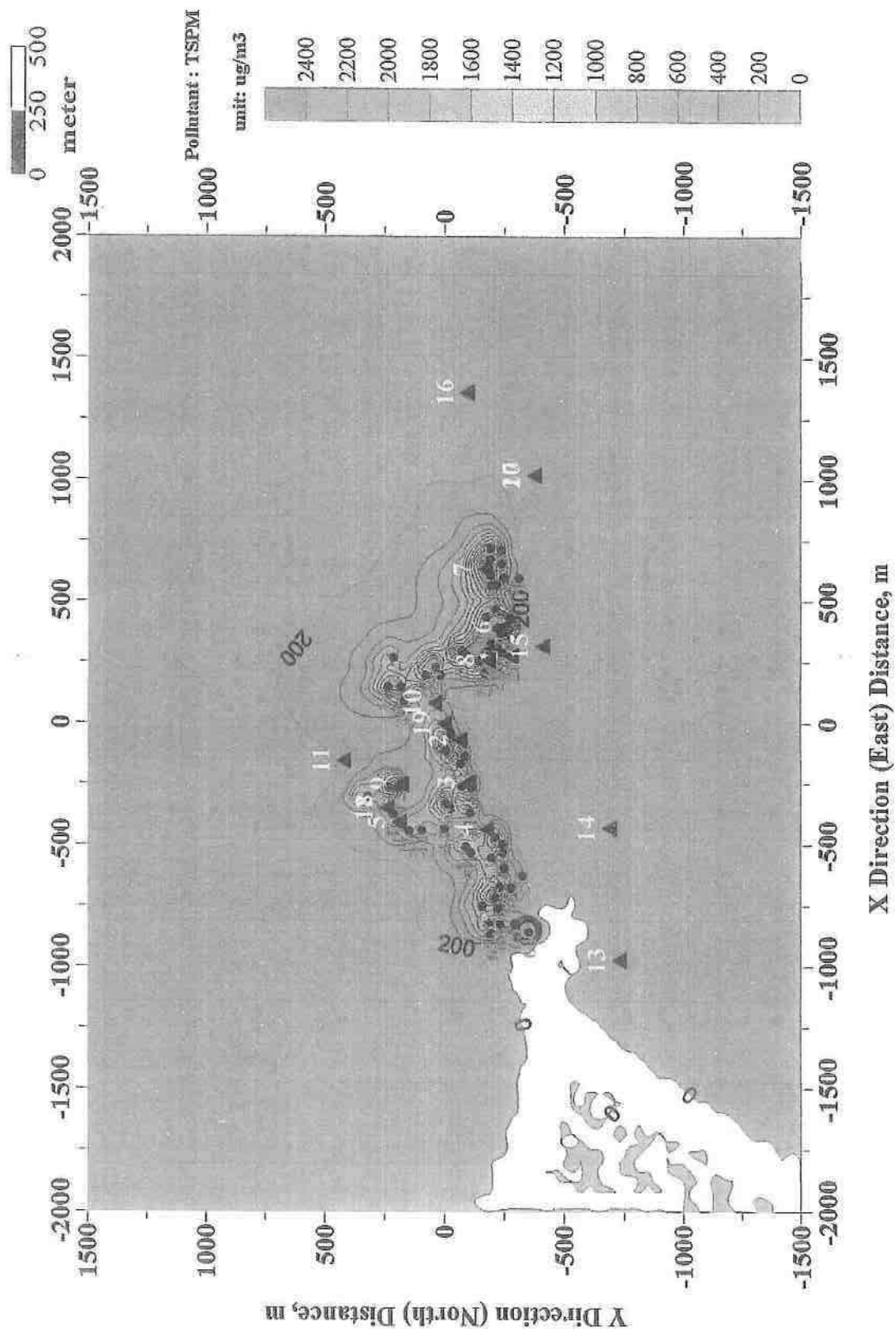


Fig. 5.41 Isopleths showing AERMOD predicted concentration (all the crushers in operation)

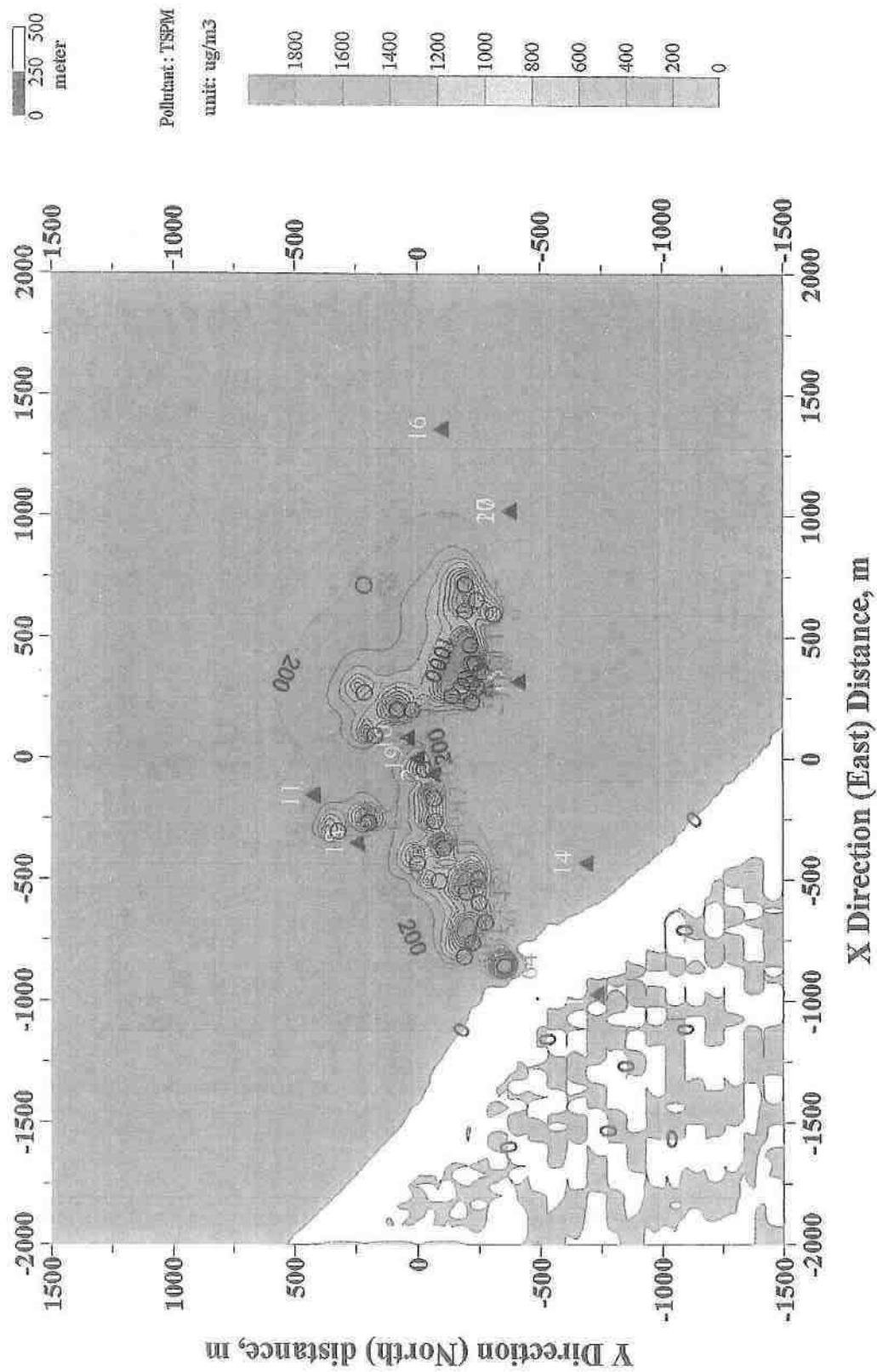


Fig. 5.43 Isopleths showing AERMOD predicted concentration (half of the crushers in operation)

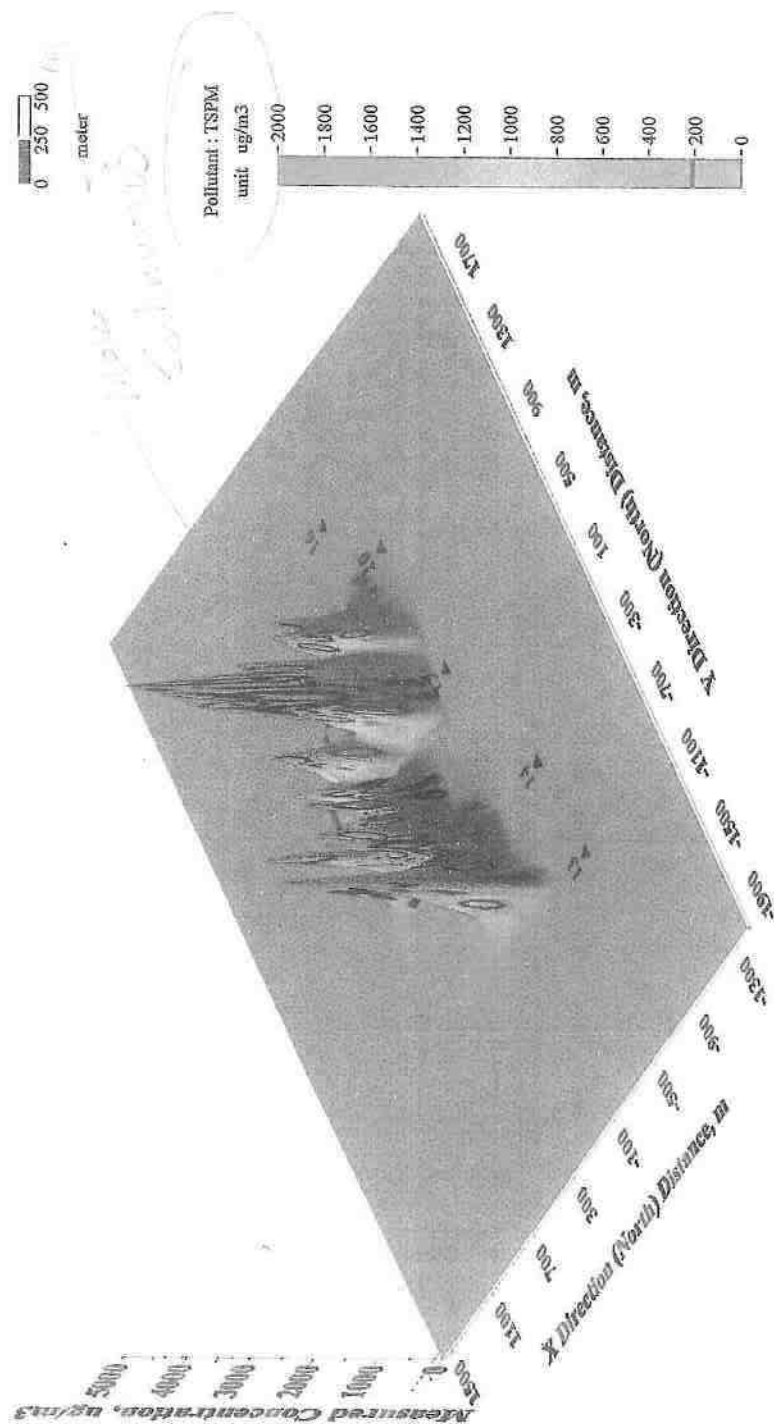


Fig. 5.44 Surfer showing AERMOD Predicted concentration (half of the crushers in operation)

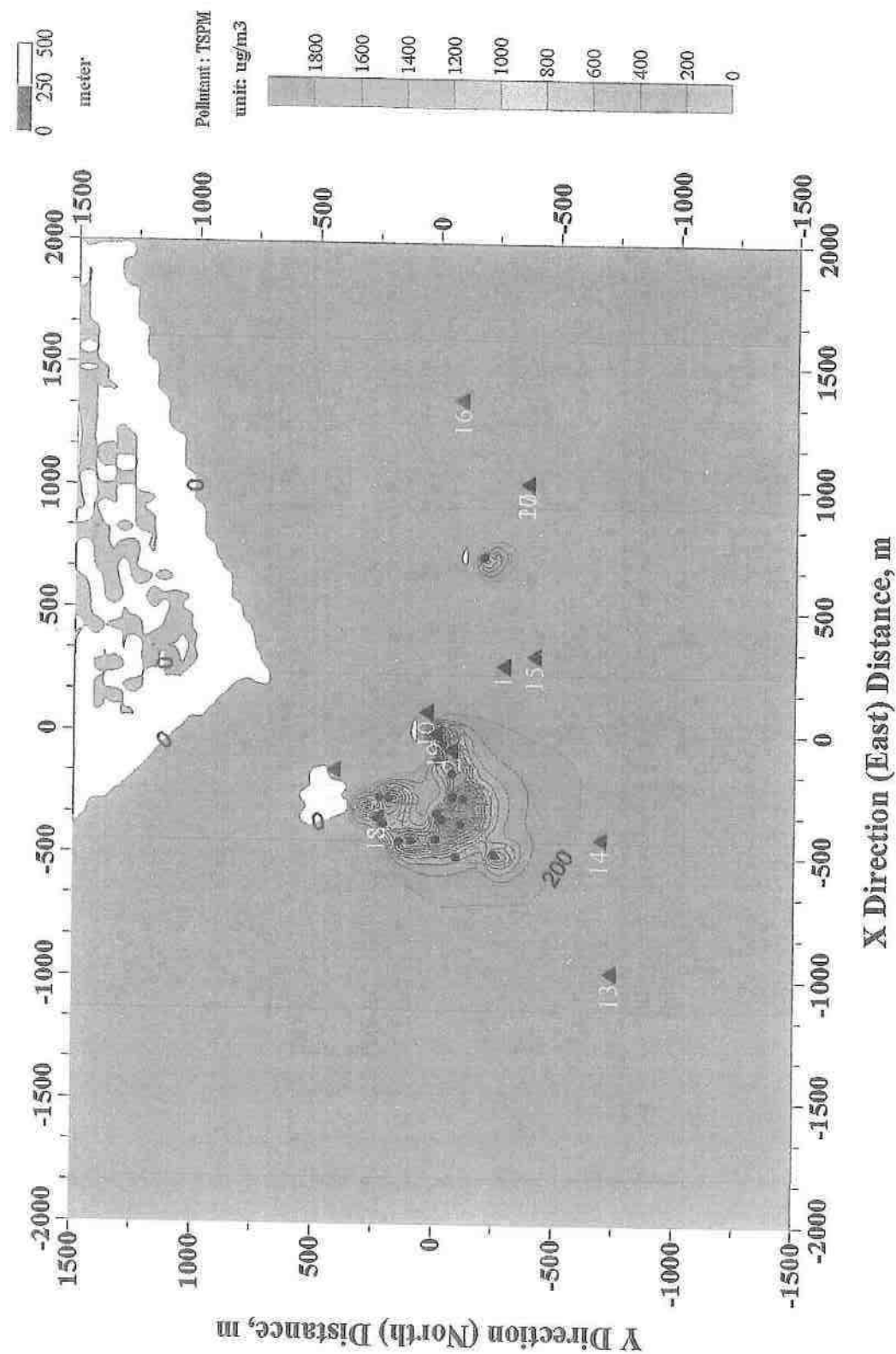


Fig. 5.45 Isopleths showing AERMOD predicted concentration (1/4th of the crushers in operation)

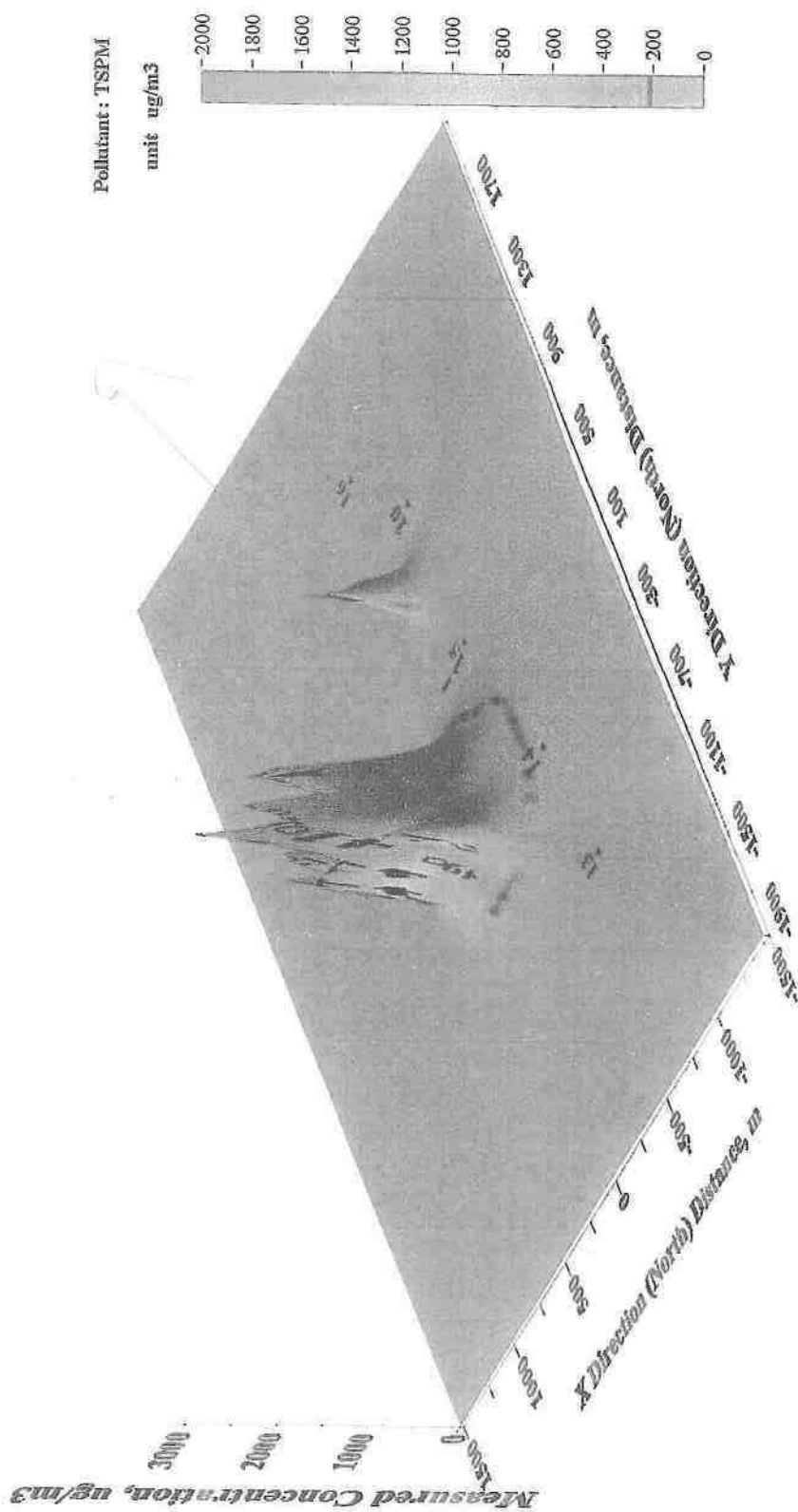


Fig. 5.46 Surfer showing AERMOD Predicted concentration (1/4th of the crushers in operation)

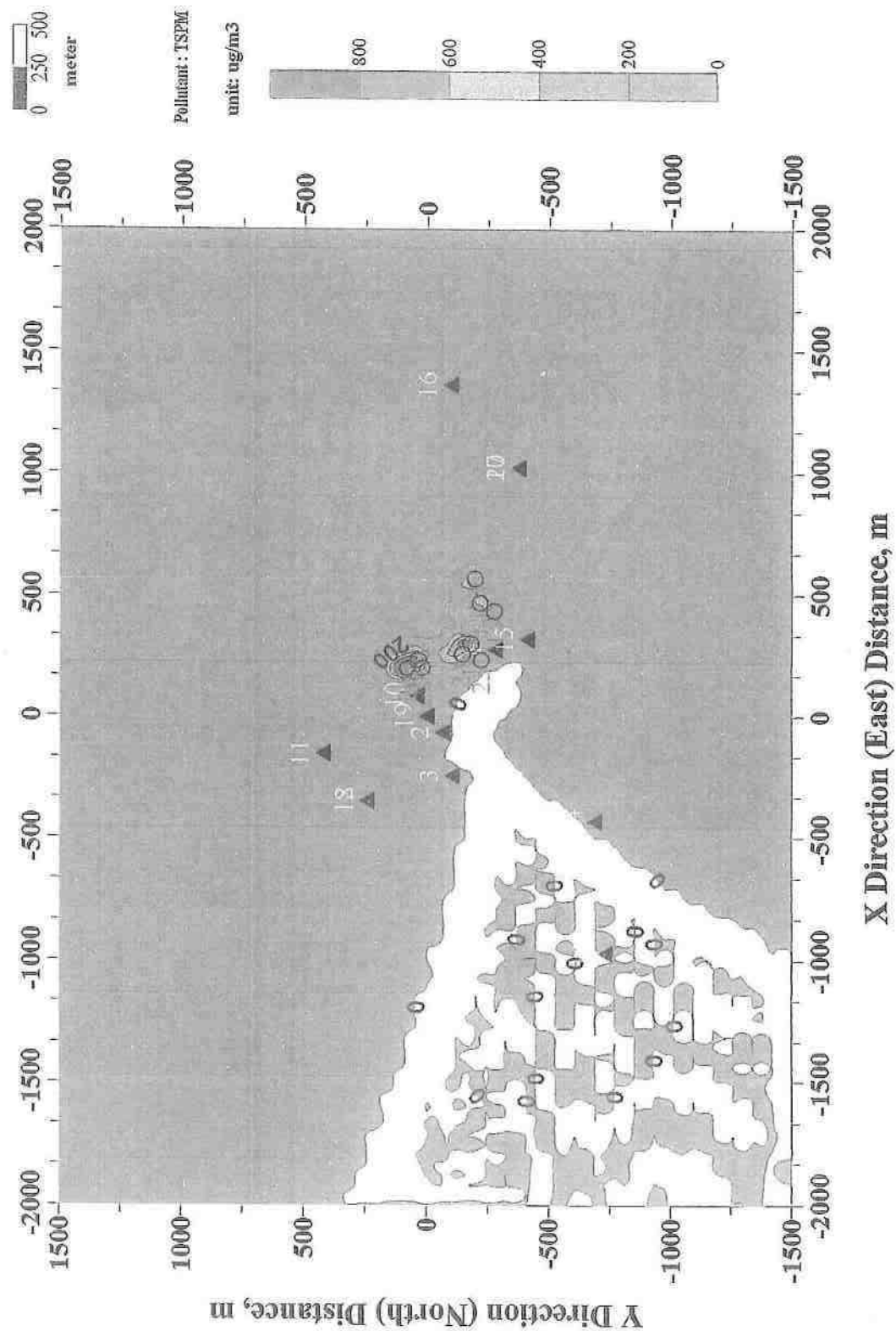


Fig. 5.47 Isopleths showing AERMOD predicted concentration (1/8th of the crushers in operation)

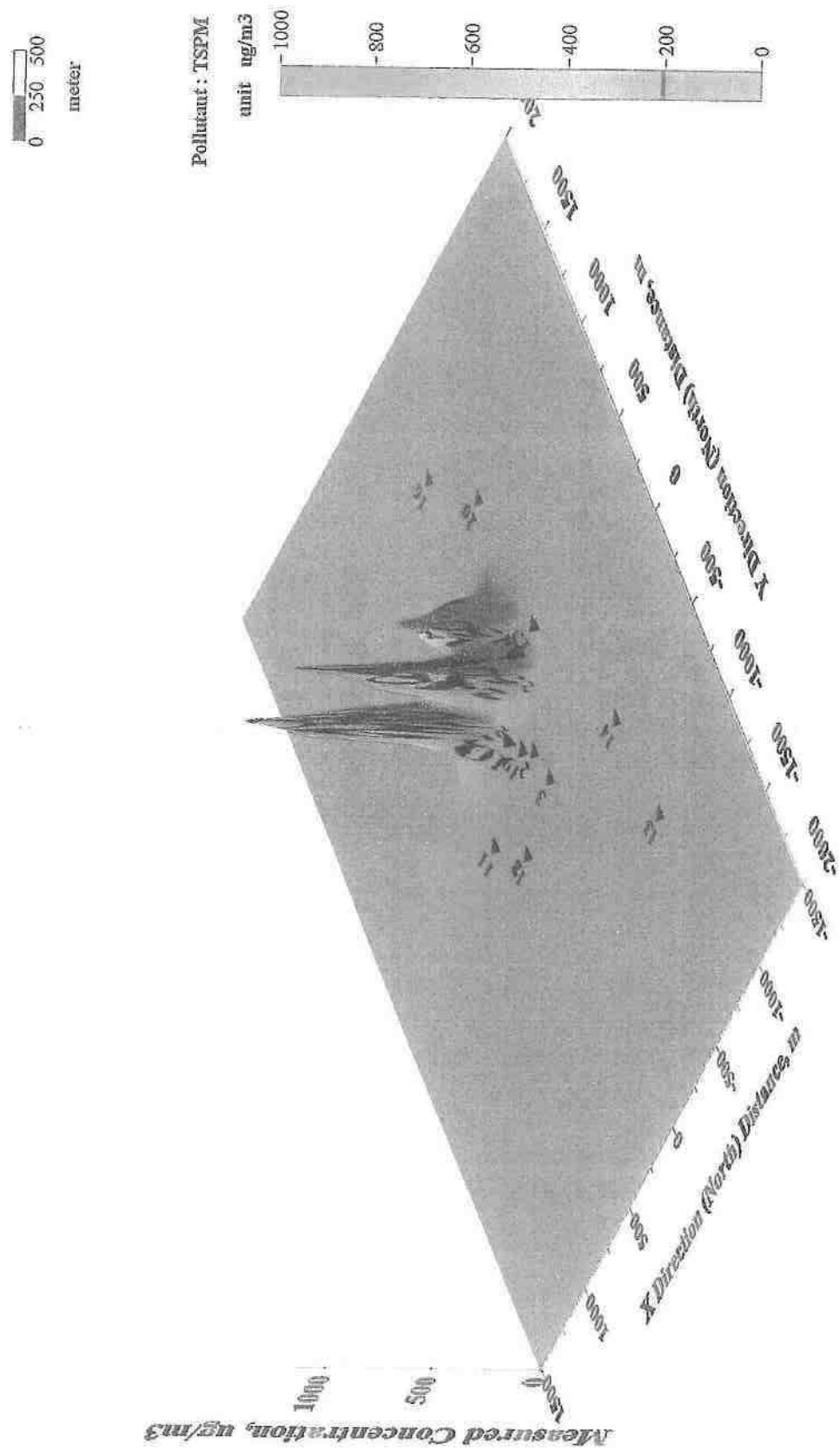


Fig. 5.48 Surfer showing AERMOD Predicted concentration (1/8th of the crushers in operation)

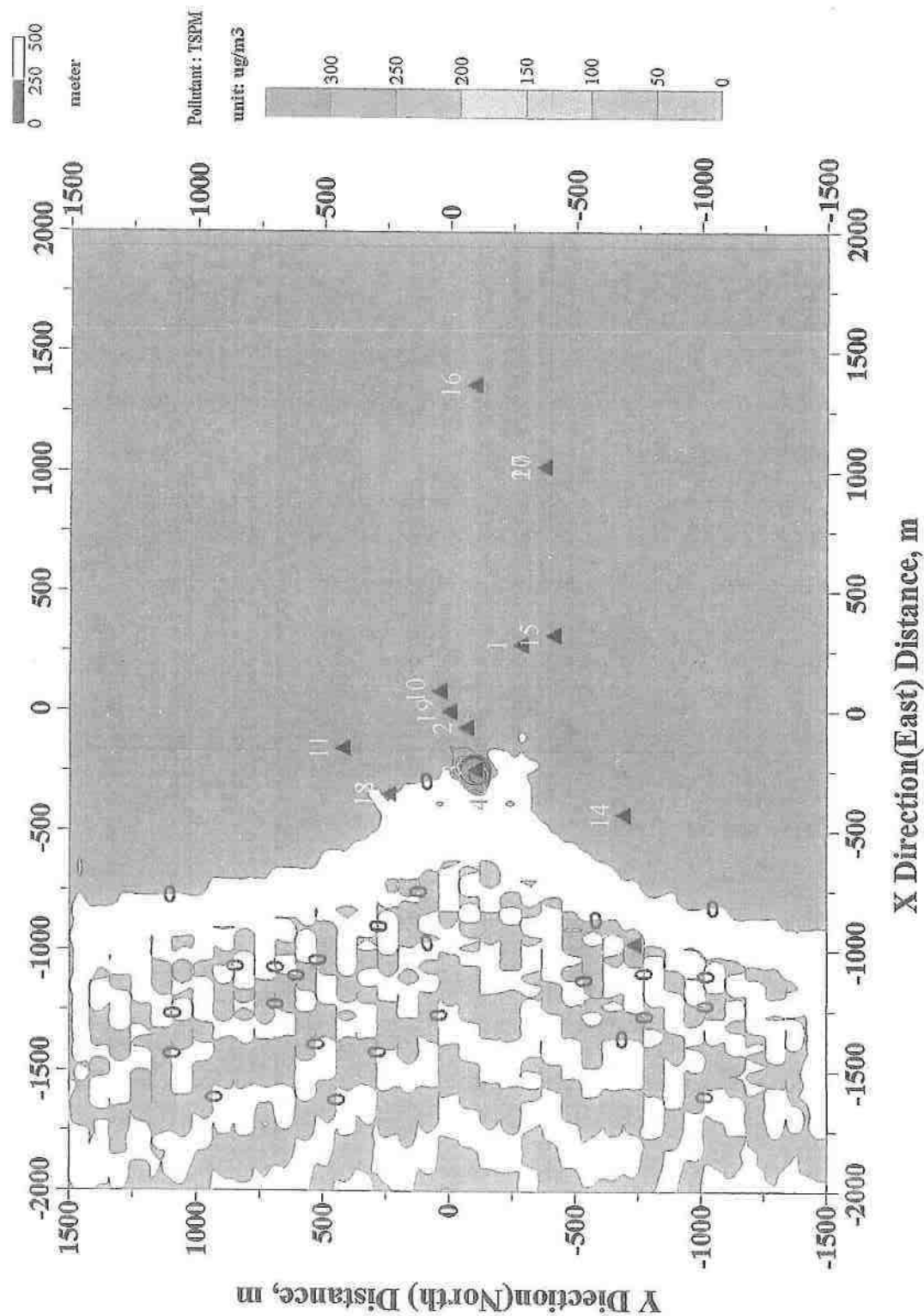


Fig. 5.49 Isopleths showing AERMOD predicted concentration (only one crusher in operation)

0 250 500
meter

Pollutant : TSPM
unit ug/m3

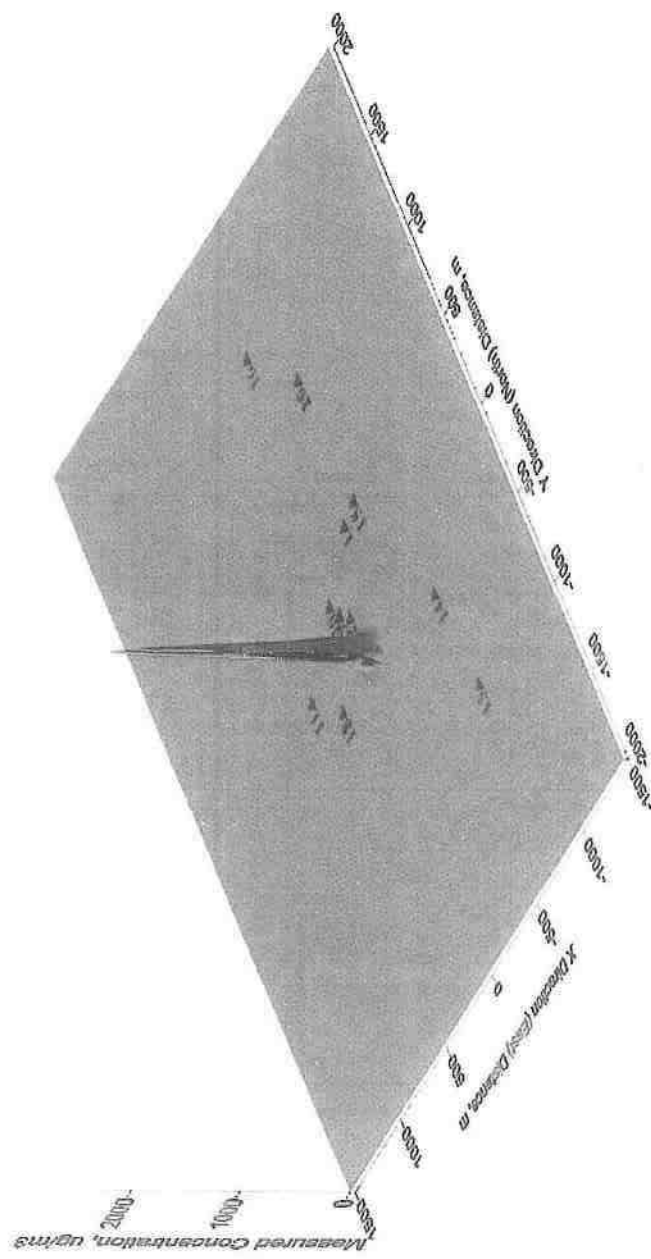
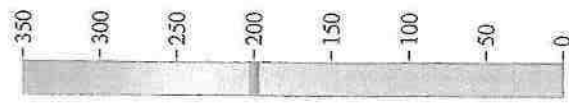


Fig. 5.50 Surfer showing AERMOD Predicted concentration (only one crusher in operation)

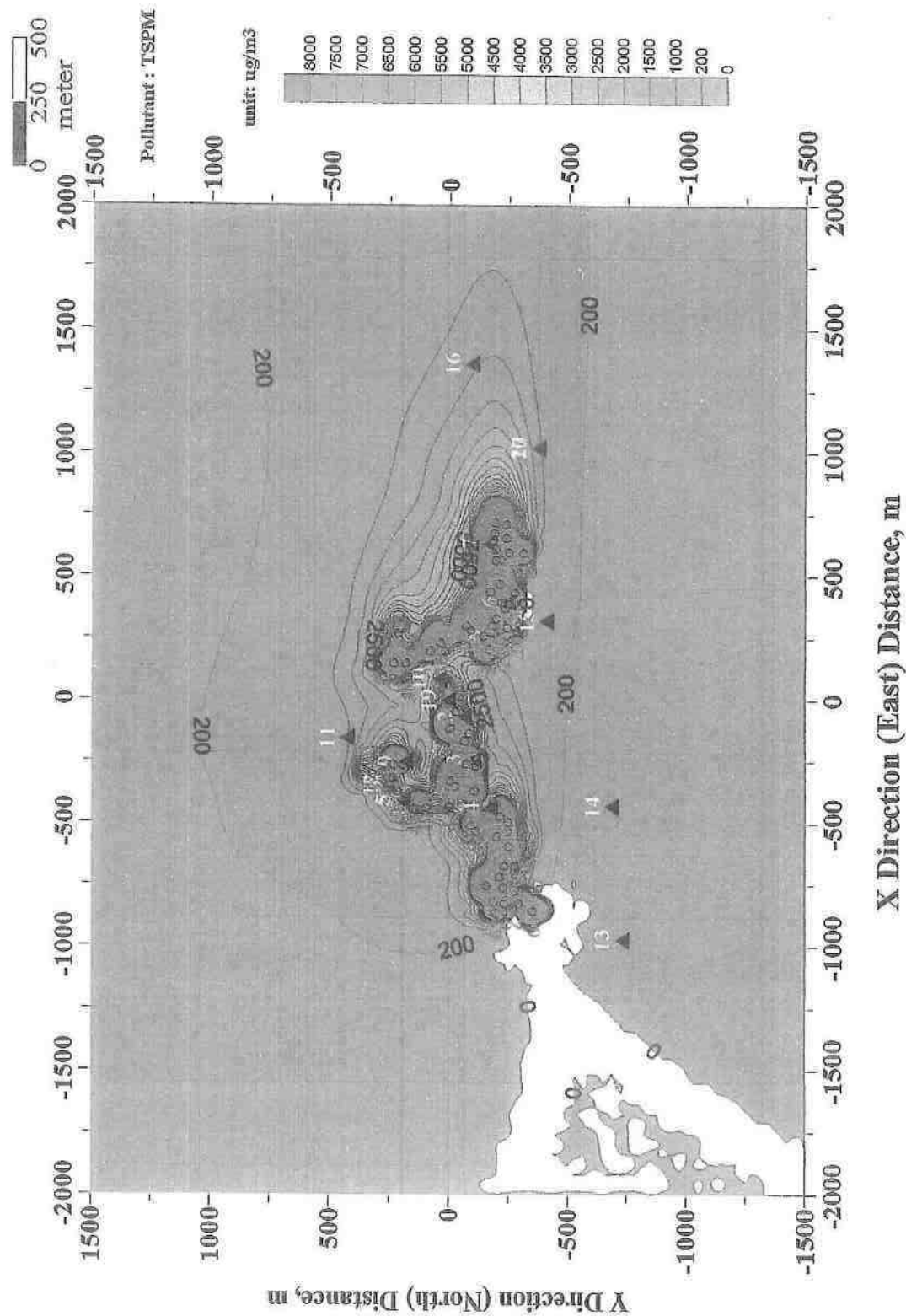


Fig. 5.51 Isopleths showing AERMOD predicted deposition (all the crushers in operation)

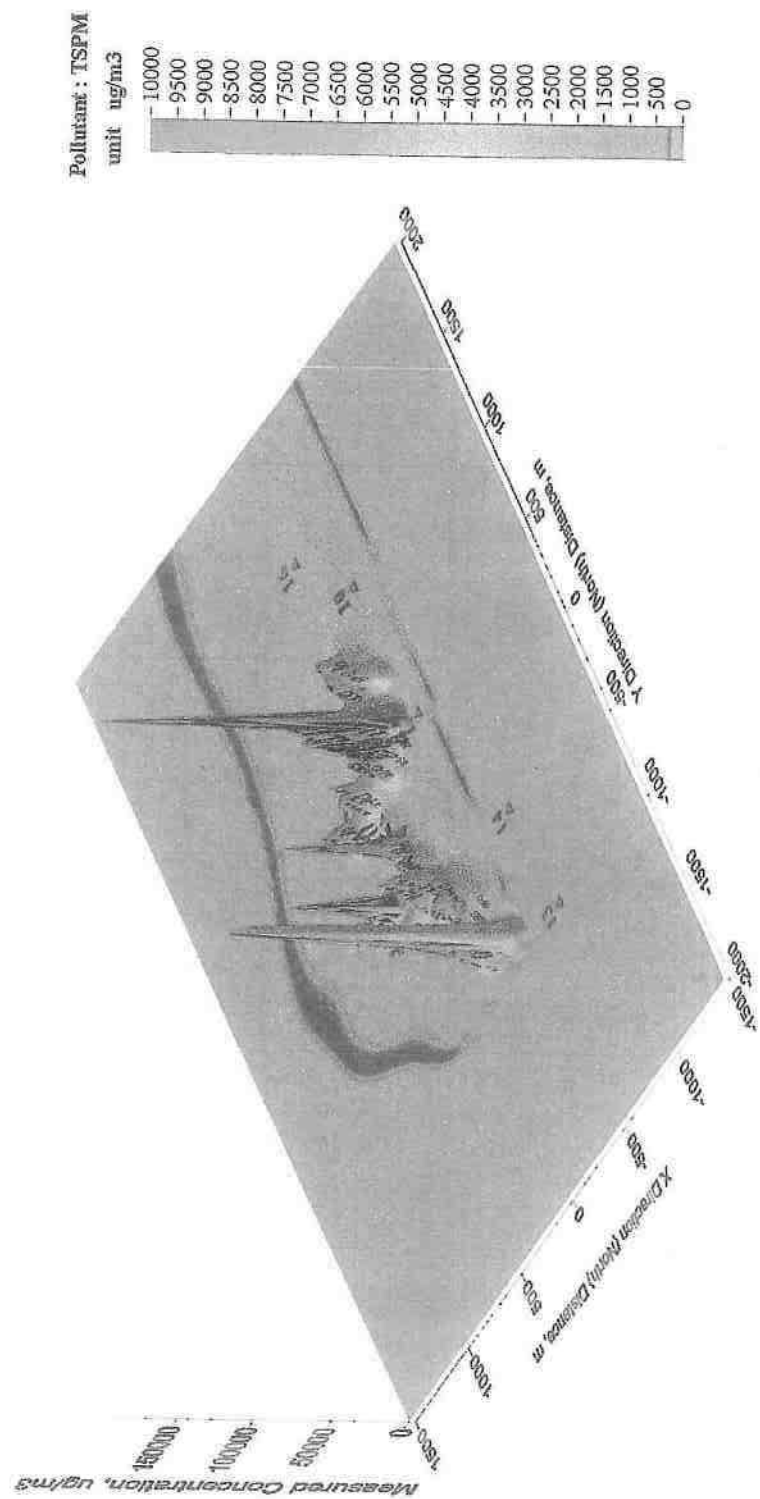


Fig. 5.52 Surfer showing AERMOD Predicted deposition (all the crushers in operation)

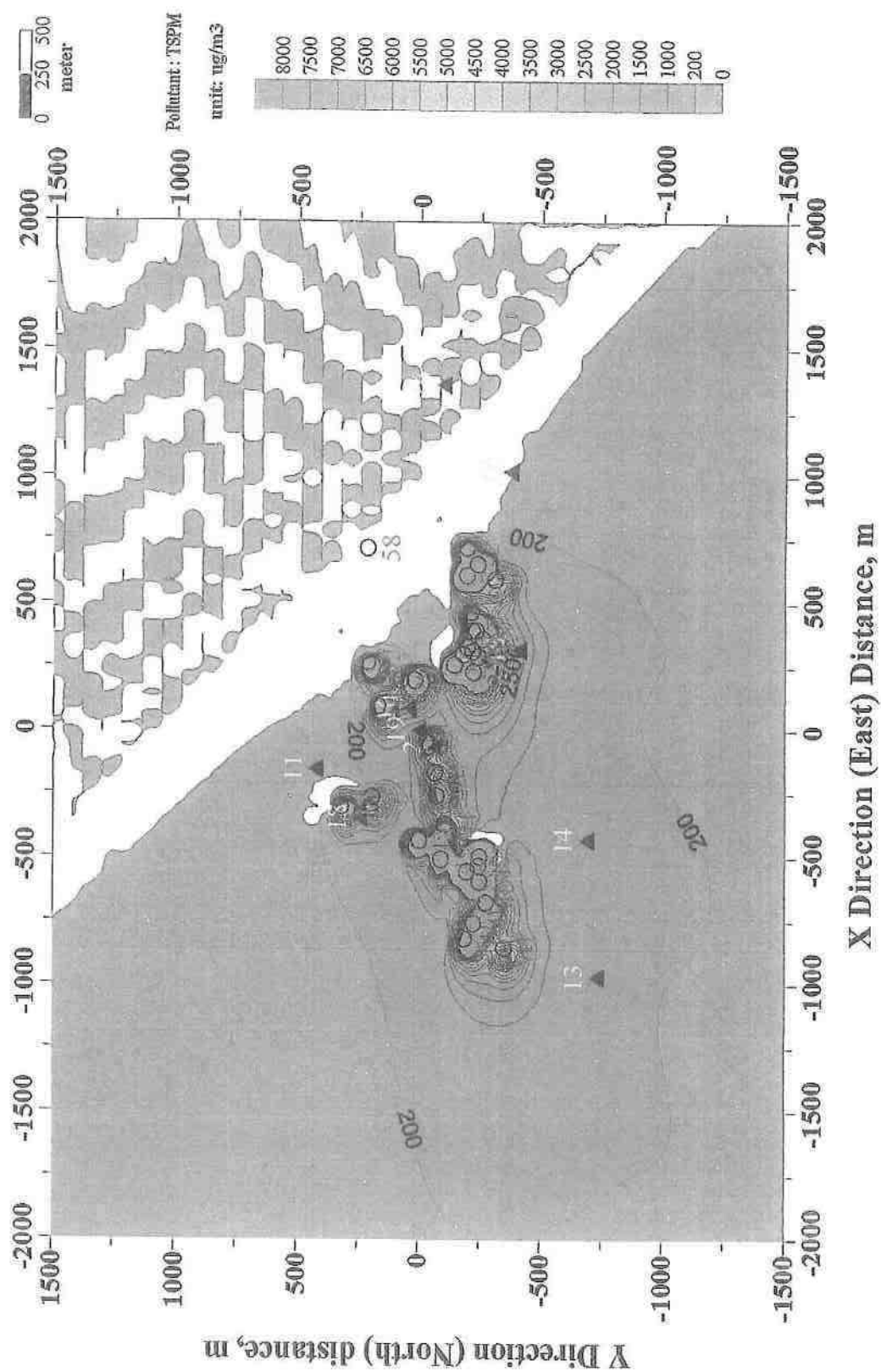


Fig. 5.53 Isopleths showing AERMOD predicted deposition (half of the crushers in operation)

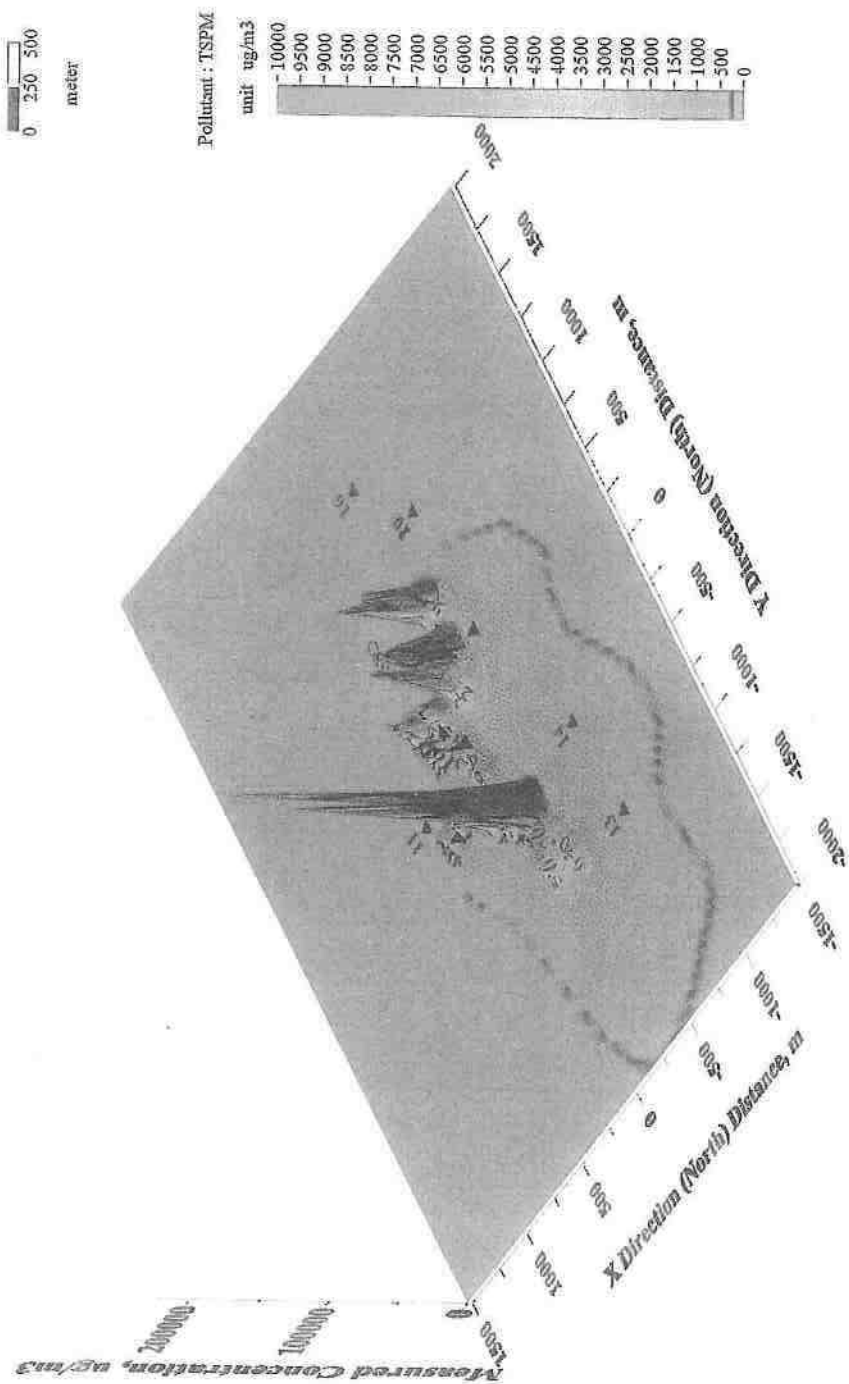


Fig. 5.54 Surfer showing AERMOD Predicted deposition (half of the crushers in operation)

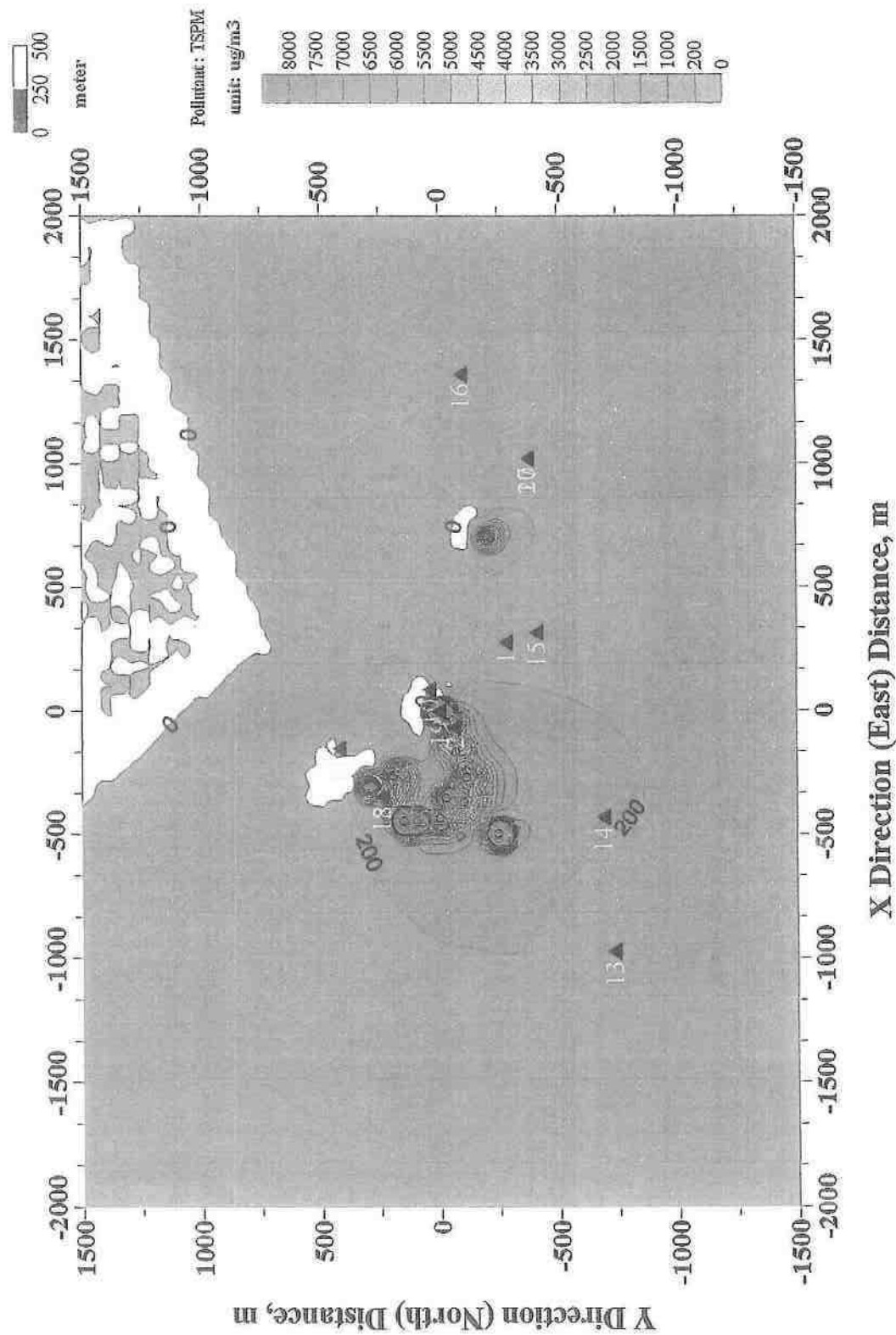


Fig. 5.55 Isopleths showing AERMOD predicted deposition (1/4th of the crushers in operation)

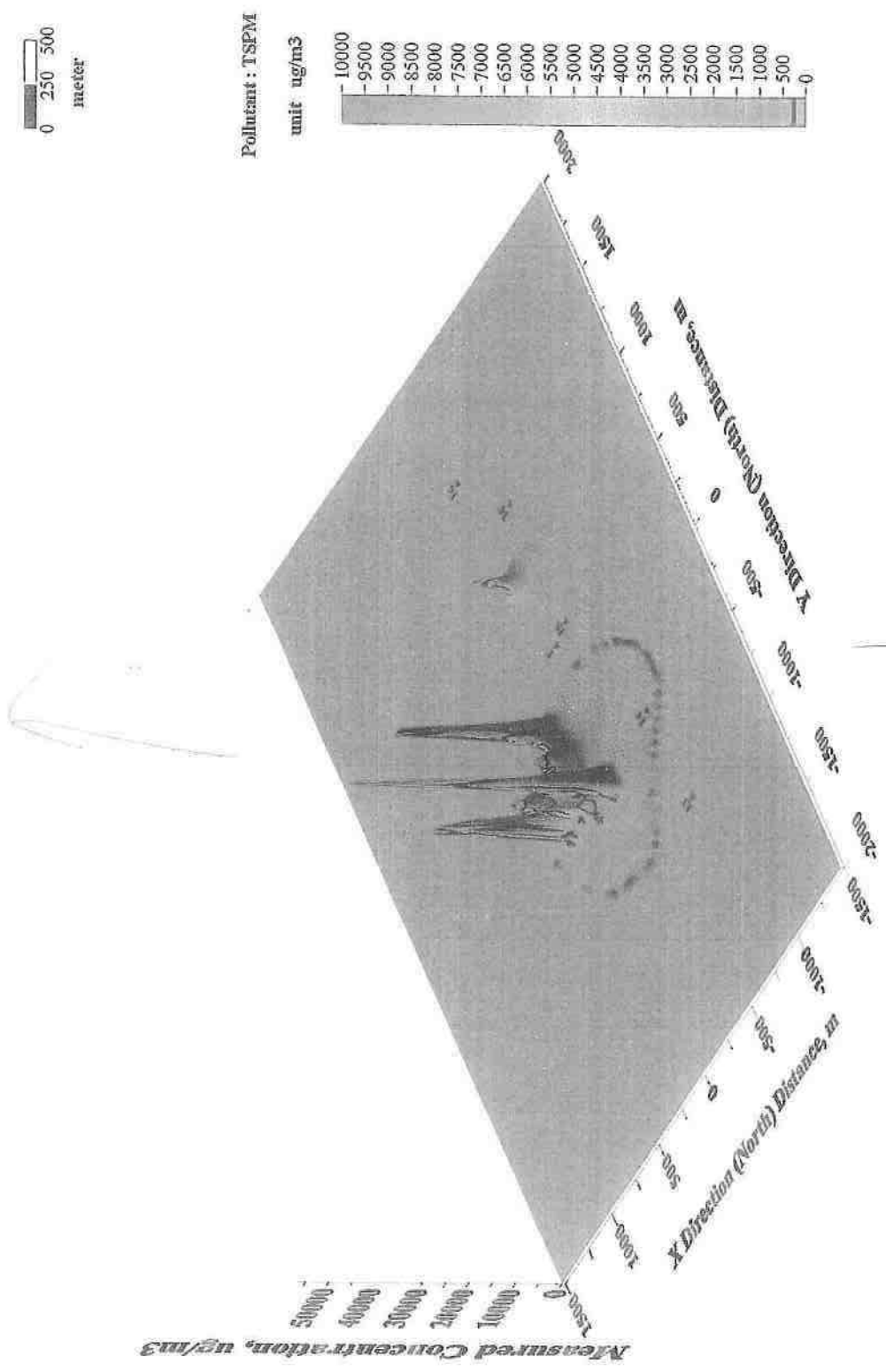


Fig. 5.56 Surfer showing AERMOD Predicted deposition (1/4th of the crushers in operation)

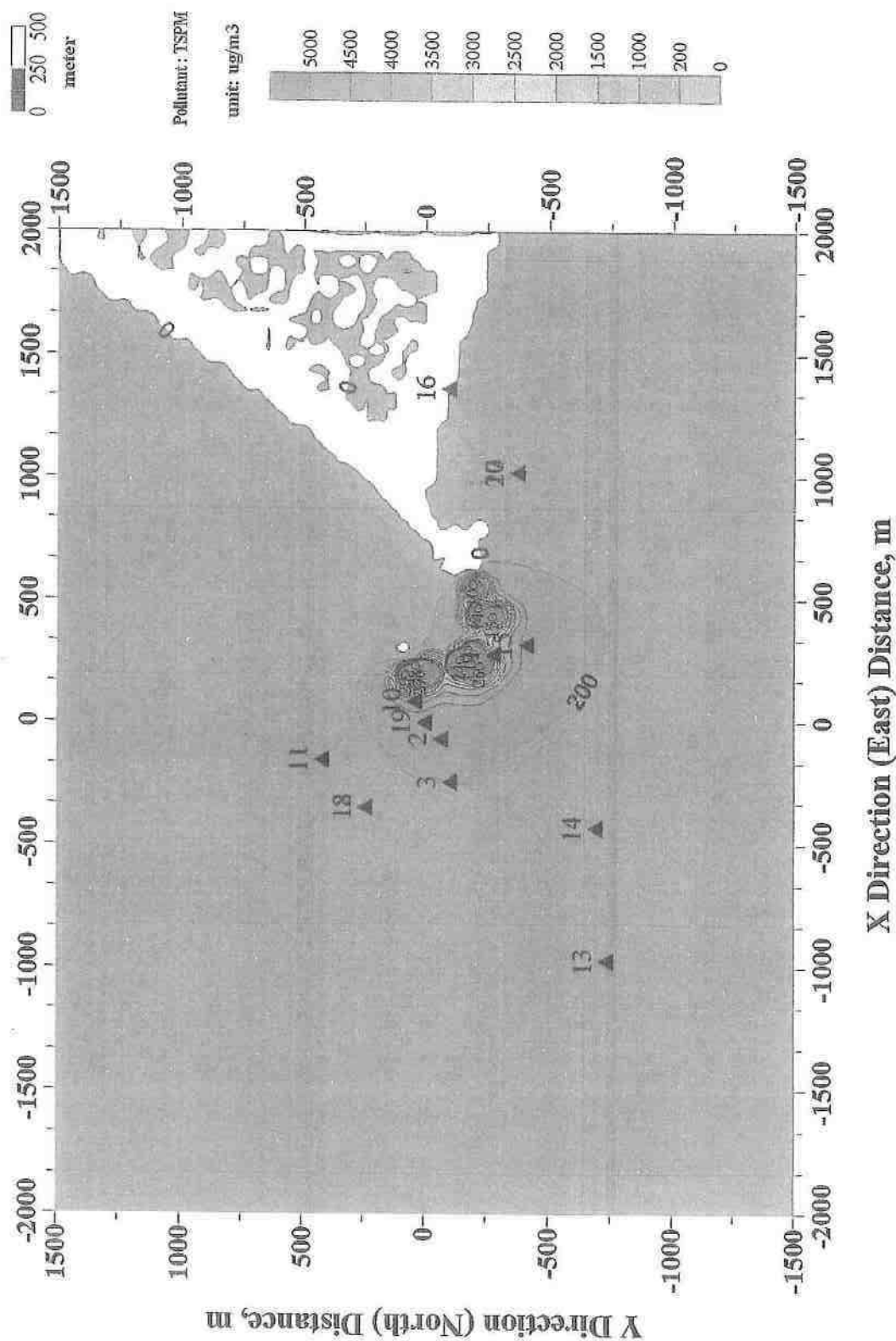


Fig. 5.57 Isopleths showing AERMOD predicted deposition (1/8th of the crushers in operation)

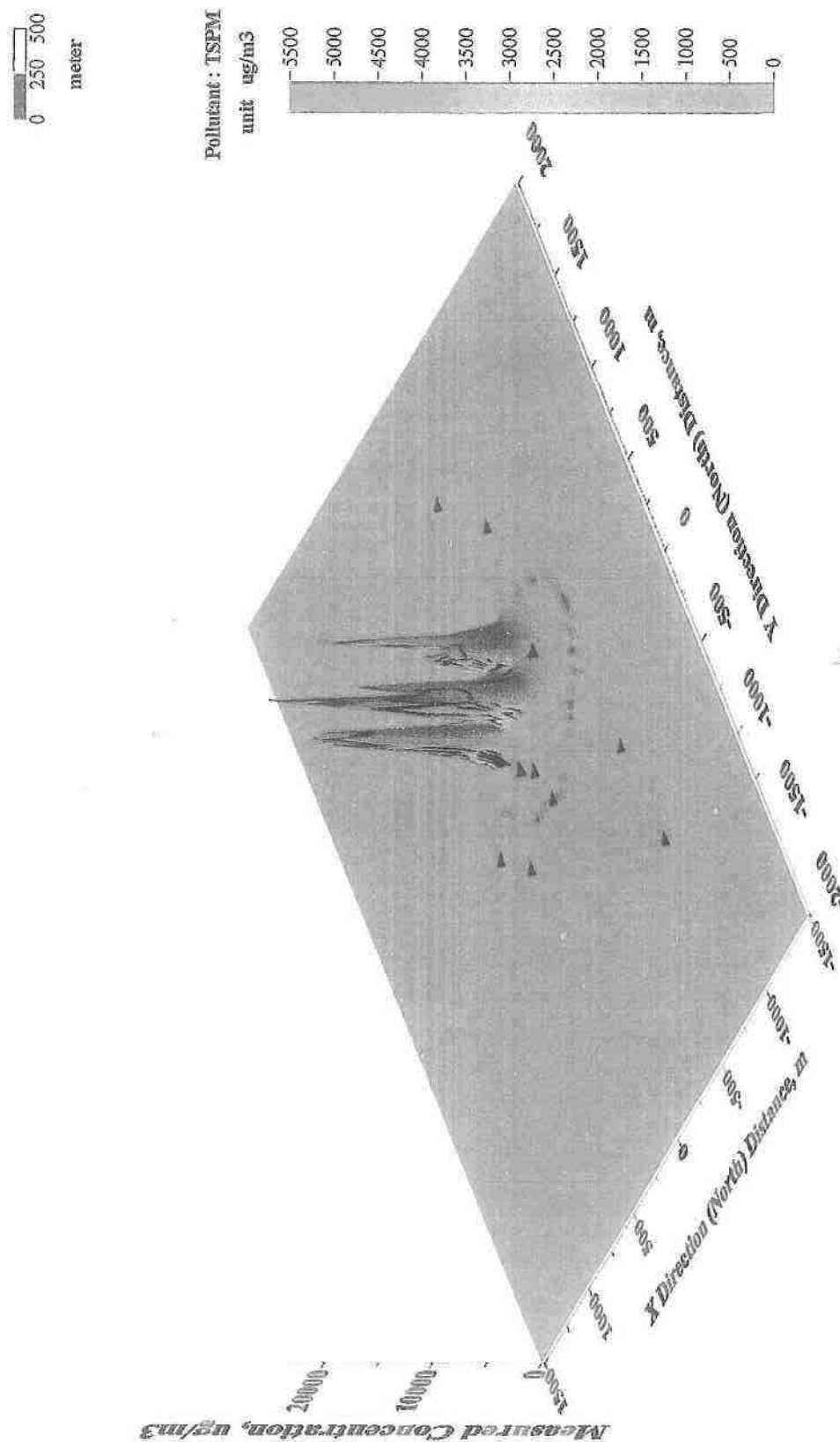


Fig. 5.58 Surfer showing AERMOD Predicted deposition (1/8th of the crushers in operation)

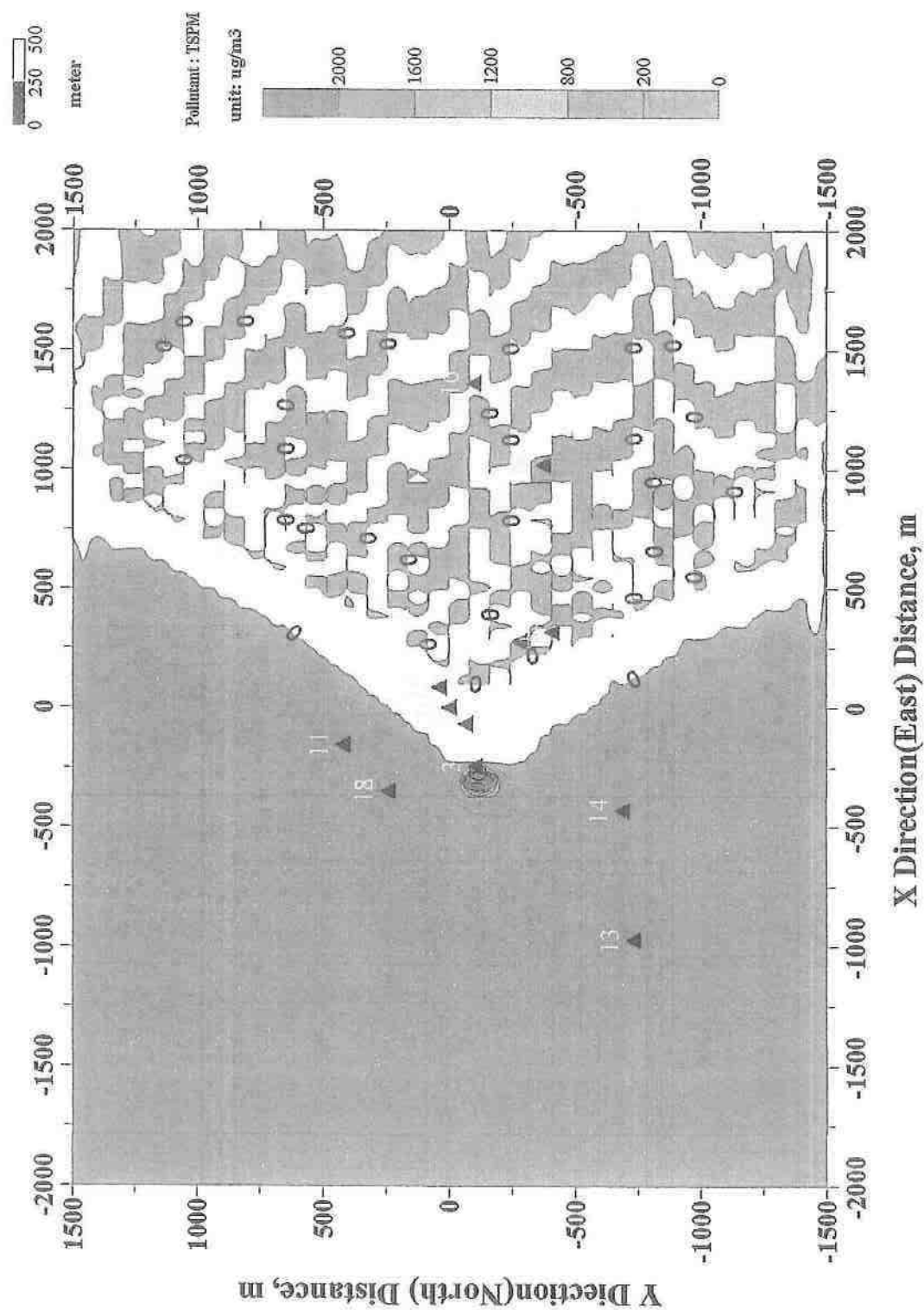


Fig. 5.59 Isopleths showing AERMOD predicted deposition (only one crusher in operation)

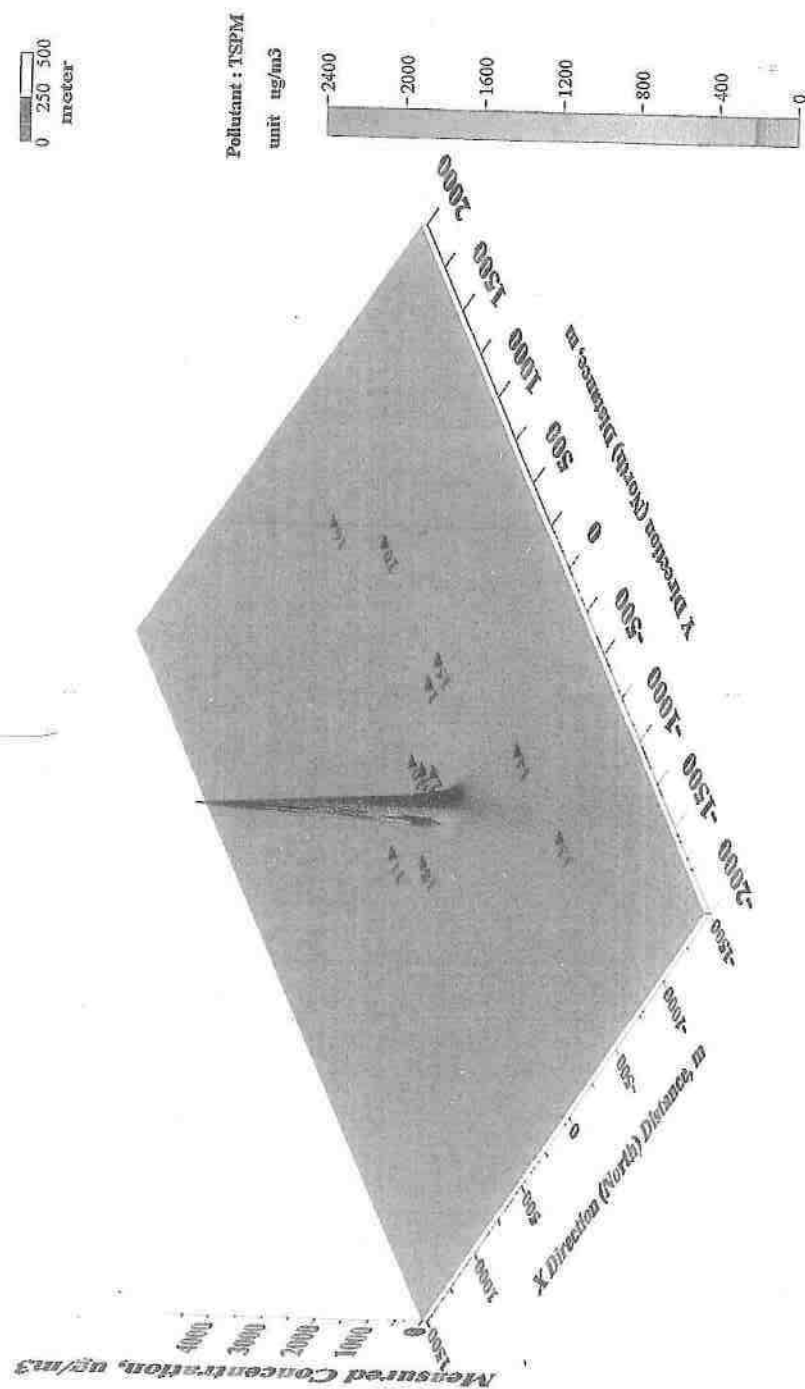


Fig. 5.60 Surfer showing AERMOD Predicted deposition (only one crusher in operation)

Table 5.18 Safe distance for single crusher and cluster of crushers based on measured concentration

No of crushers	Maximum			Minimum			North		East		South		West		Average
	Dir, degree	Dist, m	crusher no.	Dir, degree	Dist, m	crusher no.	Dist, m	crusher no	Dist, m	crusher no	Dist, m	crusher no	Dist, m	crusher no	
All	68	1350	24	230	211	64	589	19	1314	32	716	33	571	50	784
Half	70	1705	24	180	126	15	1274	29	486	10	263	25	800	27	776
1/4th	48	1242	29	270	126	64	547	30	1014	29	758	37	486	49	696
1/8th	60	1095	27	220	25	52	505	39	771	44	463	41	286	14	524
one	70	771	40	300	116	40	158	40	714	40	616	40	771	40	379

Table 5.19 Safe distance for single crusher and cluster of crushers based on FDM predicted concentration

No of crushers	Maximum			Minimum			North		East		South		West		Average
	Dir, degree	Dist, m	crusher no	Dir, degree	Dist, m	crusher no	Dist, m	crusher no	Dist, m	crusher no	Dist, m	crusher no	Dist, m	crusher no	
All	46	2650	23	235	53	64	1211	72	2050	23	1474	20	575	50	1335
Half	48	1650	27	220	26	27	1447	37	1500	27	1500	74	1175	29	1216
1/4th	105	1138	44	195	74	52	907	45	1207	44	333	43	724	46	731
1/8th	330	1109	19	210	50	25	388	29	606	19	288	27	274	28	452
one	350	263	40	190	13	40	97	40	151	40	72	40	69	40	111

Table 5.20 Safe distance for single crusher and cluster of crushers based on ISCST3 predicted concentration

No of crushers	Maximum		Minimum		North		East		South		West		Average
	Dir, degree	Dist, m	crusher no	Dir, degree	Dist, m	crusher no	Dir, degree	Dist, m	crusher no	Dist, m	crusher no	Dist, m	
All	110	1056	30	225	43	64	500	833	72	261	39	315	501
Half	135	833	30	230	33	9	565	611	24	261	43	296	433
1/4th	85	537	38	190	26	52	435	333	44	109	36	111	260
1/8th	335	370	14	270	22	25	261	164	14	152	14	148	184
One	45	174	40	215	11	40	130	74	40	76	40	74	90

Table 5.21 Safe distances for single crusher and cluster of crushers based on AERMOD predicted concentration

No of crushers	Maximum		Minimum		North		East		South		West		Average
	Dir, degree	Dist, m	crusher no	Dir, degree	Dist, m	crusher no	Dir, degree	Dist, m	crusher no	Dist, m	crusher no	Dist, m	
All	65	1255	59	15	35	59	217	1481	35	587	30	278	679
Half	58	1395	65	45	47	62	283	1389	27	652	30	278	582
1/4th	165	481	41	45	14	47	261	500	52	478	41	185	262
1/8th	325	296	15	175	27	25	65	130	19	109	28	74	116
one	50	95	40	245	32	40	33	65	40	54	40	148	59



5.10.1 Safe distance when all the crushers in operation

Safe distance for measured concentration varied from 211 to 1350 m with a mean of 784 m. Safe distance for predicted concentration of AERMOD varied from 59 to 1255 m with a mean of 679 m. The safe distance based on predicted concentration of ISCST3 and FDM varied from 45 to 1056 m and 55 to 2650 m with a mean of 501 m and 1335 m respectively.

5.10.2 Safe distance when half of the crushers in operation

Safe distance for measured concentration varied from 126 to 1750 m with a mean of 776 m. Safe distance for predicted concentration of AERMOD varied from 47 to 1395 m with a mean of 582 m. The safe distance for predicted concentration of FDM and ISCST3 varied from 1650 to 26 m and 35 to 833 m with a mean of 1216 m and 433 m respectively.

5.10.3 Safe distance when 1/4th of the crushers in operation

Safe distance for measured concentration varied from 126 to 1242 m with a mean of 696 m. Safe distance for predicted concentration of AERMOD varied from 15 to 481 m with a mean of 262 m. The safe distance for predicted concentration of FDM and ISCST3 varied from 74 to 1138 m and 38 to 537 m with a mean of 731 m and 260 m respectively.

5.10.4 Safe distance when 1/8th of the crushers in operation

Safe distance for measured concentration varied from 25 to 1095 m with a mean of 524 m. Safe distance for predicted concentration of FDM varied from 50 to 1109 m with a mean of 184 m. The safe distance for predicted concentration of AERMOD and ISCST3 varied from 27 to 325 m and 22 to 335 m with a mean of 116 m and 501 m respectively.

5.10.5 Safe distance when only one crusher in operation.

Safe distance for measured concentration varied from 116 to 771 m with a mean of 379 m. Safe distance for predicted concentration of ISCST3 varied from 11 to 174 m with a mean of 90 m. The safe distance for predicted concentration of AERMOD and FDM varied from 32 to 95 m and 13 to 263 m with a mean of 59 m and 111 m respectively.

5.11 Prediction of impact with control measures

Prediction was also carried out for controlled emissions from stone crushers assuming the implementation of the suggested control measures given below which are essential for stone crushers at Trisoolam area to bring down the dust levels which are presently exceeding the limits and traveling to far away distances and causing nuisance to the surrounding residential areas.

check

Is it
order
by
Rank



1. NPC dust suppression system
2. Reducing drop heights
3. Spray nozzle for regular wetting of dust
4. Pavement of road surfaces inside stone crushers area
5. Collection of fine powder below ground level and complete covering
6. Covering of loaded trucks using tarpaulins while transportation
7. Arresting re-entrainment of settled dust from surfaces

It is estimated that the above control measures will bring down the emissions from stone crushers by 50%. Prediction carried out with control measures indicated that the safe distance for single and cluster of crushers for FDM, ISCT3 and AERMOD models can be reduced as indicated in the **Tables 5.22 - 24.**

5.12 Model performance evaluation

The evaluation of model performance is a matter of great interest, and it becomes particularly important when modeling is used as a decision making tool. There is a need for a comprehensive discussion on the evaluation of air quality models as well as on the development of general evaluation methods, that can easily be implemented. Studies in this direction have been carried out by many investigators; however, standard evaluation procedures as well as performance standards, still do not exist. However, comparison between model predicted values and the monitored field data provides enough confidence in prediction exercise.)

5.12.1 Air quality monitoring

(The ambient air quality data depends upon the emission scenario, meteorological conditions and the background concentrations of pollutants. The study on ambient air quality status is an essential and primary requirement for assessing model prediction accuracy. ||

Representative selection of sampling location is primarily guided by the source location, topography and micro-meteorology of the region. An ambient air quality monitoring network covering 17 sampling locations was designed using the following criteria: persistence of wind direction and speed, representation of background concentration, location of and distribution of stone crushers at Trisoolam area.) The measurement was done continuously for the above period at a distance of 3, 5, 10, 15, 30, 50, 100, 125, 150, 200, 250, 300, 400, 500, 600m. During the same period meteorological data recording was also



Table 5.22 Safe distance for single crusher and cluster of crushers after control measures based on FDM predicted concentration

No of crushers	Maximum			Minimum			North		East		South		West		Average
	Dir, degree	Dist, m	crusher no	Dir, degree	Dist, m	crusher no	Dist, m	crusher no	Dist, m	crusher no	Dist, m	crusher no	Dist, m	crusher no	
All	46	1325	23	235	27	64	606	72	1025	23	737	20	288	50	668
Half	48	825	27	220	13	27	724	37	750	27	750	74	588	29	608
1/4th	105	569	44	195	37	52	454	45	604	44	167	43	362	46	366
1/8th	330	555	19	210	25	25	194	29	303	19	144	27	137	28	226
one	350	132	40	190	10	40	100	40	76	40	36	40	35	40	56

Table 5.23 Safe distance for single crusher and cluster of crushers after control measures based on ISCST3 predicted concentration

No of crushers	Maximum			Minimum			North		East		South		west		Average
	Dir, degree	Dist, m	crusher no	Dir, degree	Dist, m	crusher no	Dist, m	crusher no	Dist, m	crusher no	Dist, m	crusher no	Dist, m	crusher no	
All	110	528	30	225	43	64	250	16	417	72	131	39	158	50	251
Half	135	417	30	230	33	9	283	66	306	24	131	43	148	49	217
1/4th	85	269	38	190	26	52	218	39	167	44	167	36	56	14	130
1/8th	335	185	14	270	22	25	131	19	82	14	76	14	74	15	92
One	45	87	40	215	11	40	65	40	37	40	38	40	37	40	45

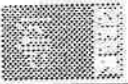


Table 5.24 Safe distance for single crusher and cluster of crushers after control measures based on AERMOD predicted concentration

No of crushers	Maximum			Minimum			North			East			South			west			Average		
	Dir, degree	Dist, m	crusher no	Dir, degree	Dist, m	crusher no	Dist, m	crusher no	Dist, m	crusher no	Dist, m	crusher no	Dist, m	crusher no	Dist, m	crusher no	Dist, m	crusher no	Dist, m	crusher no	Dist, m
All	65	628	59	15	18	59	109	24	741	35	294	30	139	29	340						
Half	58	698	65	45	24	62	142	34	695	27	326	30	139	43	291						
1/4th	165	241	41	45	7	47	131	49	250	52	239	41	93	49	131						
1/8th	325	148	15	175	14	25	33	19	65	19	55	28	37	28	58						
one	50	48	40	245	16	40	17	40	33	40	27	40	74	40	30						



done simultaneously. A total of 17 monitoring stations (source:10, ambient air:7) were located in the study area. The locations of the stations are shown in Fig. 3.1 and Table 3.1.

5.12.2 Statistical analysis

Evaluation of performance of an air quality model generally focuses on assessing the accuracy of the model prediction relative to observed concentrations, and a model needs to be validated for correct interpretation. The performance of the models used in this study is tested by a comprehensive package of model accuracy assessment methods suggested in the literature. The package includes several different criteria for evaluating the performance of a model, all of which can be calculated from the observed concentration (O_i) and the predicted values (P_i). Literature review suggested that small differences between O_i and P_i concentration will result in negative values of correlation coefficient (γ) which can be misleading while interpreting model performance. It is better to use index of agreement (d) and root mean square error (RMSE) for model performance evaluation. The index of agreement is used along with mean square error (MSE) and its components, viz., systematic and unsystematic errors (MSEs and MSEu). The index (d) determines the degree to which magnitudes and signs of the observed value about O (mean) are related to the predicted deviation about P, and allows for sensitivity toward difference in O and P as well as proportionality changes.

5.12.3 Model performance assessment

Comparison between predicted and observed values was done by qualitative data analysis using statistical methods and quantitative data analysis techniques to evaluate model performance. To assess the performance of two models employed in the study, the summary measures, difference measures; regression analysis and index of agreement measures were used for assessing their accuracy along with their capability to produce prediction within a factor of 2.

Air quality data were averaged over 24 hour period for all the sampling locations and were grouped with respect to upwind down directions and receptor distance from the stone crusher and then compared with air quality standards to assess the pollution potential. The percent of time, measured one hour average concentrations exceeded the standard at each receptor was analyzed with respect to source strength and meteorological condition prevailing at that time.



5.12.4 Qualitative data analysis

Evaluation of an air quality model was based on the accuracy of model predictions as compared to observed concentrations. The statistical package employs several criteria for evaluating the performance of a model, all of which can be calculated from the observed concentration (O_i) and the predicted values (P_i). The small differences between observed (O) and predicted (P) concentration will result in negative values of correlation coefficient (γ) which may be misleading while interpreting model performance and recommended the use of index of agreement (d) and root mean square error (RMSE) which indicate the accuracy and error involved in the prediction. For a good model the value of d should be close to '1' and RMSE should be close to '0'. In general, the various statistical parameters used for testing model performance are mean, standard deviation, regression analysis and difference measures (Table 5.25).

5.13 Model performance evaluation results

A comparison of the measured and predicted concentrations indicated that AERMOD and ISCST3 model underpredicted the concentrations while the FDM model overpredicted them. Important statistical parameters of the observed and predicted concentrations were used for the comparison. In addition quantitative data analysis technique was also used to evaluate models' accuracy in prediction.

5.13.1 Classification of data

In the statistical analysis, comparison between measured and predicted concentration were done for the models, FDM, ISCST3 and AERMOD for the following condition

1. All crushers in operation
2. Half of the crushers in operation
3. $1/4^{\text{th}}$ of the crushers in operation
4. $1/8^{\text{th}}$ of the crushers in operation
5. Only one crusher in operation

A statistical analysis was done with all the data combined and in addition, to the above condition. The various statistical parameters namely index of agreement, root mean square error, regression constant (a) and regression coefficient (b) along with observed and predicted mean were used for this purpose (Table 5.25).

Table 5.25

Statistical parameters used for model performance evaluation

I. Summary Measures

$$1. \bar{O} = \frac{\sum_{i=1}^n O_i}{N}$$

$$2. \bar{P} = \frac{\sum_{i=1}^n P_i}{N}$$

$$3. \sigma_o = \left[\frac{1}{N} \sum_{i=1}^n (O_i - \bar{O})^2 \right]^{1/2}$$

$$4. \sigma_p = \left[\frac{1}{N} \sum_{i=1}^n (P_i - \bar{P})^2 \right]^{1/2}$$

II. Linear Regression

$$5. b = \frac{\left[N \sum_{i=1}^n (O_i P_i) - \sum_{i=1}^n O_i \sum_{i=1}^n P_i \right]}{\left[N \sum_{i=1}^n O_i^2 - \sum_{i=1}^n (O_i)^2 \right]}$$

$$6. a = \bar{P} - b\bar{O}$$

$$7. \gamma = \left[\frac{N^{-1} \sum_{i=1}^n (O_i P_i) - \bar{O} \bar{P}}{\sigma_o \sigma_p} \right]$$



III. Difference Measures

$$8. \quad \text{MSEs} = \text{RMSEs}^2 = N^{-1} \sum_{i=1}^n [(a+bO_i) - O_i]^2$$

$$9. \quad \text{MSEu} = \text{RMSEu}^2 = N^{-1} \sum_{i=1}^n [P_i - (a+bO_i)]^2$$

$$10. \quad \text{Total MSE} = \text{Total RMSE}^2 = \text{MSEs} + \text{MSEu}$$

IV. Index of Agreement

$$11. \quad d = 1 - \frac{\sum_{i=1}^n (P_i - O_i)^2}{\sum_{i=1}^n (|P_i - \bar{O}| + |O_i - \bar{O}|)^2}, \quad 0 \leq d \leq 1$$



5.13.2 All the data combined

All the data combined and put together for statistical analysis indicated that, the models exhibited comparable accuracies, with AERMOD (70%) proving to be better than ISCST3 (47%) and FDM (44%). The accuracy was less for ISCST3 and FDM compared to AERMOD in this case due to more error ($1227 \mu\text{g}/\text{m}^3$ for ISCST3; $3224 \mu\text{g}/\text{m}^3$ for FDM) than AERMOD ($1114 \mu\text{g}/\text{m}^3$) as given in Table 5.26.

5.13.3 All Crushers running

From the observed and predicted mean concentrations, it is inferred that the model AERMOD predicted mean of $1094 \mu\text{g}/\text{m}^3$ is closer to the observed mean ($1285 \mu\text{g}/\text{m}^3$) than FDM ($4722 \mu\text{g}/\text{m}^3$) and ISCST3 ($661 \mu\text{g}/\text{m}^3$). Regression analysis indicated that the intercept a and slope b are nearer to 0 and 1 for the model AERMOD ($a = 776$, $b = 0.25$) than ISCST3 ($a = 551$, $b = 0.081$) and FDM ($a = 2638$, $b = 1.6$). The model AERMOD and model ISCST3 underpredicted the concentrations whereas FDM model overpredicted them. The difference measure 'd' indicated that the accuracy of the model was 53% for AERMOD compared to 45% for ISCST3 and 33% for FDM. The comparison of RMSE indicated that there was less error ($1519 \mu\text{g}/\text{m}^3$) for AERMOD results as compared to $1694 \mu\text{g}/\text{m}^3$ for ISCST3 and $5621 \mu\text{g}/\text{m}^3$ in FDM as given in Table 5.26.

5.13.4 Half of the crushers in operation

From the observed and predicted mean concentrations, it is inferred that the model AERMOD predicted mean of $813 \mu\text{g}/\text{m}^3$ is closer to the observed mean ($961 \mu\text{g}/\text{m}^3$) than FDM ($1359 \mu\text{g}/\text{m}^3$) and ISCST3 ($152 \mu\text{g}/\text{m}^3$). Regression analysis indicated that the intercept a and slope b are nearer to 0 and 1 for the model AERMOD ($a = 152$, $b = 0.7$) than FDM ($a = 504$, $b = 0.89$) and ISCST3 ($a = 97.45$, $b = 0.057$). The model ISCST3 underpredicted the concentration whereas AERMOD and FDM model overpredicted them. The difference measure 'd' indicated that the accuracy of the model was 85% for AERMOD, 81% for FDM, and 47% for ISCST3. The comparison of RMSE indicated that there was less error in AERMOD ($896 \mu\text{g}/\text{m}^3$) results as compared to $1237 \mu\text{g}/\text{m}^3$ for FDM and $1468 \mu\text{g}/\text{m}^3$ for ISCST3 as given in Table 5.26.

5.13.5 1/4th of the crushers in operation

The RMSE analysis indicated that AERMOD model had the least error of $1059 \mu\text{g}/\text{m}^3$ than ISCST3 ($1144 \mu\text{g}/\text{m}^3$) and FDM ($1601 \mu\text{g}/\text{m}^3$). In general, accuracy was good when the receptors were in the downwind direction to the source and the accuracy decreased when the

Table 5.2.6 Performance evaluation of the model tested (SPM: $\mu\text{g}/\text{m}^3$)

Sl.No	Parameters	All Crushers			35 Crushers			18 Crushers		
		FDM	ISCST3	AERMOD	FDM	ISCST3	AERMOD	FDM	ISCST3	AERMOD
I	Summary measure									
1	Observed mean	1285	1285	1285	961	961	961	1018	1018	1018
2	Predicted mean	4722	661	1049	1359	152	1010	1037	279	343
3	Observed deviation	1311	1311	1310	1289	1289	1289	980	980	980
4	Predicted deviation	4862	1029	1125	1633	105	1454	1504	284	560
II	Linear regression									
5	intercept	2638	551	775	504	97	208	687	132	19
6	slope	1.62	0.085	0.2134	0.89	0.057	0.835	0.34	0.145	0.317
7	correlation coefficient	0.44	0.109	0.2487	0.7	0.696	0.739	0.22	0.5002	0.5558
III	Difference measures									
	Root mean square error									
8	Systematic (MSEs)	3532	1351	1057.7	423	1460	218	643	1117	950
9	Unsystematic (MSEu)	4372	1023	1090	1163	76	979	1466	246	466
10	Total root mean square error (TRMSE)	5621	1694	1518.9	1237	1468	1002	1601	1144	1059
IV	Accuracy measures									
11	Index of agreement	0.33	0.454	0.527	0.81	0.469	0.8495	0.53	0.5185	0.6559

Table 5.26 (continued)
Performance evaluation of the model tested (TSPM: $\mu\text{g}/\text{m}^3$)

Sl.No	Parameters	9 Crushers				Only one Crusher				All the data combined			
		FDM	ISCST3	AERMOD	FDM	ISCST3	AERMOD	FDM	ISCST3	AERMOD	FDM	ISCST3	AERMOD
I	Summary measure												
1	Observed mean	518	518	518	148	148	148	830	830	830	830	830	830
2	Predicted mean	201	76	131.6	572	166	68	1911	309	580	1911	309	580
3	Observed deviation	494	494	494	114	144	114	1078	1078	1078	1078	1078	1078
4	Predicted deviation	254	18	114	1728	310	1.5147	3399	627	990	3399	627	990
II	Linear regression												
5	intercept	23	72	88	-683	-55	68	665	195	185	665	195	185
6	slope	0.34	0.007	0.08296	8.47	1.491	-0.0045	1.5	0.1374	0.4759	1.5	0.1374	0.4759
7	correlation coefficient	0.67	0.179	0.5968	0.56	0.55	-0.306	0.48	0.2363	0.517	0.48	0.2363	0.517
III	Difference measures												
8	Root mean square error												
9	systematic(MSEs)	454	661	595	953	59	140	1209	1065	617.47	1209	1065	617.47
10	Unsystematic (MSEu)	189	18	106	1432	259	1.442	2989	609	847.15	2989	609	847.15
IV	Total root mean square error (TRMSE)	492	661	605	1720	265	140	3224	1227	1048	3224	1227	1048
	Accuracy measures												
11	Index of agreement	0.67	0.464	0.496	0.133	0.558	0.46653	0.437	0.4681	0.699	0.437	0.4681	0.699

receptors were in upwind direction. This is not surprising since these models are meant to simulate air quality in the downwind direction (Table 5.26).

5.13.6 1/8th of the crushers in operation

Under this condition, all three models underpredicted with the FDM proving to be the best. The accuracy was more for FDM (67%) as compared to AERMOD (50%) and ISCST3 (46%) as given in Table 5.26.

5.13.7 Only one crusher in operation

Under this condition FDM and ISCST3 model overpredicted the concentration and AERMOD underpredicted the concentration and it is least for ISCST3 ($166 \mu\text{g}/\text{m}^3$) as compared to AERMOD ($68 \mu\text{g}/\text{m}^3$) and FDM ($572 \mu\text{g}/\text{m}^3$) against measured concentration. The accuracy of ISCST3 is more (56%) when compared to AERMOD (47%) and FDM (13%) which is the lowest among the all conditions tested. This is mainly due to the inability of FDM to take into account hourly variation of emission rate while modeling (Table 5.26).

5.13.8 Quantitative data Analysis

Quantitative data analysis was carried out to verify whether the model's predictions are within a factor of 2 for all the measurements. The model's predictions were also compared with observed concentrations and grouped under overprediction, exact prediction and underprediction for assessing their performance. This analysis will be of use for regulatory application to ensure compliance with the air quality standards.

The results of the quantitative data analysis done for the models are presented in Table 5.27 - 5.29. It was found that the model FDM predicted the concentration within a factor of 2 for most of the time with the least amount of underprediction. Most of the time, FDM overpredicted the concentration, where as AERMOD and ISCST3 underpredicted the concentration. On overall basis, the model AERMOD proved to be better.

5.13.9 Summary

In this study, performances of three Gaussian models were evaluated. The model AERMOD provided a better simulation than the ISCST3 and FDM in this case. Its prediction accuracy (70%) was more when compared to ISCST3 (47%) and FDM (44%) for all the conditions under which the study was conducted. FDM predictions were within a factor of 2 of the observed concentrations for the most of the time. Of the three models FDM over predicted to the highest degree. Based on the study it is appropriate to rank the models in the order of AERMOD, ISCST3 and FDM.

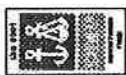


Table 5.27
Qualitative data analysis of the models tested (Number)

Condition	Number of data	Model	Rank	with in a factor of $0.5 \leq P/M \leq 2$	Under prediction $0.5 \leq P/M < 0.95$	Over prediction $1.05 < P/M \leq 2$	Exact prediction $0.95 \leq P/M \leq 1.05$	P/M factor > 2	P/M factor < 0.5
All crusher	17	FDM	AERMOD	3	0	2	1	11	3
		ISCST3	ISCST3	4	2	2	0	1	12
		AERMOD	FDM	6	0	6	0	3	8
35 crusher	10	FDM	AERMOD	3	1	2	0	3	4
		ISCST3	FDM	1	1	0	0	0	9
		AERMOD	ISCST3	2	1	1	0	4	4
18 crusher	10	FDM	AERMOD	4	2	1	1	1	5
		ISCST3	FDM	0	0	0	0	1	9
		AERMOD	ISCST3	2	1	1	0	0	8
9 crusher	11	FDM	FDM	5	5	0	0	0	6
		ISCST3	AERMOD	0	0	0	0	0	11
		AERMOD	ISCST3	1	0	1	0	0	10
1 crusher	11	FDM	ISCST3	1	1	0	0	1	9
		ISCST3	AERMOD	0	0	0	0	1	10
		AERMOD	FDM	0	0	0	0	0	11
All the data combined	59	FDM	AERMOD	16	9	5	2	16	27
		ISCST3	ISCST3	5	3	2	0	3	51
		AERMOD	FDM	11	2	9	0	7	41

* M - Measured concentration

* P - Predicted concentration



Heard
Duck

Table 5.28
Qualitative data analysis of the models tested (%)

Condition	Number of data	Model	Rank	with in a factor of $0.5 \leq P/M \leq 2$	Under prediction $0.5 \leq P/M < 0.95$	Over prediction $1.05 < P/M \leq 2$	Exact Prediction $0.95 \leq P/M \leq 1.05$	P/M factor > 2	P/M factor < 0.5
All crusher	17	FDM	AERMOD	18	0	12	6	65/64	18
		ISCST3	ISCST3	24	12	12	0	6	71
		AERMOD	FDM	40	5	35	0	18	47/42
35 crusher	10	FDM	AERMOD	30	10	20	0	30	40
		ISCST3	FDM	10	10	0	0	0	90
		AERMOD	ISCST3	20	10	10	0	40	40
18 crusher	10	FDM	AERMOD	40	20	10	10	10	50
		ISCST3	FDM	0	0	0	0	10	90
		AERMOD	ISCST3	20	10	10	0	0	80
9 crusher	11	FDM	FDM	45	45	0	0	0	55
		ISCST3	AERMOD	0	0	0	0	0	100
		AERMOD	ISCST3	9	0	9	0	0	91
1 crusher	11	FDM	ISCST3	9	9	0	0	9	82
		ISCST3	AERMOD	0	0	0	0	9	91
		AERMOD	FDM	0	0	0	0	0	100
All the data combined	59	FDM	AERMOD	27	15	8	3	27/28	46
		ISCST3	ISCST3	8	5	3	0	5/6	86
		AERMOD	FDM	19	3	15	0	12	69

* M - Measured concentration
* P - Predicted concentration

Table 5.29

Qualitative data analysis of the models tested within a factor of 2, % ($0.5 \leq P/M \leq 2$)

Condition	Model	Rank	Number of data	Under prediction $0.5 \leq P/M < 0.95$	Over prediction $1.05 < P/M \leq 2$	Exact prediction $0.95 \leq P/M \leq 1.05$
All crusher	FDM	AERMOD	3	0	67	33
	ISCST3	ISCST3	4	50	50	0
	AERMOD	FDM	6	0	100	0
35 crusher	FDM	AERMOD	3	33	67	0
	ISCST3	FDM	1	100	0	0
	AERMOD	ISCST3	2	50	50	0
18 crusher	FDM	AERMOD	4	50	25	25
	ISCST3	FDM	0	0	0	0
	AERMOD	ISCST3	2	50	50	0
9 crusher	FDM	FDM	5	100	0	0
	ISCST3	AERMOD	0	0	0	0
	AERMOD	ISCST3	1	0	100	0
1 crusher	FDM	ISCST3	1	100	0	0
	ISCST3	AERMOD	0	0	0	0
	AERMOD	FDM	0	0	0	0

* M – Measured concentration

* P – Predicted concentration



CHAPTER 6

GREEN BELT DEVELOPMENT

Urban green belts are considered as the lungs of the cities as they act as a sink for some of the harmful gases released by vehicles and industries operating in the area. Whether sprawling over a large or a smaller area, these green belts are found in all cities and play a very important role. They serve as sink for the pollutants, check the flow of dust and bring down noise pollution level.

6.1 Design for Trisoolam quarry

There are 72 stone crushers in the site to be improved by tree planting. Each stone crusher has to be environmentally improved by planting trees apart from the main road bearing incessant plying vehicles augmenting dust and noise.

It is proposed to plant tree species, around the stone crushers initially and gradually grow green belt on the road side also. Soil samples were collected at a depth of 3 feet and tested for macro and micronutrients. It was found that the electrical conductivity is normal i.e. less than 1.0 and the pH was ranging from 6.0 to 7.0 which is again normal. The soil test values for micro nutrients viz., Zinc, Copper, Iron, and Manganese are well above 3 to 5 ppm. The macronutrient, Nitrogen was in a lower availability level, Phosphorous at a medium level and Potassium at a higher level. It is proposed to apply abundant quantities of Vermicastings, an ecofriendly bionutrient which will supply the nutrients as well as act as a binding agent.

6.2 Peripheral planting to protect the nearby residential area

To minimize the impact of dust produced from the stone crushers, tall dense trees will be planted as indicated below:

Polyalthia	-	நெட்டிலிங்கம்
Casuarina junghuniana	-	தாய்லாந்து சவுக்கு
Kaya senegalensis	-	ஆப்பிரிக்கன் மஹாகனி
Melia dubia	-	மலை வேம்பு
Cassia siamia	-	மஞ்சக் கொன்றை



6.3 Avenue planting

Avenue plantation will include green belt development along the roads on both sides of the roads as indicated below:

Casuarina junghuniana	-	தாய்லாந்து சவுக்கு
Hibiscus tiliaceous	-	காட்டுப் பூவரசு
Delonix regia	-	மயில் கொன்றை
Samanea saman	-	தூங்கும் வாகை
Cassia alata	-	சீமை அகத்தி

Planting around crusher

To avoid dust emanating from each stone crusher, tree plantation was so designed to arrest the fugitive dust at the source itself. This includes plantation of the following species:

1, Delonix regia	-	மயில் கொன்றை
2, Peltophoursum ferrugineum	-	இயல் வாகை
3, Pongamia pinnata	-	புங்கன்
4, Cassia fistula	-	சரக் கொன்றை
5, Azadirachta indica	-	வேம்பு
6, Acacia auriculiformis	-	கத்தி சவுக்கு
7. Simaruba glauca, etc	-	சொர்க்க மரம்

The species chosen are such that they have profuse foliage to abate pollution and are fast growing. The number of trees and species will be based on the availability of the seedlings. Fruit yielding trees were not specifically selected to avoid polluted edible fruits entering into the food chain. Advanced planting technique will be used to impart better performance of the species.

6.5 Planting around Quarry

To reduce noise and dust pollution from quarrying operations the following species were identified:

1. Polyalthia longifolia	5' distance
2. Casuarina equisetifolia	5'
3. Acacia auriculiformis	8'
4. Calophyllum inophyllum	12'
5. Bassia latifolia	15'



6. Ficus benjamina	10'
7. Murraya exotica	5'
8. Nerium oleander	5'
9. Bougainvillea varieties	5'
10. Thevetia nerifolia	8'
11. Tabernaemontana coronaria	8"

6.6 Hill top planting

Hill top plantation was designed to improve aesthetics of the crushing environment and minimize dust material blown away towards residential areas. The species for this purpose will include:

1. Mimosa elengi
2. Pithecellobium dulce
3. Cassia fistula
4. Eugenia jambolanum
5. Tamarindus indica
6. Ficus carica
7. Cassia auriculata
8. Cassia alata
9. Plumeria Varieties

6.7 Planting technique

The Pit Size will be 1 m³ the pits will be filled with two parts & manure especially, vermicasting, one part sand and one part red earth. 1 m³ pits have been found to promote fast growth in trees which is very much essential in this case as the tree growth is likely to be retarded because of the constant dust produced and deposited on the surface soil. Two soil workings are must per year to enable fast growth.

6.7.1 Espacement

Except for the species, Casuarina and Polyalthia, where the espacement will be 1 x 1 m, for the rest of the species the spacing will be 3 x 3 m.

6.7.2 Selection of plant

Plant selection: Healthy grown saplings free from pests with a height of minimum 1 m are preferable. The seedlings will be transported from the different available nursery points.



6.8 Maintenance after planting

Staking should be given for straight growth. Tree guard should be provided if necessary. Regular watering is must for minimum of two years and it may vary according to the climatic condition. Technical expert's inspection is must to monitor proper growth. If necessary pesticide or fungicide should be applied / sprayed as per experts advise to prevent from pests and diseases. Casualties should be immediately replaced. Two soil workings are absolutely necessary.



CHAPTER 7

CONTROL MEASURES

The CPCB stipulates the following standards for suspended particulate matter in stone crushing units:

The standards consist of two parts:

- i) Implementation of following pollution control measures
 - a) Dust containment cum suppression system for the equipment
 - b) Construction of wind breaking walls
 - c) Construction of metalled roads within the premises
 - d) Regular cleaning and wetting of the ground within the premises
 - e) Growing of a green belt along the periphery
- i) Quantitative standard for the TSPM

The suspended particulate matter measured between 3 - 10 meters from any process equipment of a stone crushing unit shall not exceed $600 \mu\text{g}/\text{m}^3$

The National Productivity Council vide their report of 1995 have demonstrated a suitable dust suppression and containment system for the stone crusher units in Tamil Nadu. The dust containment system comprises of building enclosures over the major dust emission sources so as to contain the dust within the housing. Only the rotary screen is considered for dust containment enclosures. It is not recommended to enclose the jaw crusher as frequent manual intervention and attention is required. The dust suppression system comprises of spraying of water as a fine mist through special nozzles over such dust generation sources as material transfer points.

Control measures for reducing or eliminating fugitive emissions from stone crushing plants include the following:

- ❖ Wetting of material or surfaces with water with or without surfactants or foaming agents
- ❖ Covering open operations to prevent dust entrainment by the wind
- ❖ Reducing the drop height of dusty material
- ❖ Using hooding, industrial ventilation systems and dust collectors (e.g. Bag houses) on dusty processes amenable to enclosure



7.1 Recommendation

7.1.1 Cluster of crushers

Emissions from stone processing are considered to be fugitive when the sources are not vented to a bag house or contained in an enclosure with a forced air vent or stack. Water sprinkling at dust discharge points wets the dust particles and augments settling. The other control measures for reducing dust emission should include the following good housekeeping practices:

- A minimum distance of 500 m with a green belt of 100 m width should be provided around the periphery of the crushing area at Trisoolam
- Raising a green belt around the crushing area to arrest the spread of particulate matter is advocated along the boundary of the crushing area on all the sides with evergreen high foliage trees like Neem, Ashoka, Coconut, Tamarind and other local trees belonging to *cesalpinaceae* like Gul Mohar and Fire of the Forest. On the road sides also trees should be planted to arrest the dust from vehicular movement
- Sprinkling of water should be increased to arrest the spread of dust (RSPM & TSPM) with periodical cleaning of spray nozzles
- Fine dust accumulated in the crushing area should be periodically cleared and the dumps should be covered with tarpaulins to arrest the spread of dust
- Construction of metalled road (paved) within the premises
- No more stone crushers should be allowed in this area
- The drop height should be kept at a minimum while loading and unloading operation
- Fine powder should be collected at the ground level and disposed of immediately
- Conveyor chutes should be provided at the discharge points
- Covering open operations to prevent dust entrainment by the wind
- As an occupational safety measure all the workers should be provide with nose masks to avoid dust entering the respiratory system
- Evergreen trees like Neem, Ashoka, Tamarind and other local trees belonging to the family *cesalpinaceae* like Gul Mohar and Fire of the Forest should be planted all around the crushing area. Similarly trees should be planted along the roads to arrest the spread of particulate arising from vehicular movement inside the area



- Roads leading to the individual crushers should be paved
- The fine powder accumulated so far should be immediately disposed off and the crushers should follow periodical disposal practice in consultation with TNPCB
- Good house keeping by way of spraying water at the vulnerable points/locations to arrest the spread of dust particles should be practiced
- Drop height of the conveyors should be kept at the minimum
- Wind breaking wall/net should be provided all along the stone crushers adjacent to residential areas]
- If for other pressing reasons more than one stone crushers are required to come in existence, then they should be as much close to each other as may be permitted without causing difficulty in operation. In such a situation the source would be recognized as a collective one and the safe distance is to be estimated accordingly as applicable
- Special recommendation for stone crushers located near Kennedy Valley on the eastern side of the crushing area: should be provided wind breaks/ barrier of length 100m x 15m (50m x 15m at periphery of Parthibhan BM and 50m x 15m at periphery of Geetha BM) should be constructed at the periphery of the stone crushers at North (Parthibhan BM) and South (Getha BM) of the Moovarasampet road (Fig 1.1). No enclosure is required at the top.

7.1.2 Single crusher

Based on the study conducted at Trisoolam stone crushing area by operating only one crusher the following recommendations are made:

- NPC dust containment and dust suppression system should be provided
- Paving of roads should be adopted
- The minimum distance from single crusher source should be kept as 100m with a 25m green belt within it at the periphery
- Fine powder should be collected at the ground level
- Conveyor chute should be provided at the discharge points
- Drop height for the conveyor operations should kept at the minimum
- The fine powder should be disposed off periodically
- Covering of fine dust with tarpaulin during storage and transport to final destination should be practiced

CHAPTER 8

SUMMARY AND CONCLUSIONS

8.1 Summary

The findings of the study are summarized below:

- ❖ In Trisoolam area, there are 72 crushing units where particulate sampling was carried out during June 24 - July 16, July 27 - August 5, 2005, both at source and in the ambient air
- ❖ During the study each crusher was operating at crushing capacity of 60 MT/day
- ❖ The parameters studied were TSPM, RSPM and cyclone dust at the source and in ambient air
- ❖ The ambient particulate sampling was carried out in the predominant upwind and downwind directions at different distances from the source, at 40, 130, 200, 340, 400, 430 and 640 m
- ❖ TSPM, RSPM and cyclone dust concentrations nearer to the source were high and exceeded the Indian national standards
- ❖ Ambient TSPM concentrations in the Sara Nagar site were the highest during different phases of sampling
- ❖ The contribution of all crushers to the TSPM concentration at source varied from 682 to 2656 $\mu\text{g}/\text{m}^3$ within a distance of 3 - 10 m from the source. The contribution of all crushers to the TSPM concentration in ambient air varied from 319 to 465 $\mu\text{g}/\text{m}^3$ at a distance of 130 - 430 m. The contribution of all crushers to the RSPM concentration in ambient air varied from 41 to 203 $\mu\text{g}/\text{m}^3$ at distance of 40 - 640 m
- ❖ The contribution of one crusher to the TSPM concentration at source varied from 21 to 284 $\mu\text{g}/\text{m}^3$ within a distance of 3 - 10 m from the source. The contribution of one crusher to the TSPM concentration in ambient air varied from 2 to 17 $\mu\text{g}/\text{m}^3$ at a distance of 340 - 940 m. The contribution of one crusher to the RSPM concentration in ambient air varied from 1 to 14 $\mu\text{g}/\text{m}^3$ with a mean of 7 $\mu\text{g}/\text{m}^3$ at a distance of 1320 - 1640 m

- ❖ With no crushing activity and only vehicle traffic/movement, the background TSPM concentration at source varied from 306 to 1266 $\mu\text{g}/\text{m}^3$ within a distance of 3 - 10 m from the source. The background TSPM concentration in ambient air varied from 44 to 107 $\mu\text{g}/\text{m}^3$ at a distance of 40 - 440 m.
- ❖ During the study period the predominant wind directions were Southwest, West and West of South West.
- ❖ The PM_{10} concentration at the source with all the crushers running varied from 274 to 654 $\mu\text{g}/\text{m}^3$ with a mean of 464 $\mu\text{g}/\text{m}^3$ and exceeded the standard of 100 $\mu\text{g}/\text{m}^3$
- ❖ The PM_{10} concentration in ambient air with all the crushers running varied from 91 to 276 $\mu\text{g}/\text{m}^3$ with a mean of 183 $\mu\text{g}/\text{m}^3$ and exceeded the standard of 100 $\mu\text{g}/\text{m}^3$
- ❖ The $\text{PM}_{2.5}$ concentration at source with all the crushers running varied from 123 to 678 $\mu\text{g}/\text{m}^3$ with a mean of 378 $\mu\text{g}/\text{m}^3$ and exceeded the EPA standard of 65 $\mu\text{g}/\text{m}^3$
- ❖ The $\text{PM}_{2.5}$ concentration in ambient air with all the crushers running varied from 15 to 112 $\mu\text{g}/\text{m}^3$ with a mean of 59 $\mu\text{g}/\text{m}^3$ and exceeded the EPA standard of 65 $\mu\text{g}/\text{m}^3$
- ❖ The estimated emission rate for the each crusher by upwind and downwind technique was about 129 kg/day
- ❖ $\text{PM}_{2.5}$ concentration at the source in all the locations exceeded the EPA standard of $\text{PM}_{2.5}$ (65 $\mu\text{g}/\text{m}^3$) whereas in ambient air at Trisoolam 1 (106 $\mu\text{g}/\text{m}^3$), Trisoolam 2 (70 $\mu\text{g}/\text{m}^3$) and Kennedy Nagar (112 $\mu\text{g}/\text{m}^3$) exceeded the standard limit of 65 $\mu\text{g}/\text{m}^3$.
- ❖ Safe distance when all the crushers in operation
Safe distance for measured concentration varied from 211 to 1350 m with a mean of 784 m. Safe distance for predicted concentration of AERMOD varied from 59 to 1225 m with a mean of 679 m. The safe distance for predicted concentration of ISCST3 and FDM varied from 45 to 1056 m and 55 to 2650 m with a mean of 501 m and 1335 m.
- ❖ Safe distance when half of the crushers in operation
Safe distance for measured concentration varied from 126 to 1750 m with a mean of 776 m. Safe distance for predicted concentration of AERMOD varied from 47 to 1395 m with a mean of 582 m. The safe distance for predicted concentration of FDM and ISCST3 varied from 1650 to 26 m and 35 to 833 m with a mean of 1216 m and 433 m respectively.
- ❖ Safe distance when 1/4th of the crushers in operation



Safe distance for measured concentration varied from 126 to 1242 m with a mean of 696 m. Safe distance for predicted concentration of AERMOD varied from 15 to 481 m with a mean of 262 m. The safe distance for predicted concentration of FDM and ISCST3 varied from 74 to 1138 m and 38 to 537 m with a mean of 731 m and 260 m respectively.

❖ Safe distance when 1/8th of the crushers in operation

Safe distance for measured concentration varied from 25 to 1095 m with a mean of 524 m. Safe distance for predicted concentration of FDM varied from 50 to 1109 m with a mean of 184 m. The safe distance for predicted concentration of AERMOD and ISCST3 varied from 27 to 325 m and 22 to 335 m with a mean of 116 m and 501m respectively.

❖ Safe distance when only one crusher in operation

Safe distance for measured concentration varied from 116 to 771 m with a mean of 379 m. Safe distance for predicted concentration of ISCST3 varied from 11 to 174 m with a mean of 90 m. The safe distance for predicted concentration of AERMOD and FDM varied from 32 to 95 m and 13 to 263 m with a mean of 59 m and 111 m respectively.

8.2 Recommendations

Emissions from stone processing are considered to be fugitive when the sources are not vented to a bag house or contained in an enclosure with a forced air vent or stack. Water sprinkling at dust discharge points wets the dust particles and augments settling. The other control measures for reducing dust emission should include the following good housekeeping practices:

- A minimum distance of 500 m with a green belt of 100 m width should be provided around the periphery of the crushing area at Trisoolam
- Raising a green belt around the crushing area to arrest the spread of particulate matter is advocated along the boundary of the crushing area on all the sides with evergreen high foliage trees like Neem, Ashoka, Coconut, Tamarind and other local trees belonging to *cesalpinaceae* like Gul Mohar and Fire of the Forest. On the road sides also trees should be planted to arrest the dust from vehicular movement



- Sprinkling of water should be increased to arrest the spread of dust (RSPM & TSPM) with periodical cleaning of spray nozzles
- Fine dust accumulated in the crushing area should be periodically cleared and the dumps should be covered with tarpaulins to arrest the spread of dust
- Construction of metalled road (paved) within the premises ✓
- No more stone crushers should be allowed in this area
- The drop height should be kept at a minimum while loading and unloading ✓
- Fine powder should be collected ^{nearby and in individual bags} at the ground level and disposed off immediately
- Conveyor chutes ~~should be~~ provided at the discharge points ^{to the extent possible}
- Covering open operations to prevent dust entrainment by the wind
- As an occupational safety measure all the workers should be provide with nose masks to avoid dust entering the respiratory system
- Evergreen trees like Neem, Ashoka, Tamarind and other local trees belonging to the family *cesalpinaceae* like Gul Mohar and Fire of the Forest should be planted all around the crushing area. Similarly trees should be planted along the roads to arrest the spread of particulate arising from vehicular movement inside the area
- Roads leading to the individual crushers should be paved
- The fine powder accumulated ^{so far} should be immediately disposed off, ~~and the crushers should follow periodical disposal practice in consultation with TNPCB~~
- Good house keeping by way of spraying water at the vulnerable points/locations to arrest the spread of dust particles should be practiced
- Drop height of the conveyors should be kept at the minimum ✓
- Wind breaking wall/net should be provided all along the stone crushers adjacent to residential areas] ^{particular in the direction where complaint was running}
- If for other pressing reasons more than one stone crushers are required to come in existence, then they should be as much close to each other as may be permitted without causing difficulty in operation. In such a situation the source would be recognized as a collective one and the safe distance is to be estimated accordingly.
- Special recommendation for stone crushers located near Kennedy Valley on the eastern side of the crushing area: should be provided an enclosure of suitable material (brick) to a height of 5m on all sides adjacent to the residential area



Based on the study conducted at Trisoolam stone crushing area by operating only one crusher the following recommendations are made:

- NPC dust containment and dust suppression system^{4/2} should be provided
- Paving of roads should be adopted
- The minimum distance from single crusher source should be kept as 100m with a 25m green belt within it at the periphery
- Fine powder should be collected at the ground level
- Conveyor chute should be provided at the discharge points
- Drop height for the conveyor operations should kept at the minimum
- The fine powder should be disposed off periodically
- Covering of fine dust with tarpaulin during storage and transport to final destination should be practiced

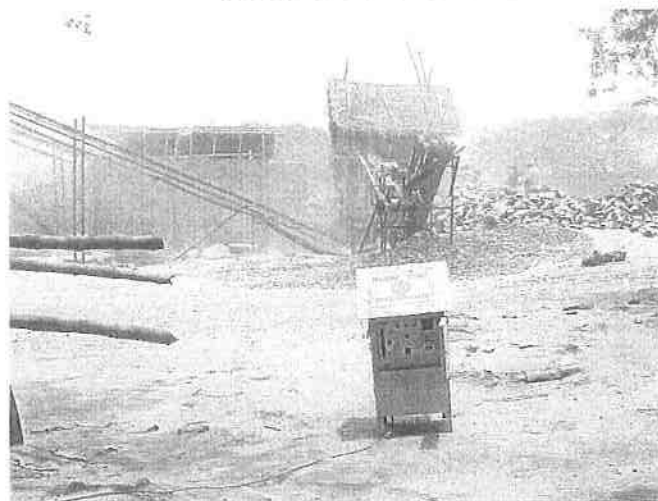
8.3 Conclusions

The dust generated from stone crushing activities contains a significant amount of fine inhalable matter. The effect of fine particulate matter can be disproportionately large even though it constitutes only a small fraction of the total suspended particulate matter. The presence of a high percentage of silica in the dust and the particle size distribution further suggest that the occupational environment of the workers and surrounding areas may be hazardous to human health. Air quality and the health survey conducted at the site indicate that the observed dust caused significant damage to respiratory health.

Most of the stone crushers have inadequate dust control systems. Mostly all units have neither enclosures nor water spraying arrangements. As a result, the dust emissions are substantial which leads to adverse impacts on workers as well as the surrounding environment. The existing control measures such as dust containment enclosures, water spray arrangements etc are generally found to be inadequate, largely due to reasons like inadequate containment, inadequate water quantity and pressure, dirt in the water leading to choking of spray nozzles, inappropriate spray locations, etc., ^{with scope for further improvement} The re-entrainment of settled dust from unpaved roads and surfaces is another phenomenon which seriously contributes to dust pollution in these areas which should be controlled immediately by paving the roads and surfaces inside crushing area and reducing the drop heights and covering potential fugitive dust emission sources.

APPENDIX 1 / I

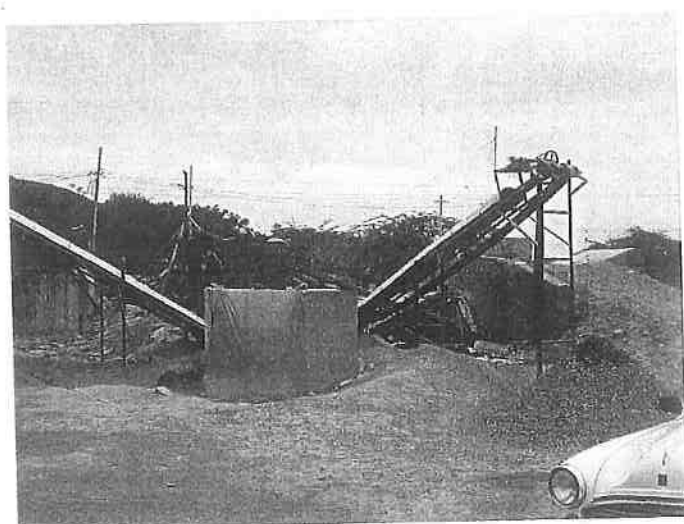
Stone crushers and their environment: Trisoolam area

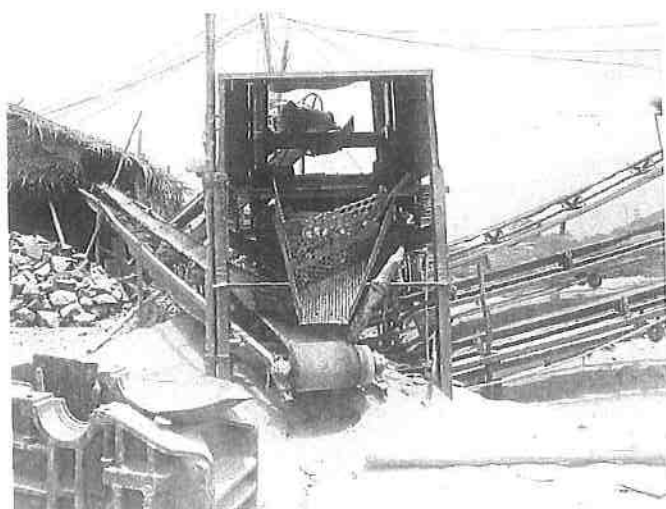


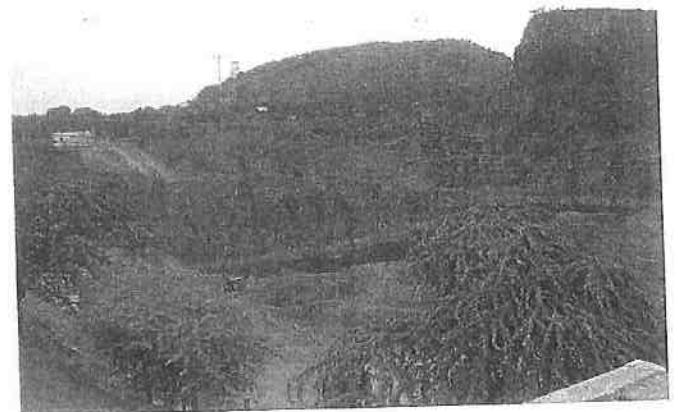
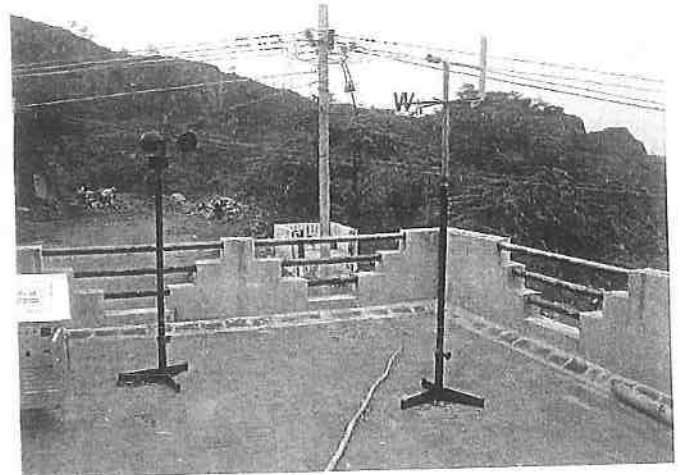
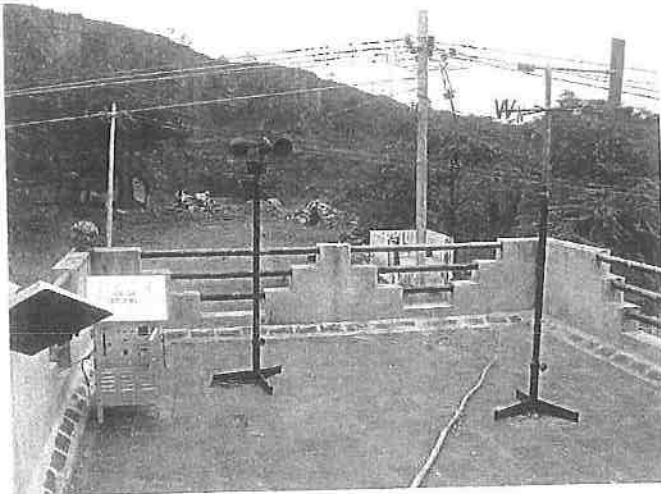


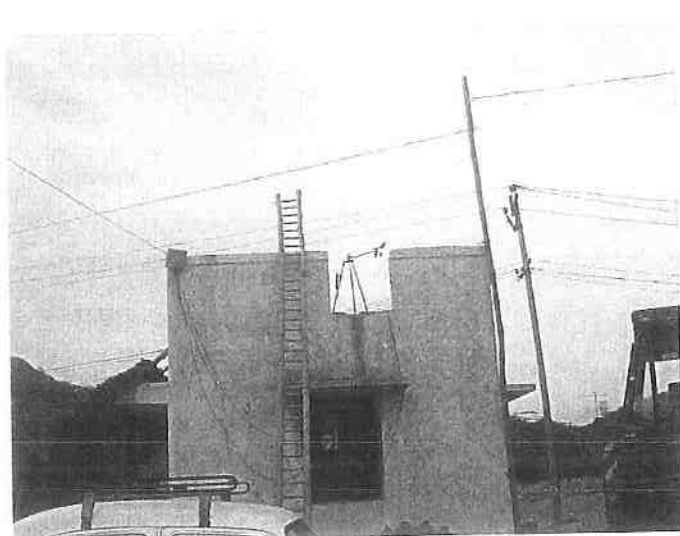


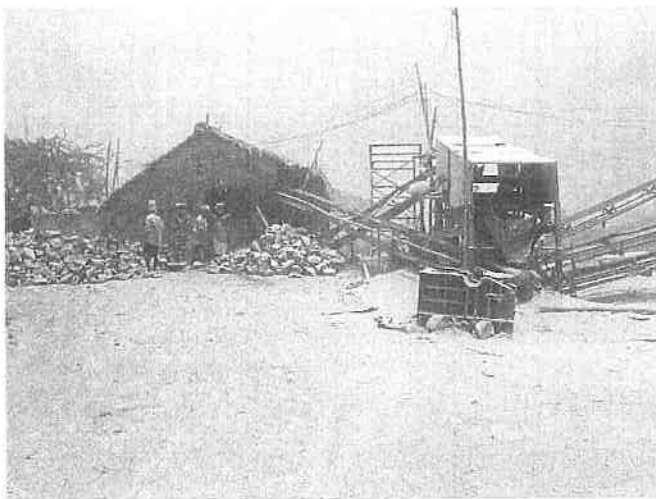
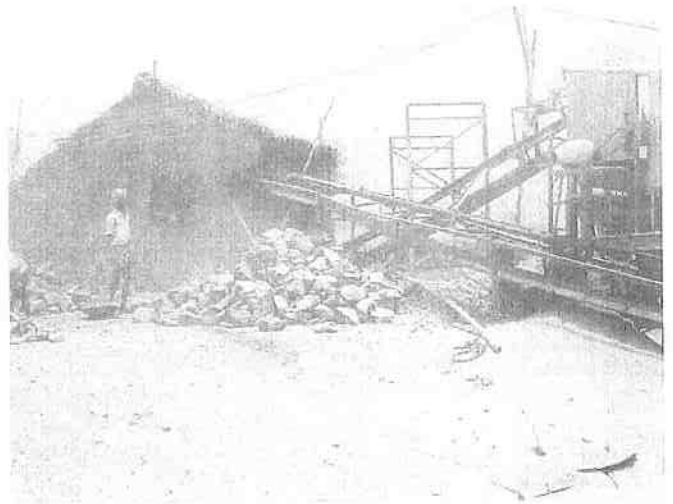
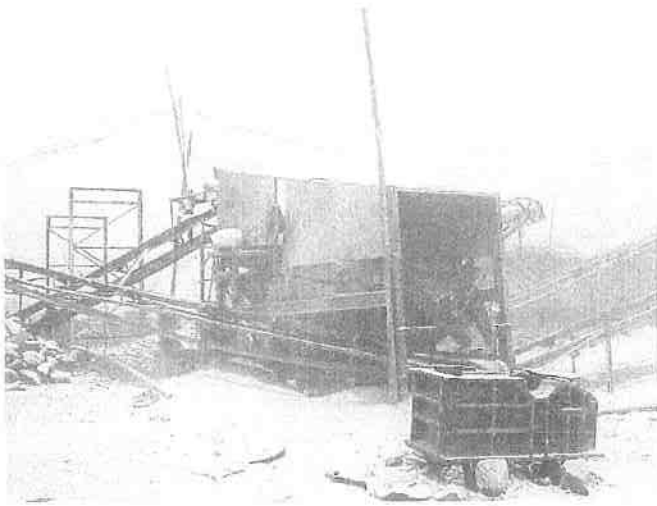














APPENDIX II

CPCB STANDARDS FOR SUSPENDED PARTICULATE MATTER FROM STONE CRUSHING UNIT

The standards consist of two parts:

- updated June 29, 2017*
- i) Implementation of the following pollution control measures:
 - ii) (1) Dust contaminant cum suppression system for the equipment. ✓
 - iii) (2) Construction of wind breaking walls. ✓
 - iv) (3) Construction of the metalled roads within the premises. ✓
 - v) (4) Regular cleaning and wetting of the ground within the premises. ✓ (R)
 - vi) (5) Growing of a green belt along the periphery.
 - vii) Quantitative standard for the SPM:

The suspended particulate matter measured between 3 meters to 10 meters from any process equipment of a stone crushing unit shall not exceed 600 $\mu\text{g}/\text{m}^3$.

In case of SCU, the suspended PM contribution value at a distance of 40 meters from a controlled, isolated as well as from a unit located in cluster should be less than 600 $\mu\text{g}/\text{m}^3$.



NAAQS, CPCB, Notification
New Delhi, the 18th November, 2009

National
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APPENDIX III NATIONAL AMBIENT AIR QUALITY STANDARDS

Pollutants	Time weighted average	Concentration in ambient air			Method of Measurement
		Industrial Area	Residential, Rural & other areas	Sensitive Area	
1	2	3	4	5	6
Sulphur Dioxide (SO ₂)	Annul Average*	80 µg/m ³	60 µg/m ³	15 µg/m ³	1. Improved west and Gaeke
	24 hours**	120 µg/m ³	80 µg/m ³	30 µg/m ³	2. Ultraviolet fluorescence
Oxides of Nitrogen as NO ₂	Annul Average*	80 µg/m ³	60 µg/m ³	15 µg/m ³	1. Jacob & Hochheiser modified (Na-Arsenite) Method
	24 hours**	120 µg/m ³	80 µg/m ³	30 µg/m ³	2. -Gas Phase Chemluminescence
Suspended particulate Matter (SPM)	Annul Average*	360 µg/m ³	140 µg/m ³	70 µg/m ³	-High Volume sampling, (Average flow rate not less than 1.1 m ³ /minute)
	24 hours**	500 µg/m ³	200 µg/m ³	100 µg/m ³	
Respirable Particulate matter, RPM (< 10µm)	Annul Average*	120 µg/m ³	60 µg/m ³	50 µg/m ³	Respirable Particulate matter sampler
	24 hours**	150 µg/m ³	100 µg/m ³	75 µg/m ³	
Lead (Pb)	Annul Average*	1.0 µg/m ³	0.75 µg/m ³	0.50 µg/m ³	-AAS method after sampling
	24 hours**	1.5 µg/m ³	1.00 µg/m ³	0.75 µg/m ³	Using EPM 2000 or equivalent Filter Paper
Carbon Monoxide (CO)	8 hours**	5.0 mg/m ³	2.0 mg/m ³	1.0 mg/m ³	-Non dispersive infrared spectroscopy
	1 hour	10.0 mg/m ³	4.0 mg/m ³	2.0 mg/m ³	

* Annual Arithmetic mean of minimum 104 measurements in a year taken twice a week 24 hourly at uniform interval.

** 24 hourly / 8 hourly values should be met 98% of the time in a year. However, 2% of the time, it may exceed but not on two consecutive days.

NOTE:

1. National Ambient Air Quality Standard: The levels of air quality with an adequate margin of safety, to protect the public health, vegetation and property.



2. Whenever two consecutive values exceed the limit specified above or the respective category, it would be considered adequate reason to institute regular/Continuous monitoring and further investigations.
3. The State Government/State Board shall notify the sensitive and other areas in the respective states within a period of six months from the date of Notification of National Ambient Air Quality Standards.