MALCOLM PIRNIE

SUPPLEMENTAL REMEDIAL INVESTIGATION REPORT ROCHESTER FIRE ACADEMY SITE

VOLUME II — APPENDICES

CITY OF ROCHESTER
ROCHESTER, NEW YORK

MAY 1992

MALCOLM PIRNIE, INC.

S-3515 Abbott Road
P. O. Box 1938
Buffalo, New York 14219

0965-07-1

MALCOLM PIRNIE

APPENDIX A

WORK PLAN MODIFICATION DOCUMENTATION

MALCOLM PIRNIE

MALCOLM PIRNIE, INC.
ENVIRONMENTAL ENGINEERS, SCIENTISTS & PLANNERS

November 14, 1991

Mr. Mark Gregor
Department of Environmental Services
City Hall
30 Church Street
Rochester, New York 14614

Re: Rochester Fire Training Academy Site
Treatability Testing

Dear Mark:

This letter is prepared to document the recent changes we've discussed in the scope of work as outlined in the Supplemental Remedial Investigation Work Plan prepared for the Rochester Fire Academy site. As you know, the changes in approach to pump testing have been necessitated by field conditions, as outlined in our letter of November 6, 1991. Due to the substantially reduced yield projected from this revised pump test approach it will no longer be necessary to pretreat the pump test water via air stripping prior to discharge of the pump test water to the sewer. Additionally, the difficulties associated with trying to reconfigure the air stripper testing for the reduced flow rate necessitated abandoning the side-by-side treatability testing of two different air stripping technologies. We feel that reasonable information on air stripping technology can be obtained from the literature, and do not feel that the lack of treatability testing will impair the analysis of treatment technologies in the Feasibility Study.

We anticipate proceeding with the laboratory bench-scale testing of metals removal as well as the Advanced Oxidation Process through Peroxidation Systems, Inc. as outlined in the work plan. However, the extremely low concentrations of PCBs in the groundwater as evidenced during the RI make GAC mini-column testing or bench-scale "shake tests" for PCB removal impractical. Therefore, we are proposing the following approach to sample collection and analysis.

In order to obtain a "composite sample" of the ground water, pump tests on each of the four-inch wells just installed will be performed concurrently. The ground water generated from the pump testing of these two wells will be collected in a 200-gallon polypropylene container equipped with a floating cover. At the conclusion of the pump test, an aliquot of the composite sample will be shipped to the laboratory for rush analysis (48-hour verbal results) of its constituents. Collection of samples for laboratory bench-scale testing will also be performed at this time. If, based on the rush analytical results, PCBs are not present, or are at similar concentrations to those detected during the RI, bench-scale testing for PCB removal will be abandoned. The lack of bench-scale testing results should not appreciably impact the accuracy of estimates of full-scale GAC requirements which may be performed during the Feasibility Study.

We are anticipating performing the concurrent pump tests on Tuesday, November 19, 1991 and the remaining independent pump test on MW7S sometime during that week. If you have any questions or comments on this proposed approach, do not hesitate to contact me.

Very truly yours,

MALCOLM PIRNIE, INC.

Anne Marie C. McManus

Anne Marie C. McManus, P.E.
Sr. Project Engineer

c: G. Burke, NYSDEC
File: C-1

0965-07-1
acm/rfatt

City of Rochester

November 6, 1991

Department of Environmental Services

Office of the Commissioner

City Hall
30 Church Street
Rochester, New York 14614

Gerard Burke
Bureau of Central Remedial Action
New York State Department of Environmental Conservation
50 Wolf Road
Albany, New York 12233-7010

RE: Supplemental RI scope of work change
Rochester Fire Academy Site (828015)

Dear Mr. Burke:

The Remedial Investigation identified the presence of sand and gravel directly overlying bedrock in the vicinity of well clusters MW-9 and MW-7 adjacent to the South Disposal Area. Results of the slug test performed in PZ-9 (screened in the sand and gravel material) identified a relatively high transmissive zone within the lower overburden brown sand and gravel directly above bedrock. As part of Supplemental RI field activities, a 72 hour constant rate pump test was to be conducted to evaluate the hydraulic characteristics of the overburden water-bearing zone down gradient of the South Disposal Area.

Initial Supplemental RI field information collected prior to installation of the proposed pumping well indicated that the yield from the lower overburden was substantially lower than that predicted from previous RI activities. Therefore it does not appear that the planned 72-hour constant rate pump test will be feasible. This letter summarizes the initial field information collected and outlines a revised approach to collection of the hydrogeologic data necessary to evaluate alternative means of groundwater collection and treatment (e.g., groundwater collection trenches).

Prior to the installation of a pumping well located down gradient of the South Disposal Area, a small diameter pilot hole was drilled and continuously split-spoon sampled to the top to the bedrock in order to obtain geologic information to properly design the well screen and sand pack. Sampling identified poorly sorted gray silty sand and gravel. At a depth of approximately 22 feet below grade, the poorly sorted sediment became more dense and exhibited a till-like composition. Based upon the moisture content and the fine grained nature of the sediment, it appeared that if a fully penetrating well was installed at that location, it would not produce an adequate yield to conduct a 72 hour pump test. A 2-inch diameter PVC well (LO-1) equipped with a 10-foot long screen was installed in the lower overburden directly above bedrock to serve as a piezometer and provide hydraulic information from this zone. A second pilot hole was drilled approximately 80-feet south of the initial pilot hole. Similar geologic conditions were encountered, and the second borehole was subsequently grouted to ground surface.

A third borehole was completed within the South Disposal Area located at the approximate mid-point between well cluster MW-9 and MW-7 to locate the relatively high transmissive material screened by PZ-9. The test boring identified minor interfingering between the transmissive brown sand and gravel and the denser gray sand and gravel; but generally, similar geologic conditions were observed as in the first two test borings. As with the first down gradient test boring, a 2-inch diameter PVC well equipped with a 10-foot screen was installed above the top of bedrock (LO-2) to serve as a piezometer and observation well.

Following the installation of the lower overburden wells, approximately 1 to 2 well volumes were removed and the well yields were monitored. The inflow rate to each well was measured at less than 0.5 gpm.

PROPOSAL:

Initially slug tests will be performed in each of the lower overburden wells in accordance with the RI Workplan to estimate the hydraulic conductivity of the dense sediment in the lower overburden. In order to obtain the hydrogeologic data necessary to design and evaluate the feasibility of a groundwater collection system located in the upper overburden, we propose to install two (2) 4-inch diameter PVC wells equipped with continuous slot VEE wire-wrap screens to the top of the denser material (20 to 22-feet below grade) adjacent to the existing lower overburden wells (LO-1 and LO-2) and perform "mini-rate pump tests." Mini-rate pump test procedures are described in the attached paper presented by Strausberg (1982). In addition, a mini-rate pump test will be performed on monitoring well MW-7S to verify slug test results and provide greater information on the shallow overburden. Well locations are shown in Figure 1.

Prior to mini-rate pump testing, PW-1, PW-2 and MW-7S, as well as the lower overburden wells will be developed. A step test will be conducted in each 4" diameter well (PW-1 and PW-2) and MW-7S to determine the maximum yield of each well. A centrifugal pump powered by an electric generator will be used to withdraw water during testing. Water levels will be recorded in each pumping well, the lower overburden wells (at 4" diameter pumping well locations) and a well point to be installed approximately 10 feet from each pumping well. Water levels will be recorded at the rate schedule specified in Section 2.4 of the Supplemental RI Work Plan until a response is observed in the well point or for a period of six (6) hours, which ever is greater. Recovery water level data will be recorded upon termination of pumping.

All non-sample discharge water produced during development and testing will be containerized in a 1,000 gal holding tank. Water samples required for treatability testing will be pumped from the well directly to suitable clean containers for transport to the testing laboratories. A composite sample of the water from PW-1 and PW-2 will be analyzed for halogenated and aromatic volatile organic compounds (Methods 8010 and 8020).

Analysis of the mini rate pump testing data will involve plotting of drawdown, corrected drawdown and residual drawdown (recovery) data on a semi-logarithmic graph and the determination of transmissivity and hydraulic conductivity. The results will be used in conjunction with slug test data as input to the numerical model for the evaluation of remedial alternatives involving groundwater collection, containment or diversion.

Revised budget information will be prepared and submitted for your review once costs details are worked out. If you have any questions or concerns, don't hesitate to contact me or Ann Marie McManus at Malcolm Pirnie, Inc.

Sincerely,

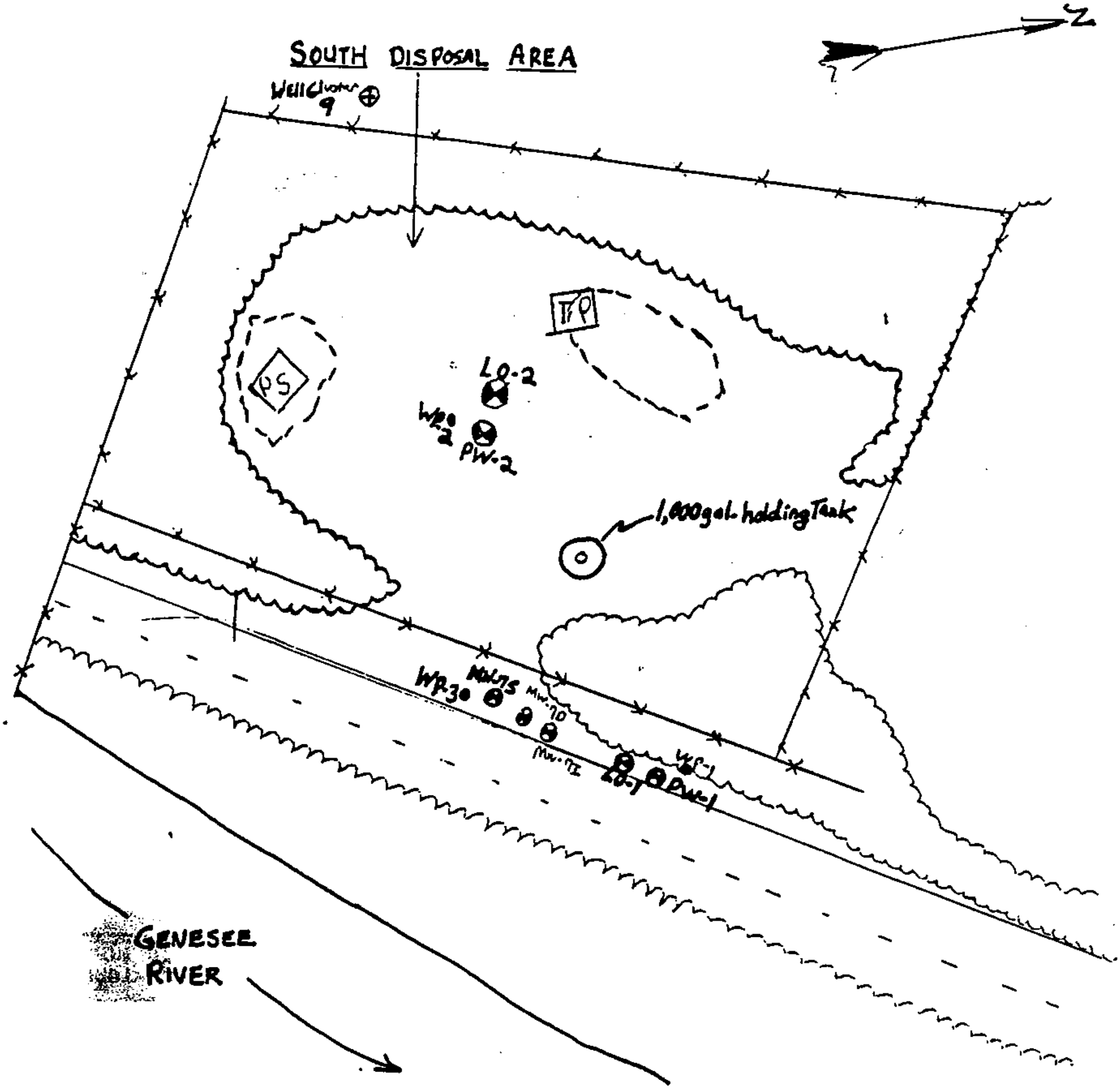
Mark Gregor
Project Manager
City of Rochester

att.

cc Ann Marie McManus, MPI
Richard Frappa, MPI
Paul Werthman, MPI
Bob Cozzy, NYS-DEC
Dave Napier, NYS-DOH
Rick Elliot, MC-DOH
Todd Caffoe, NYS-DEC, Avon

CHKD. BY .... DATE .... JOB NO. ....

SUBJECT .... *Figure 1*



SCALE: 1" = 50'

ROCHESTER FIRE ACADEMY
SUPPLEMENTAL RI
MINI RATE PUMP TEST
WELL LOCATIONS

MALCOLM PIRNIE

MALCOLM PIRNIE, INC.
ENVIRONMENTAL ENGINEERS, SCIENTISTS & PLANNERS

January 29, 1992

Mr. Mark Gregor
Department of Environmental Services
City Hall
30 Church Street
Rochester, New York 14614

Re: Rochester Fire Academy Site - Supplemental RI Ground Water Modeling

Dear Mr. Gregor:

The objectives of the Supplemental Remedial Investigation for the Fire Academy Site were to better define the extent of soil contamination across the site and to define the hydraulic characteristics of the overburden water-bearing zone in the vicinity of the South Disposal Area. The October 1991 Work Plan specified the use of a three-dimensional numerical ground water flow model (viz. MODFLOW) to evaluate selected remedial alternatives for this area.

The 3D-MODFLOW ground water model was selected since aquifer testing at monitoring well cluster MW-9 identified during the RI similar hydraulic characteristics for the lower overburden and bedrock water-bearing zone, thereby implying active hydraulic communication between these two zones. To simulate these conditions using a ground water flow model, would require the use of a model that could account for simultaneous flow in the overburden and bedrock water-bearing zones. However, field activities performed during the Supplemental RI identified different site conditions within and down-gradient of the South Disposal Area relative to the upgradient area. These different site conditions prompted significant changes to the proposed field activities which are documented in your November 6, 1991 letter to the NYSDEC (see attached). The resulting hydraulic data compiled from the Supplemental RI field activities show that material of relatively low permeability is present above the bedrock in the South Disposal Area and that active hydraulic communication between the lower overburden and bedrock water-bearing zones is not present within and down-gradient of the South Disposal Area. Based upon these results, a ground water flow model simulating simultaneous flow in the overburden and bedrock water-bearing zones is not required. This more recent hydrogeologic information indicates that the use of a two-dimensional flow model would be more appropriate for simulation of the hydrogeologic characteristics of the overburden material in the South Disposal Area. Two-dimensional models are also capable of simulating selected remedial alternatives during the Feasibility Study, such as extraction wells, trenches and barriers.

The Prickett-Lonquist Aquifer Simulation Model (PLASM) ground water flow model is a widely recognized two-dimensional flow model capable of simulating the hydraulic conditions present at the site and may be used to simulate selected remedial ground water controls.

S. 3515 ABBOTT RD. P.O. BOX 1938 BUFFALO, NY 14219-0138 716-828-1300 FAX 716-828-0431

This model will be used in lieu of the previously identified 3D-MODFLOW model. The PLASM model input parameters and model operation are similar to the three-dimensional MODFLOW model. Therefore, the amount of time previously estimated for the three-dimensional model to simulate existing conditions and ground water controls should be adequate for the application of the two-dimensional model.

If you have any questions regarding the selection of the PLASM ground water flow model or specific details concerning the model, please contact myself or Rick Frappa at (716) 828-1300.

Very truly yours,

MALCOLM PIRNIE, INC.

Anne Marie McManus, P.E.
Sr. Project Engineer

c. G. Burke (NYSDEC)
P. Werthman (MPI)
R. Frappa (MPI)
File: 0965-07-1; C-1

ACM01292.L

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APPENDIX B

HYDROGEOLOGIC FIELD ACTIVITIES

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B.1 Borehole Logs

FIELD BOREHOLE LOG

CLIENT: City of Rochester
PROJECT: Rochester Fire Academy
LOCATION: Training Grounds
CONTRACTOR: Buffalo Drilling
METHOD OF BORING: SOIL 4¼" & 8¼" HSA
ROCK:

JOB NO. C965071
LOGGED BY: J.P. Hilton
CORE DIA.:

BOREHOLE NO. LO-1
STARTED 9:00 AM 10/29 19 91
FINISHED 4:30 PM 10/29 19 91
ELEVATIONS: DATUM

SAMPLE NO.	TYPE	DEPTH	BLOWS "N"	RECOVERY %	MOISTURE TIN NO.	SAMPLE DESCRIPTION: Color, Texture Classification, Compactness/Consistency, Moisture Condition, Weathering/Fracturing, Inclusions, Odor, Etc.	NOTES: Boring, Testing and Sampling Procedures, Water Loss and Gain, Drilling and Testing Equipment, Etc.
1		0 1	3 4 12 19	.9 / 2.0		.7 Top soil Dark brown Silt, organic layer w/ leaves & roots .2 Silt light tan-brown, slight mottling trace vf Sand	DRY - Moist DRY
2		2 3	17 20 14 9	1.1 / 2.0		1.1 SAND light tan-brown vf w/ trace - little Silt	DRY
3		4 5	6 5 5 15	.5 / 2.1		.5 SAND light tan-brown vf, w/ trace - little Silt, trace light gray, moist silt laminae	DRY
4		6 7	13 25 14 17	.9 / 2.0		.2 SAND moderate brown-orange vf w/ trace Silt .7 SAND moderate - light gray, vf-fine, fine - Crs Gravel (trace - little)	Moist - Wet Wet - Saturated
5		8 9	35 50	.8 / .8		.8 SAND light - moderate gray, vf - fine, trace - little fine - Crs sub-rounded gravel to 3/4" dia, trace iron stained mottling	Saturated 50 cnt / .3 spoon refusal on apparent cobble @ approx 9' Saturated
6		10 11	15 22 21 38	1.1 / 2.0		1.1 SAND light brown-gray vfine - fine w/ trace Silt, little fine - Crs sub-rnd gravel to 3/4" dia	HNu readings @ approx 30 ppm in Augers ... background (2) in breathing Zone
7		12 13	13 27 26 37	1.7 / 2.0		1.7 SAND light brown - gray, v fine - fine, trace Silt, little fine - Crs gravel	Saturated
8		14 15	22 24 34 30	1.4 / 2.0		1.4 SAND A/A (Till)	

Sheet No. 1 of ___

MALCOLM PIRNIE

FIELD BOREHOLE LOG

CLIENT City of Rochester
PROJECT RFA
LOCATION RFA training Grounds
CONTRACTOR Bflo Drlg
METHOD OF BORING: SOIL 4 1/4" & 8 1/4" HSA
ROCK

JOB NO. 0965071
LOGGED BY J.P.H
CORE DIA.

BOREHOLE NO. LO-1
STARTED 9 AM 10/29 1991
FINISHED 430 PM 10/29 1991
ELEVATIONS: DATUM

SAMPLE NO.	TYPE	DEPTH	BLOWS "N"	RECOVERY %	MOISTURE TIN NO.	SAMPLE DESCRIPTION: Color, Texture Classification, Compactness/Consistency, Moisture Condition, Weathering/Fracturing, Inclusions, Odor, Etc.	NOTES: Boring, Testing and Sampling Procedures, Water Loss and Gain Drilling and Testing Equipment, Etc.
9		16–17	13 / 17 / 19 / 26	1.4 / 2.0		SAND Moderate gray-brown vf-fine, trace Silt, little fine-Crs sub-rnd Gravel to 3/4" dia	wet - Saturated
10		18–19	19 / 27 / 21 / 29	.6 / 2.0		.6 SAND A/A	wet - SATURATED
11		20–21	5 / 5 / 14 / 26	1.6 / 2.0		1.6 SAND Moderate gray-brown, fine grain, trace - little Crs Sand, little fine - Crs sub-rnd Gravel to 3/4" diameter, some sorting occuring as fine sand lenses < .3 thick	Saturated
12		22–23	100 / – / – / –	.2 / .45		.2 Dolostone dark brown, brittle, hard, broken along horizontal fabric (bedding features)	100 cnt / .45
13		24–25	42 / 54 / 50 / –	1.0 / 1.45		1.0 SAND Moderate brown-gray vf-fine, trace Silt, little fine - Crs sub-rnd Gravel to 3/4" dia	Moist - Wet 50 cnt / .45
14		26–27	39 / 57 / 55 / 45	1.3 / 2.0		1.3 SAND A/A	Moist - Wet
15		28–29	26 / 40 / 45 / 100	1.2 / 1.9		.5 SAND moderate brown-gray, vf-fine, trace Silt, little fine-Crs Gravel A/A .7 SAND Dark gray-brown, fine-medium, little - Some fine - Crs Gravel to 3/4" dia	wet - Saturated solvent / organic odor
16		30	100 / – / – / –	– / .2		.2 loose residual clastic debris / bedrock chips	spoon refusal @ 29.9' bgs hole making significant water on top of presumed bedrock / overburden interface

Margin notes: (7.11) beside sample 13; (7.11) beside sample 14; ▽ make H_2O @ 29.2' beside samples 15–16.

Sheet No. 2 of ___

MALCOLM PIRNIE

FIELD BOREHOLE LOG

CLIENT: City of Rochester
PROJECT: Rochester Fire Academy
LOCATION: RFA
CONTRACTOR: Bflo Drlg
METHOD OF BORING: SOIL: 4 1/4" HSA
ROCK:

JOB NO. 0965071
LOGGED BY: J.P. Hilton
CORE DIA.:

BOREHOLE NO. TB-1
STARTED: 8 20 AM 10/30 1991
FINISHED: M 10/30 1991
ELEVATIONS: DATUM

SAMPLE NO.	TYPE	DEPTH	BLOWS "N"	RECOVERY %	MOISTURE TIN NO.	SAMPLE DESCRIPTION: Color, Texture Classification, Compactness/Consistency, Moisture Condition, Weathering/Fracturing, Inclusions, Odor, Etc.	NOTES: Boring, Testing and Sampling Procedures, Water Loss and Gain, Drilling and Testing Equipment, Etc.
1		0 1	22 19 8 10	1.1 / 2.0		.2 Topsoil/Silt dark brown-black, organic roots & leaves .4 Gravel fill > 3/4" dia w/ cobbles to 5" dia .5 Silt olive gray, trace vf SAND	Moist
2		2 3	4 5 7 8	1.3 / 2.0		1.3 SAND olive gray-brown mottled, vf-fine grain, little Silt	Moist - wet
3		4 5	2 7 11 17	1.2 / 2.0		.8 SAND A/A, sharp contact w/ .4 SAND Moderate tan-brown fine, trace fine-crs gravel to 3/4" dia	wet - saturated
4		6 7	12 12 13 50	1.4 / 1.5		1.4 SAND Moderate tan-brown vf-fine, trace Silt, little fine-crs sub-angular gravel	Saturated 50 cnt / 0.0
5		8 9	100 - - -	0.0 / 2.0		No Sample - Cobble zone	100 cnt / <.1'
6		10 11	31 28 31 27	1.3 / 2.0		1.3 SAND Moderate brown-red vf-fine, trace Silt, little fine-crs Gravel to 1" dia	Saturated Solvent odor, oil sheen > 25 ppm in Augers background in breathing zone
7		12 13	14 22 35 33	1.7 / 2.0		1.7 SAND Moderate brown-red vf-fine, trace Silt, little fine-crs Gravel, sub-rnd to 1" dia	SATURATED - wet
8		14 15	16 36 59 51	1.6 / 2.0		1.6 SAND A/A appears to increase in density @ approx 14.8' bgs as indicated by blow counts, SAND unit appears to be "drier", probable increase in Silt content	Wet - moist

Sheet No. 1 of ___

MALCOLM PIRNIE

FIELD BOREHOLE LOG

CLIENT City of Rochester
PROJECT Rochester Fire Academy
LOCATION RFA
CONTRACTOR Bflo Drlg
METHOD OF BORING: SOIL 4 1/4" HSA
ROCK

JOB NO. 0965 071
LOGGED BY J. P. Hilton
CORE DIA.

BOREHOLE NO. TB-1
STARTED 8:30 AM 10/30 1991
FINISHED M 10/30 1991
ELEVATIONS: DATUM

SAMPLE NO.	TYPE	DEPTH	BLOWS "N"	RECOVERY %	MOISTURE TIN NO.	SAMPLE DESCRIPTION: Color, Texture Classification, Compactness/Consistency, Moisture Condition, Weathering/Fracturing, Inclusions, Odor, Etc.	NOTES: Boring, Testing and Sampling Procedures, Water Loss and Gain Drilling and Testing Equipment, Etc.
9		16 17	7 38 80 55	1.5/2.0		1.5 SAND Moderate brown-red vf-fine, trace Silt, little fine-Crs Gravel to 1 1/2" dia	Wet Considerable solvent like odor 25-30 ppm across opened spoon sample
10		18 19	23 26 22 28	1.6/2.0		1.6 SAND A/A w/ minor sorted fine grain SAND partings .2-.3' w/o gravel	Wet - Saturated
11		20 21	14 39 100 –	.9/1.3		.9 SAND Moderate tan-brown vf fine, little fine - Crs Gravel to 3/4" dia	wet - Saturated borehole making little water 100 cnt/.3'
12		22 23	47 100 – –	.8/.8		.8 SAND Moderate tan-brown vf, trace - little Silt, little fine-Crs sub-rnd Gravel to 3/4" dia	Wet - Moist 100 cnt/.3'
13		24 25	100 – – –	.45/.45		.45 SAND A/A w/ trace - little Silt dense, moist sand unit	Moist 100 cnt/.45'
14		26 27	Augered 32 114 100	1.0/1.45		1.0 SAND, Moderate brown-tan, vf, trace - little Silt, fine-Crs sub-rnd Gravel to 3/4" dia	Rock & Cobbles @ approx 25-28' interval 100 cnt/.45
15		28 29	44 65 100 –	.9/1.3		.9 SAND A/A, little - some fine - Crs Gravel to 3/4" dia	moist - wet 100 cnt/.25
16		30 31	100 – – –	/.25		Bedrock & auger refusal @ approx 29.8' bgs	100 cnt/.25

Sheet No. 2 of

MALCOLM PIRNIE

FIELD BOREHOLE LOG

CLIENT: City of Rochester
PROJECT: Rochester Fire Academy
LOCATION: RFA
CONTRACTOR: Buffalo Drilling
METHOD OF BORING: SOIL: 4 1/4" HSA
ROCK:

JOB NO.: 0965-071
LOGGED BY: J.P. Hilton
CORE DIA.:

BOREHOLE NO.: LO-2
STARTED: 10:00 A 10/31/1991
FINISHED: 2:30 P 10/31/1991
ELEVATIONS: DATUM

SAMPLE NO.	TYPE (HNU)	DEPTH	BLOWS "N"	RECOVERY %	MOISTURE TIN NO.	SAMPLE DESCRIPTION: Color, Texture Classification, Compactness/Consistency, Moisture Condition, Weathering/Fracturing, Inclusions, Odor, Etc.	NOTES: Boring, Testing and Sampling Procedures, Water Loss and Gain, Drilling and Testing Equipment, Etc.
1	6.2	1 2	2 4 5 5	1.7 / 2.0		.2 Topsoil Black-brown Silt and vf Sand, organic 1.5 Clay light red-gray, semi-plastic w/ dry Silt laminae minor vf Sand parting ≤.1'	DRY - Moist Moist
2	220	3 4	5 8 7 9	1.7 / 2.0		.6 Clay A/A 1.1 Silt moderate gray-brown, little Clay as partings 3-5 mm thick, gradational color change to red-brown	Moist
3	240	5 6	5 6 7 7	1.7 / 2.0		.3 Clay light brown-red, trace Silt .3 Silt and vf Sand, moderate brown 1.1 Clay moderate brown-red, firm, moderate plasticity, trace Silt w/in matrix and laminae	Moist Saturated moist
4	280	7 8	10 10 16 54	1.2 / 2.0		.4 Sand and Silt moderate red-brown vf-f w/ Silt Clay partings ≤3 mm .8 Sand moderate gray-brown fine-med, little fine-Crs sub-rnd Gravel	Saturated Strong solvent odor >30 ppm in spoon
5	300	9 10	16 18 17 21	1.6 / 2.0		1.6 Sand light brown-gray, vf-fine, trace Silt little fine-Crs Gravel	Moist - Wet
6	200	11 12	10 16 19 27	1.5 / 2.0		1.5 Sand A/A	Moist - Wet
7	5.2	13 14	11 22 42 38	1.5 / 2.0		.3 Sand dark-moderate gray, fine-med, trace fine sub-rnd Grvl 1.2 Sand moderate gray-red, vf-fine, little fine-Crs Grvl to 3/4" dia	Saturated Moist - Wet 150 ppm w/in augers
8	80	15 16	22 46 48 40	1.2 / 2.0		1.2 Sand moderate gray-brown vfine-fine, little fine-Crs Gravel to 1" dia, minor-occasional gray medium Sand parting .1' thick, sorted	Wet - Moist

Sheet No. 1 of 2

MALCOLM PIRNIE

FIELD BOREHOLE LOG

CLIENT: City of Rochester
PROJECT: RFA
LOCATION:
CONTRACTOR: Buffalo Drlg
METHOD OF BORING: SOIL: 4 1/4" HSA
ROCK:

JOB NO. 0365 071
LOGGED BY: JPH
CORE DIA.

BOREHOLE NO. LO-2
STARTED 10 AM 10/31 19 91
FINISHED 2 30 PM 10/31 19 91
ELEVATIONS: DATUM

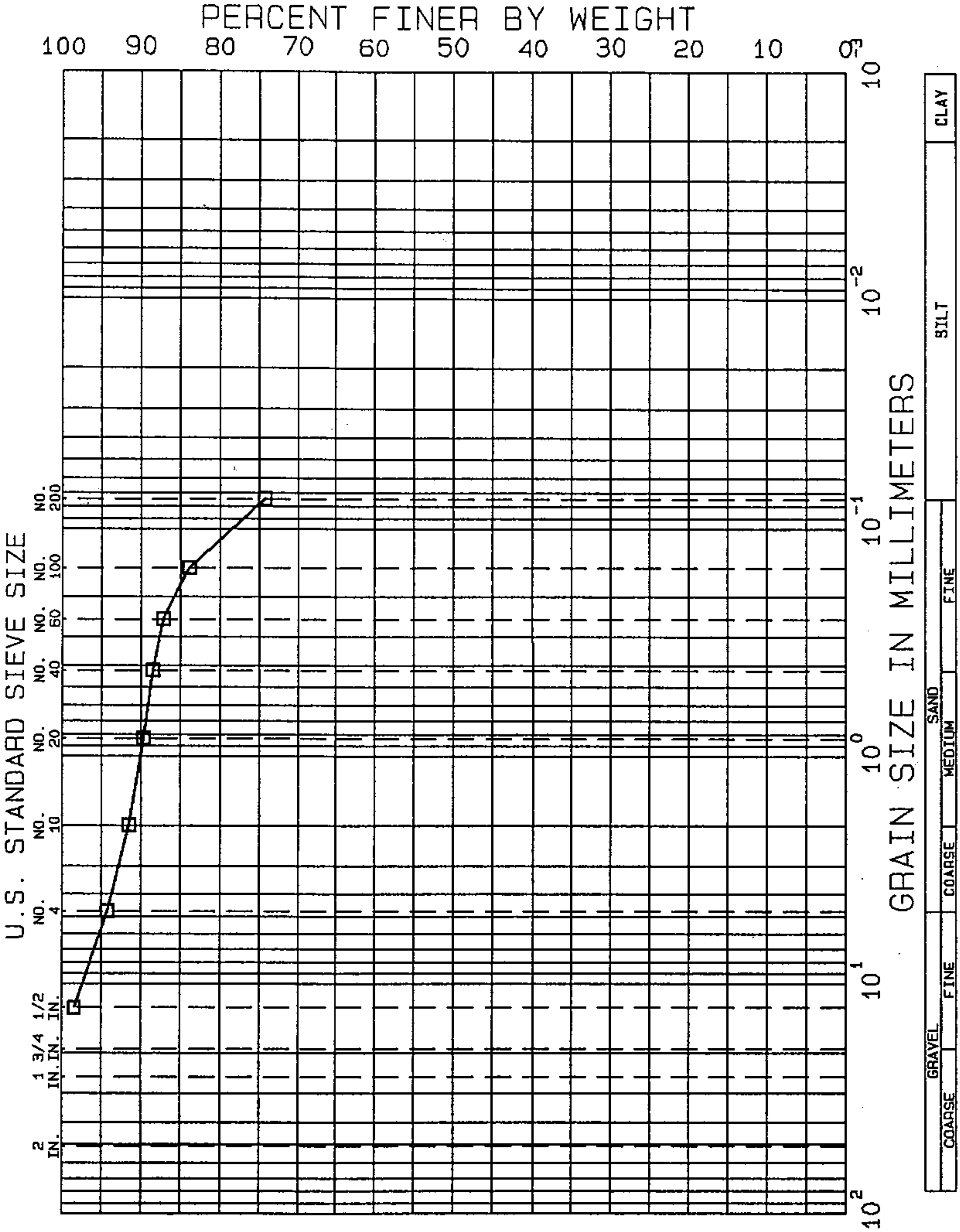
SAMPLE NO.	TYPE (HNu)	DEPTH	BLOWS "N"	RECOVERY %	MOISTURE TIN NO.	SAMPLE DESCRIPTION: Color, Texture Classification, Compactness/Consistency, Moisture Condition, Weathering/Fracturing, Inclusions, Odor, Etc.	NOTES: Boring, Testing and Sampling Procedures, Water Loss and Gain Drilling and Testing Equipment, Etc.
9	1.2	17 18	7 6 5 4	.7 / 2.0		.7 SAND, Moderate brown-gray fine, little fine-Crs Gravel to 1/2" dia	SATURATED lost considerable amt of spoon sample, presumably "loose" gray med wash sand
10	11.4	19 20	11 15 20 32	.9 / 2.0		.9 SAND, light gray-brown vf-fine, trace silt, little fine-Crs Grvl to 1" dia	WET-MOIST
11	2.8	21 22	10 18 39 71	1.0 / 2.0		1.0 SAND A/A	moist-Wet
12	3.6	23 24	21 50 22 32	1.1 / 2.0		1.1 SAND Moderate gray-brown vf-fine, trace silt little fine-Crs sub-rnd gravel to 3/4" dia, occasional fine-med gray Sand parting < .1' thick	Moist - Wet
13	2.4	25 26	29 47 61 64	1.4 / 2.0		1.4 SAND Moderate gray-brown vf-fine A/A w/ Gravel to 1" dia	Moist
14	3.2	27 28	36 71 100 —	1.4 / 1.4		1.4 SAND A/A	Moist 100 cnt/.4
15	3.0	29 30	78 100 — —	.9 / .9		.9 SAND A/A	Moist 100 cnt/.4
16	7.8	31 32	36 99 94 100	1.4 / 1.9		1.4 SAND Moderate-light brown-gray vf-fine, trace silt, little fine-C/s sub-rnd gravel to 1/2" dia Rock 32'	Moist

Sheet No. 2 of 2

MALCOLM PIRNIE

MALCOLM PIRNIE

B.2 Grain Size Analytical Results for PW-1

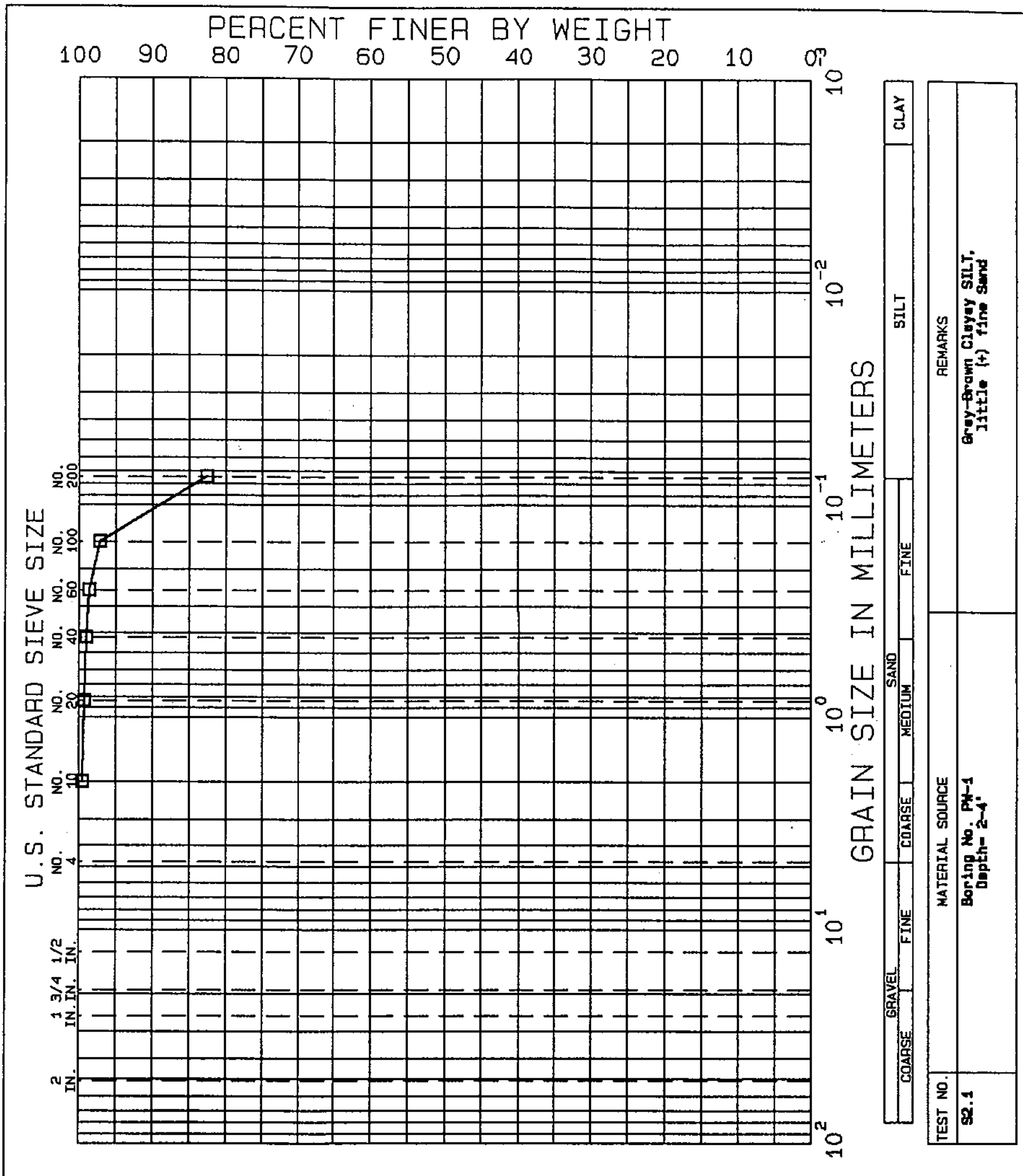


TEST NO.	MATERIAL SOURCE	REMARKS
S1.1	Boring No. PW-1 Depth- 0-2'	Brown Clayey SILT, some (-) fine Sand, trace Gravel

ROCHESTER FIRE ACADEMY
ROCHESTER, N.Y.
GRADATION TESTS

BORING NO. PW-1
SAMPLE
DEPTH 0-2'
TECH. BF
REVIEWER DAS

TEST SERIES NO. 1
DATE Dec. 91
FILE L12783

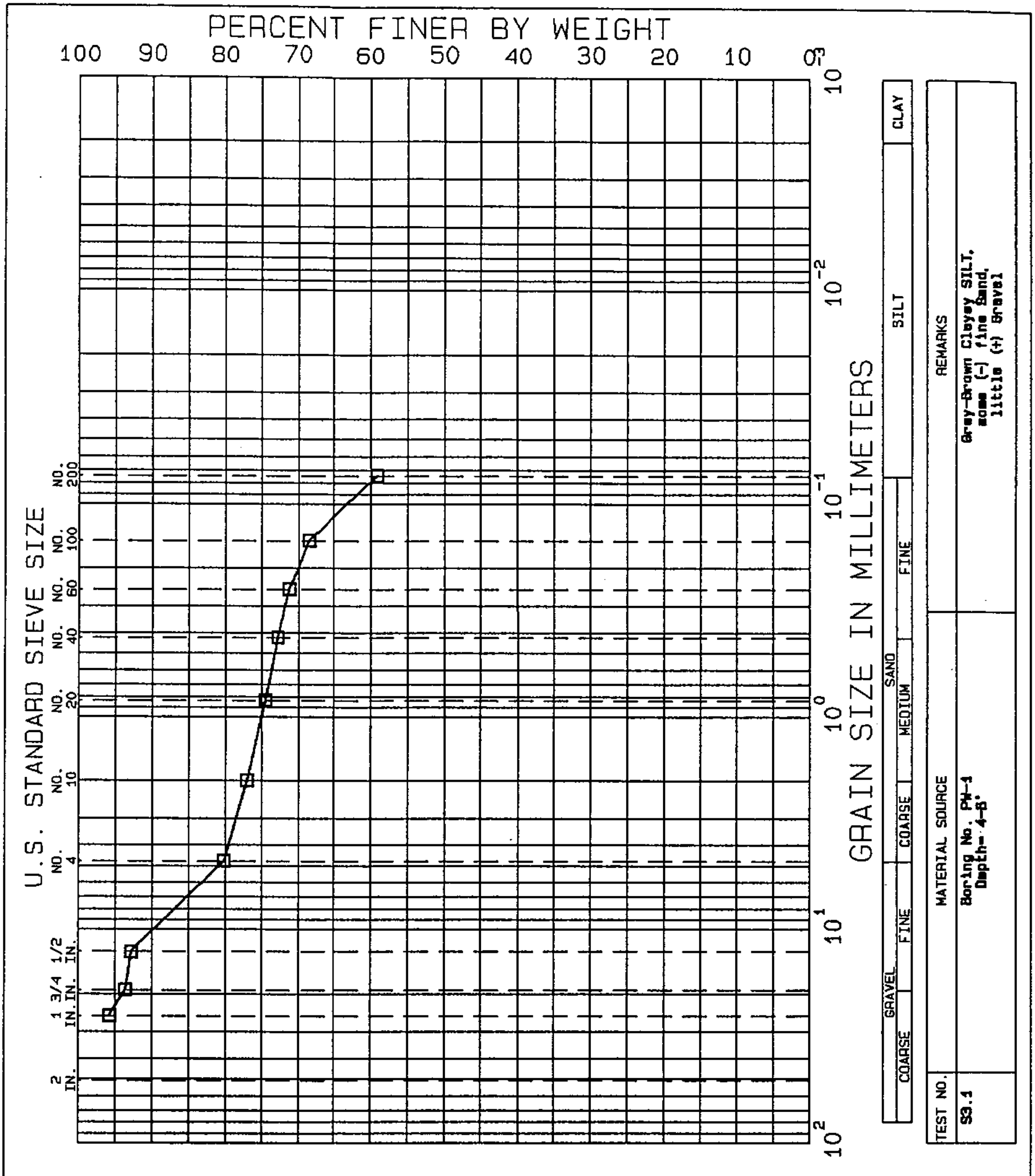


ROCHESTER FIRE ACADEMY
ROCHESTER, N.Y.
GRADATION TESTS

BORING NO. PM-1
SAMPLE
DEPTH 2-4'
TECH. BF
REVIEWER DAS

TEST SERIES NO. 2
DATE Dec. 91

FILE L12783

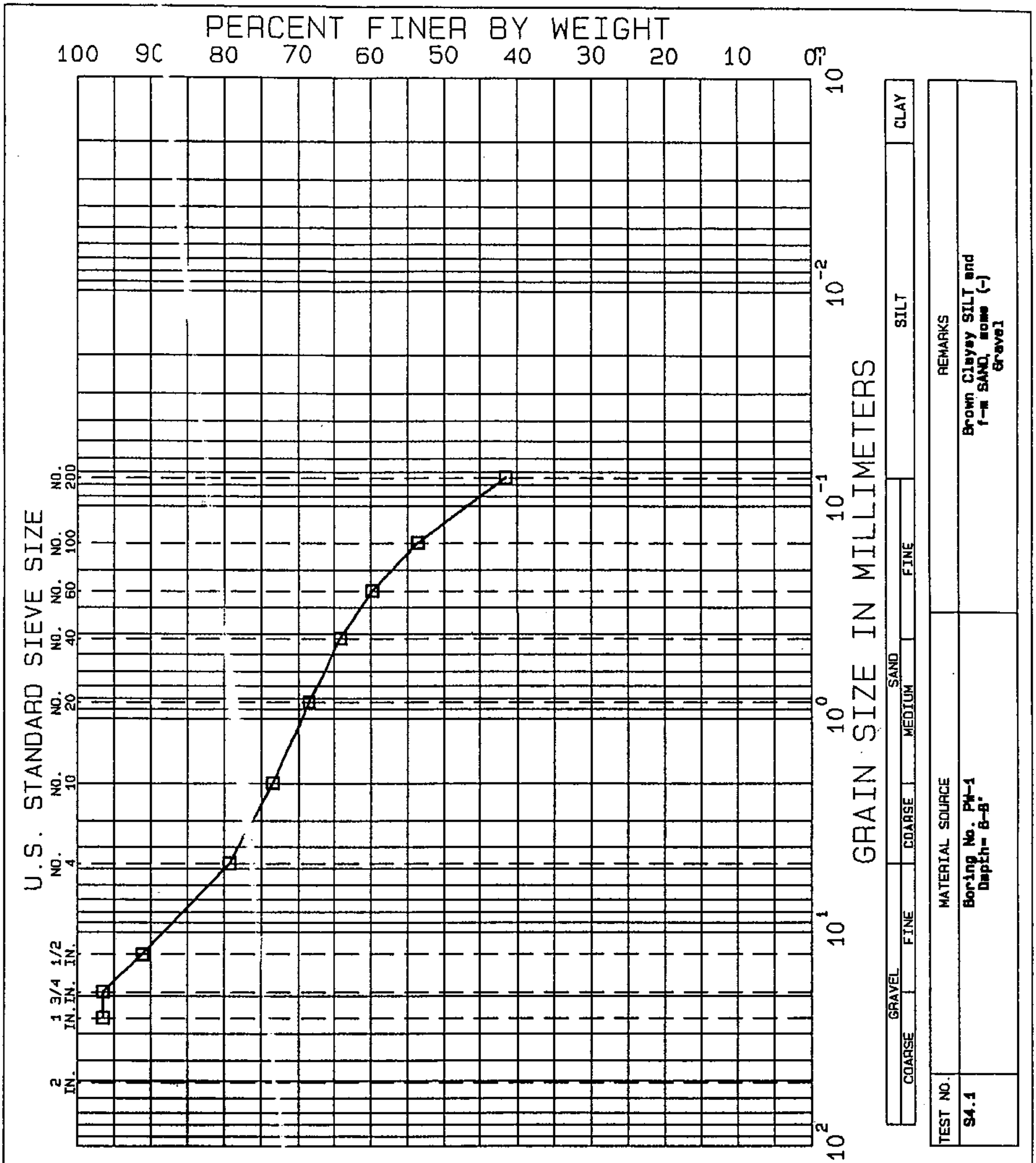


ROCHESTER FIRE ACADEMY

ROCHESTER, N.Y.

GRADATION TESTS

BORING NO. **PW-1**	TEST SERIES
SAMPLE	NO. **3**
DEPTH **4-6'**	DATE **Dec. 91**
TECH. **SF**	
REVIEWER **DAS**	FILE **L12783**

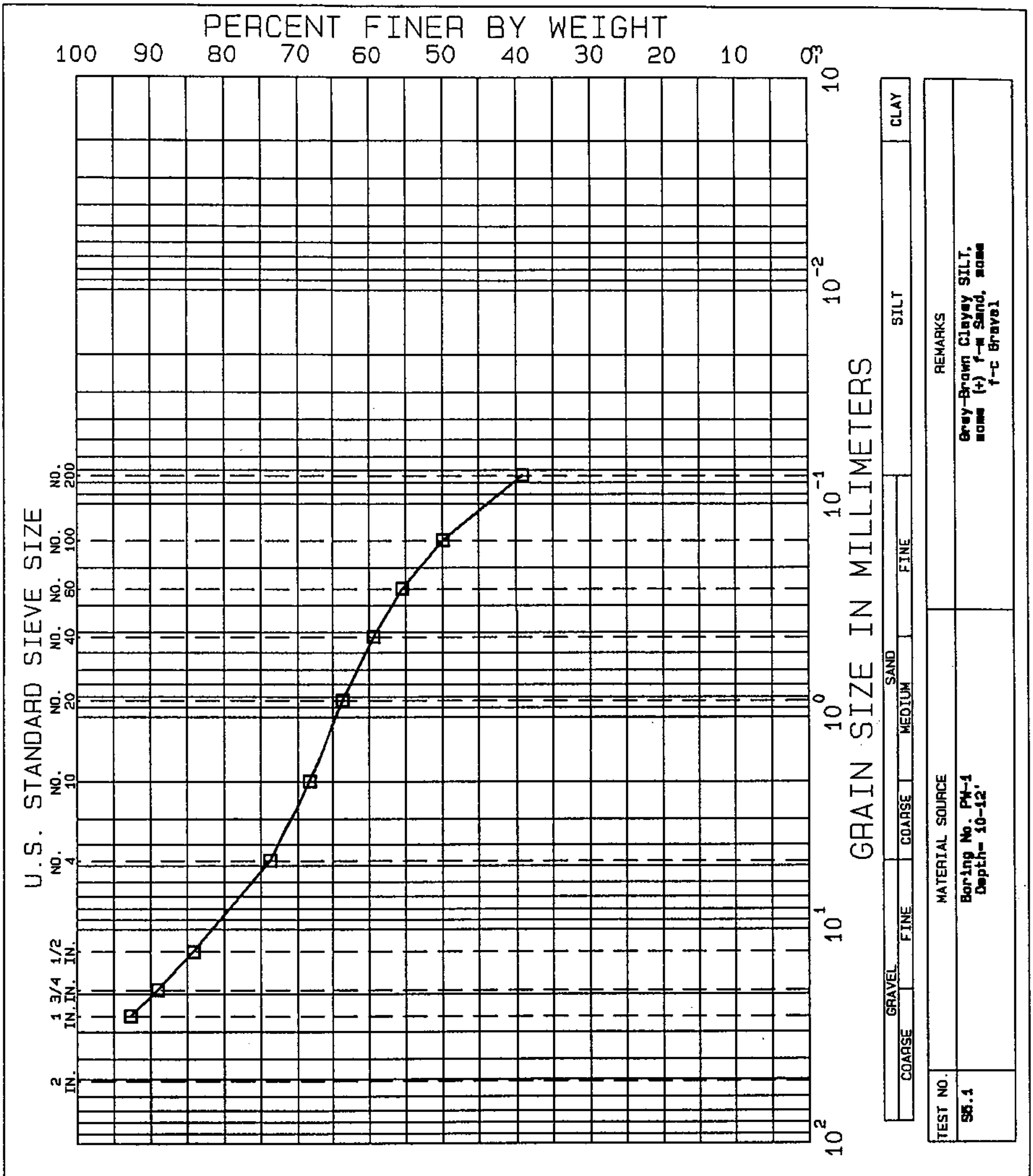


ROCHESTER FIRE ACADEMY
ROCHESTER, N.Y.
GRADATION TESTS

BORING NO. PW-1
SAMPLE
DEPTH 6-8'
TECH. BF
REVIEWER DAS

TEST SERIES
NO. 4
DATE Dec. 91

FILE L12783

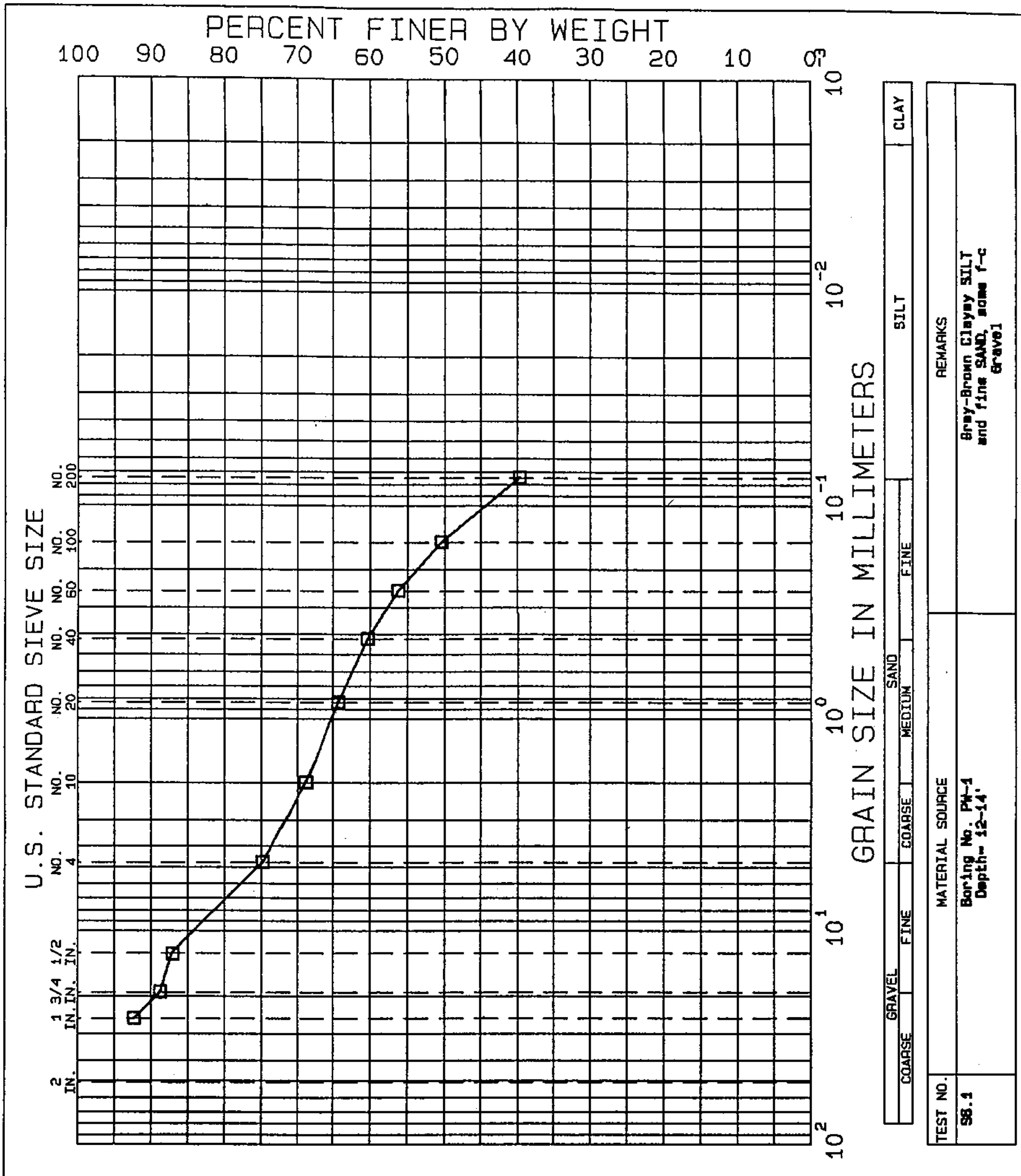


ROCHESTER FIRE ACADEMY
ROCHESTER, N.Y.
GRADATION TESTS

BORING NO. PW-1
SAMPLE
DEPTH 10-12'
TECH. BF
REVIEWER DAS

TEST SERIES
NO. 5
DATE Dec. 91

FILE L12783

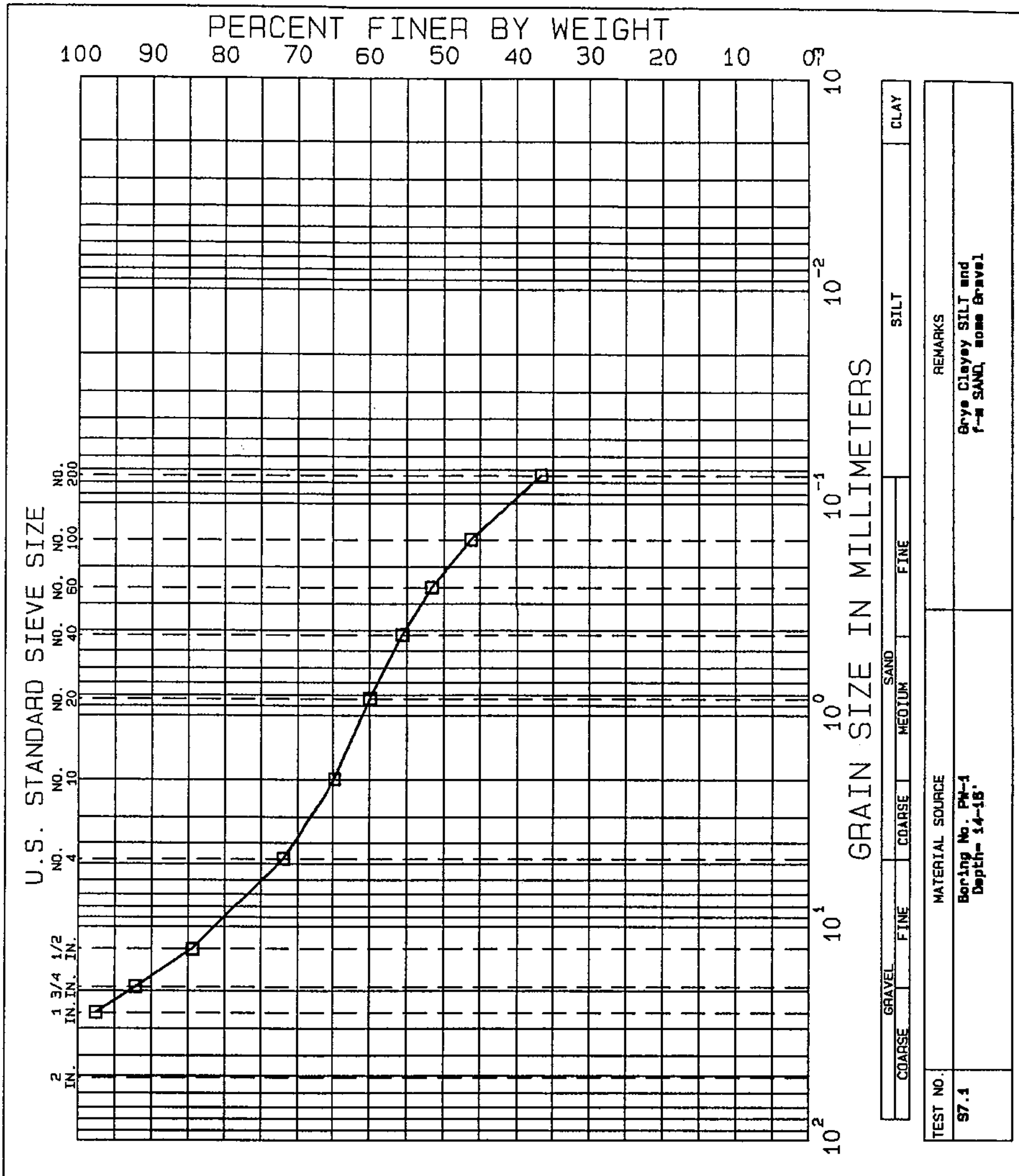


ROCHESTER FIRE ACADEMY

ROCHESTER, N.Y.

GRADATION TESTS

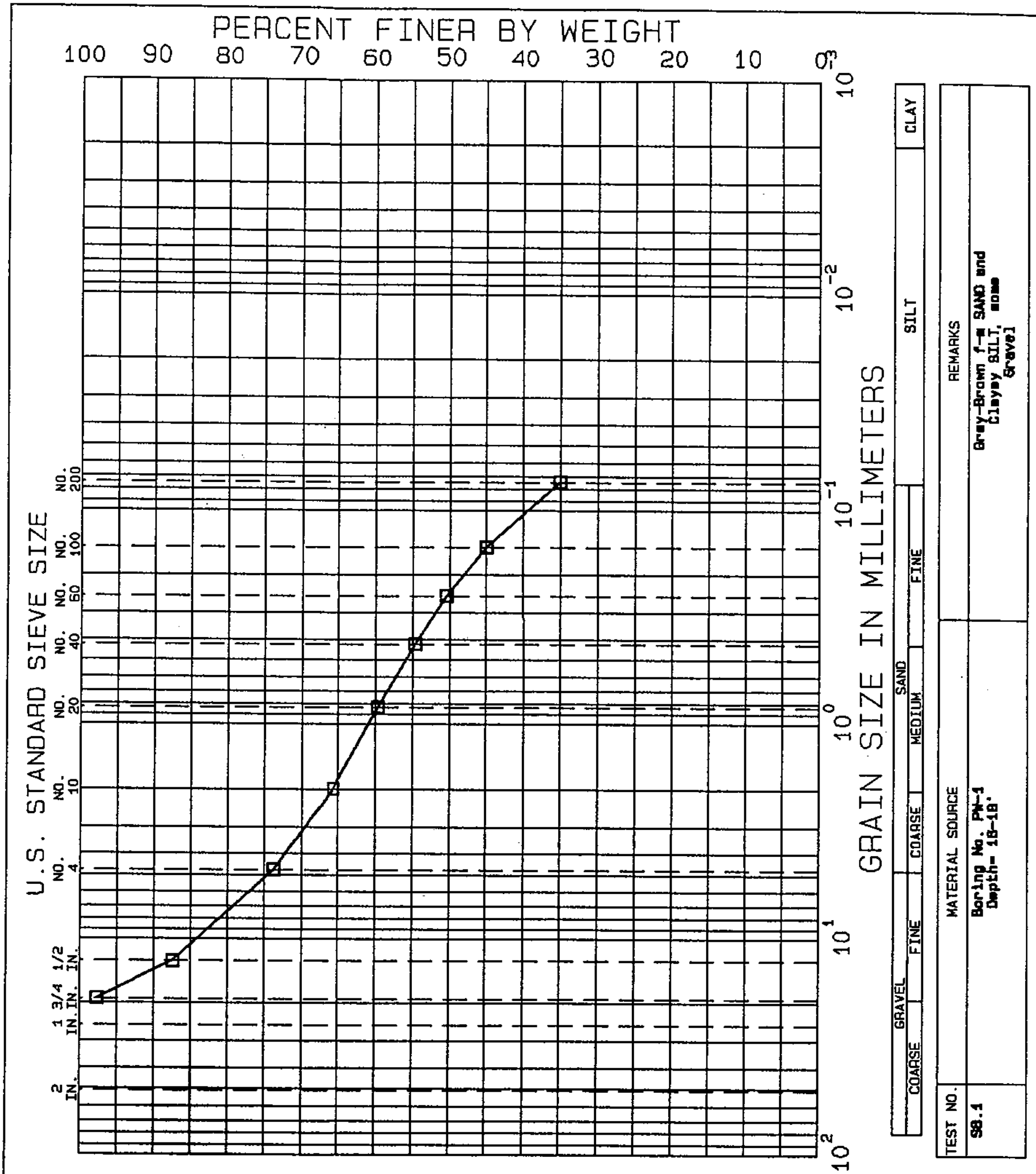
BORING NO. **PW-1**		TEST SERIES
SAMPLE		NO. **8**
DEPTH	**12-14'**	DATE **Dec. 91**
TECH.	**BF**	
REVIEWER	**DAS**	FILE **L12783**



ROCHESTER FIRE ACADEMY
ROCHESTER, N.Y.
GRADATION TESTS

BORING NO. **PW-1**
SAMPLE
DEPTH **14-16'**
TECH. **BF**
REVIEWER **DAS**

TEST SERIES NO. **7**
DATE **Dec. 91**
FILE **L12783**

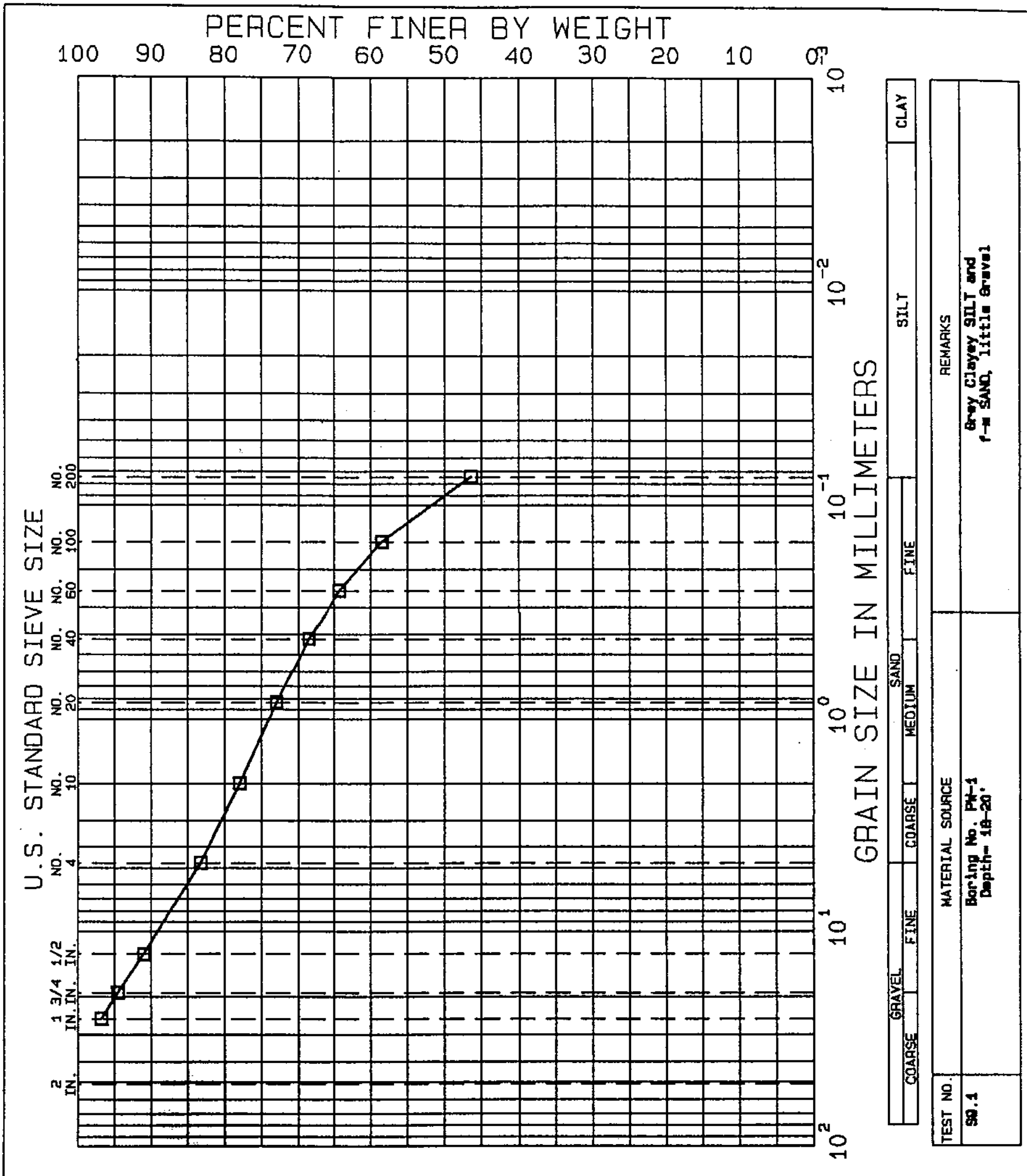


ROCHESTER FIRE ACADEMY
ROCHESTER, N.Y.
GRADATION TESTS

BORING NO. PW-1
SAMPLE
DEPTH 16-18'
TECH. BF
REVIEWER DAS

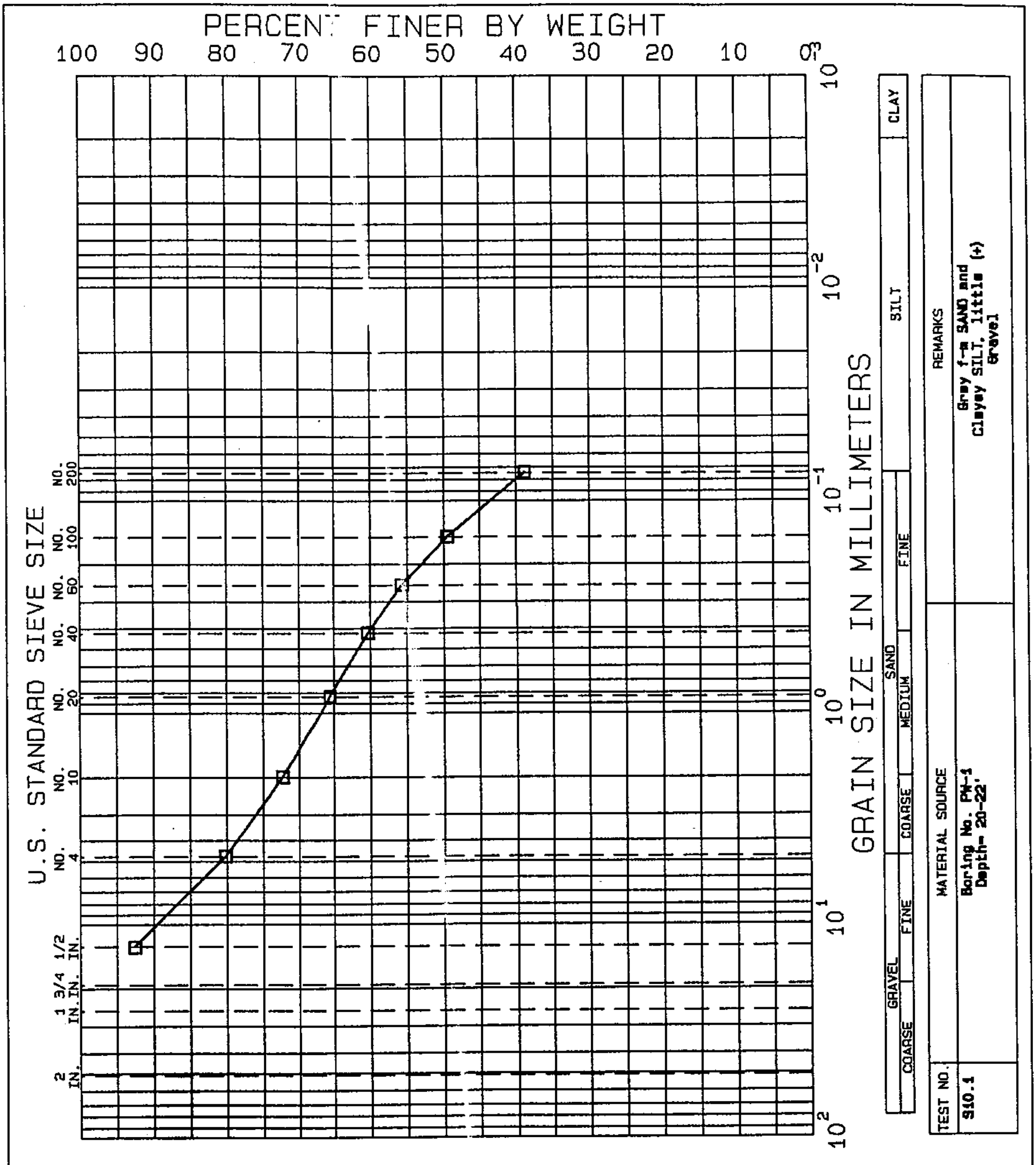
TEST SERIES
NO. 8
DATE Dec. 91

FILE L12783



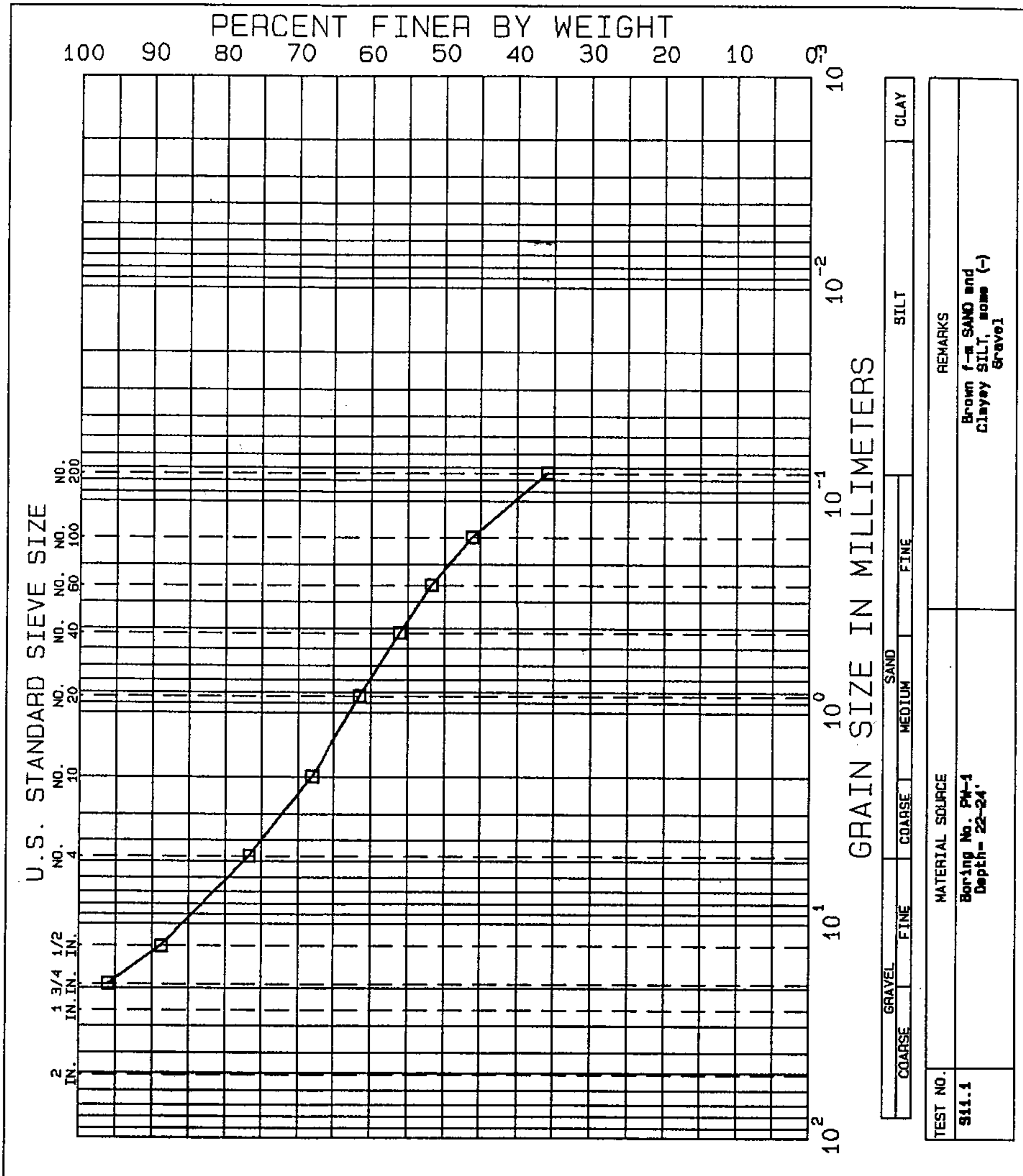
ROCHESTER FIRE ACADEMY
ROCHESTER, N.Y.
GRADATION TESTS

BORING NO.	PW-1	TEST SERIES NO.	9
SAMPLE		DATE	Dec. 91
DEPTH	18-20'		
TECH.	SF		
REVIEWER	DAS	FILE	L12783



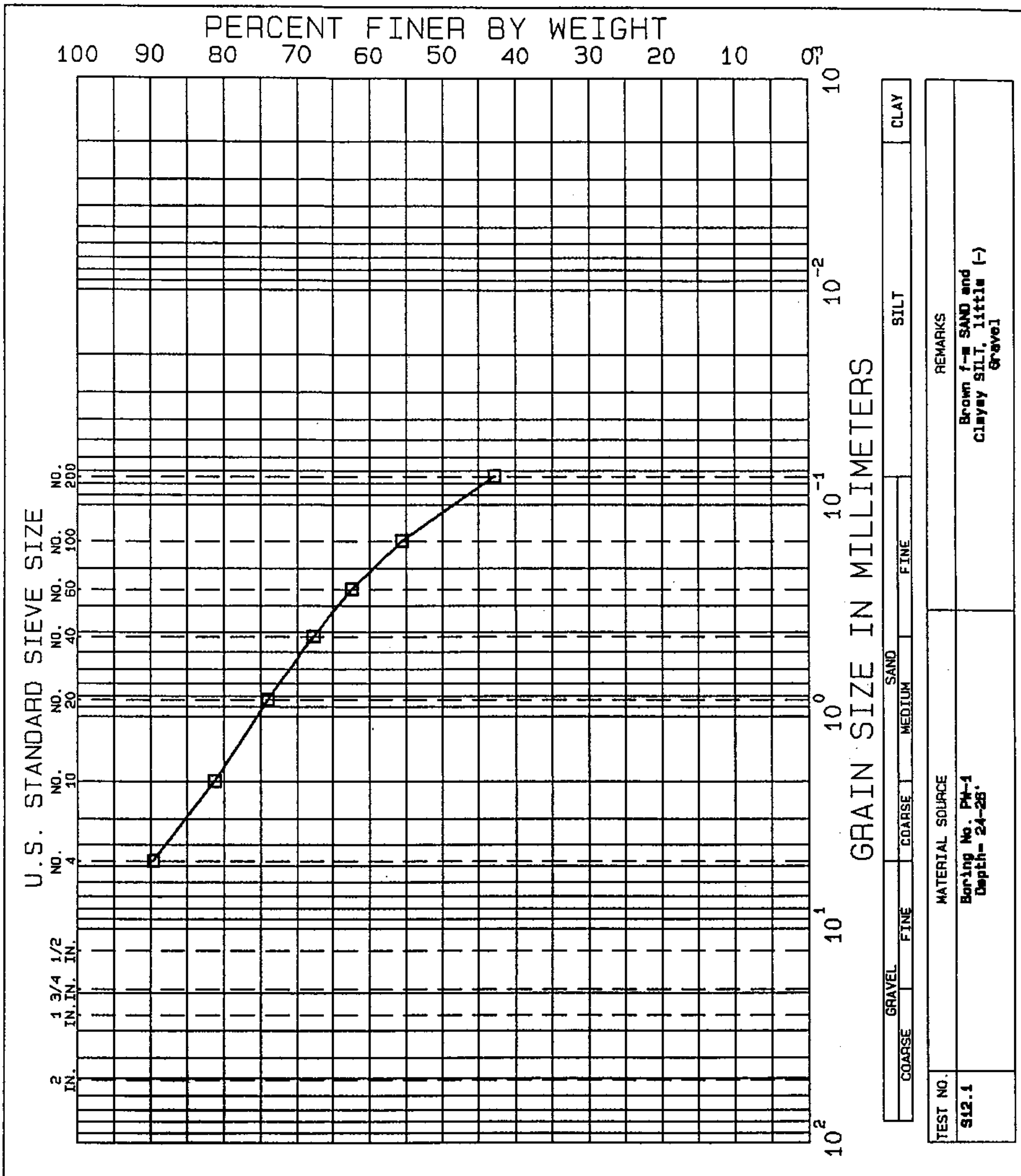
ROCHESTER FIRE ACADEMY
ROCHESTER, N.Y.
GRADATION TESTS

BORING NO. PW-1	TEST SERIES
SAMPLE	NO. 10
DEPTH 20-22'	DATE Dec. 91
TECH. BF	
REVIEWER DAB	FILE L12783



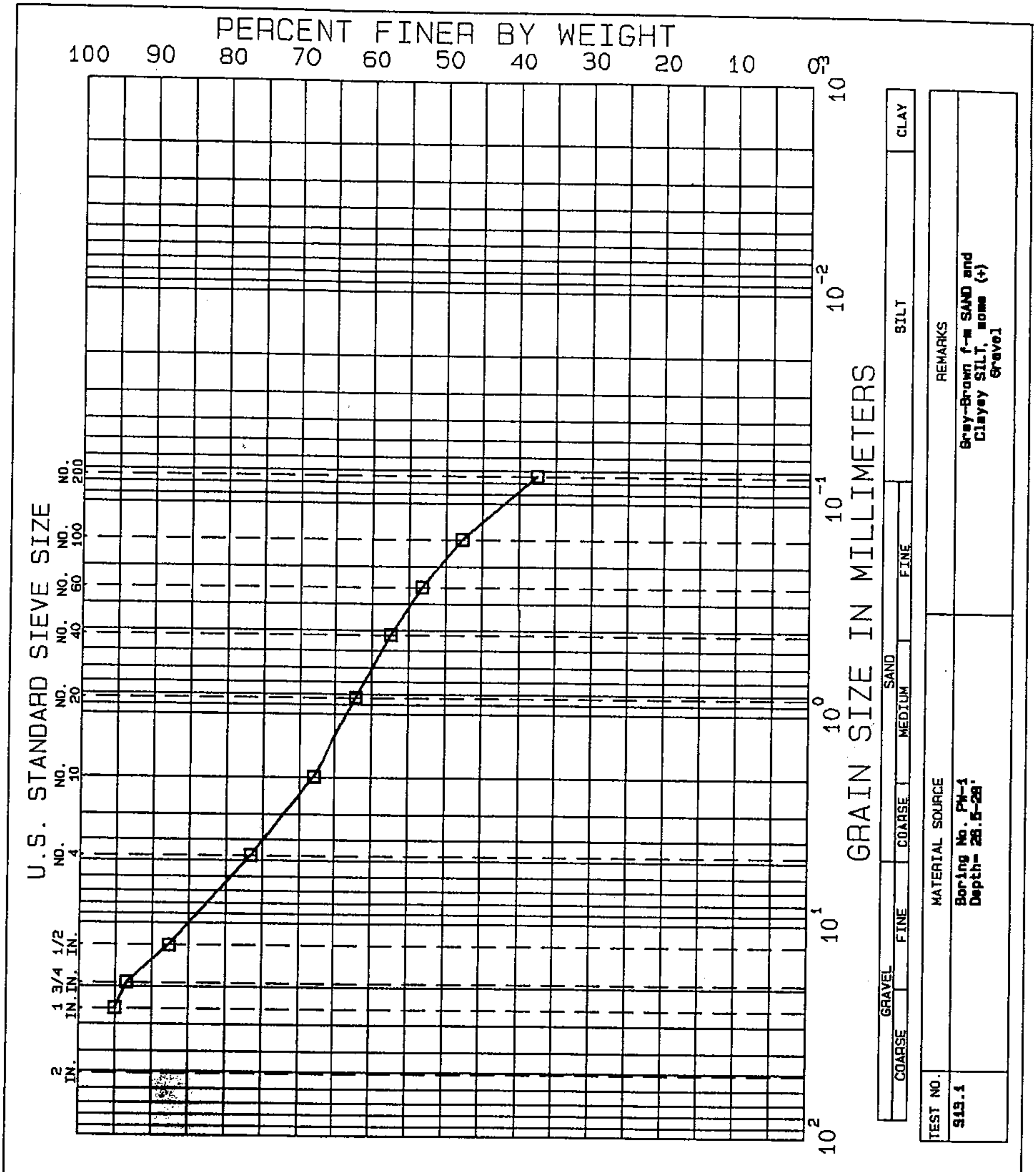
ROCHESTER FIRE ACADEMY
ROCHESTER, N.Y.
GRADATION TESTS

BORING NO.	PW-1	TEST SERIES NO.	11
SAMPLE DEPTH	22-24'	DATE	Dec. 91
TECH.	BF		
REVIEWER	DAS	FILE	L12783



ROCHESTER FIRE ACADEMY
ROCHESTER, N.Y.
GRADATION TESTS

BORING NO.	PW-1	TEST SERIES NO.	12
SAMPLE		DATE	Dec. 91
DEPTH	24-26'		
TECH.	BF		
REVIEWER	DAS	FILE	L12783

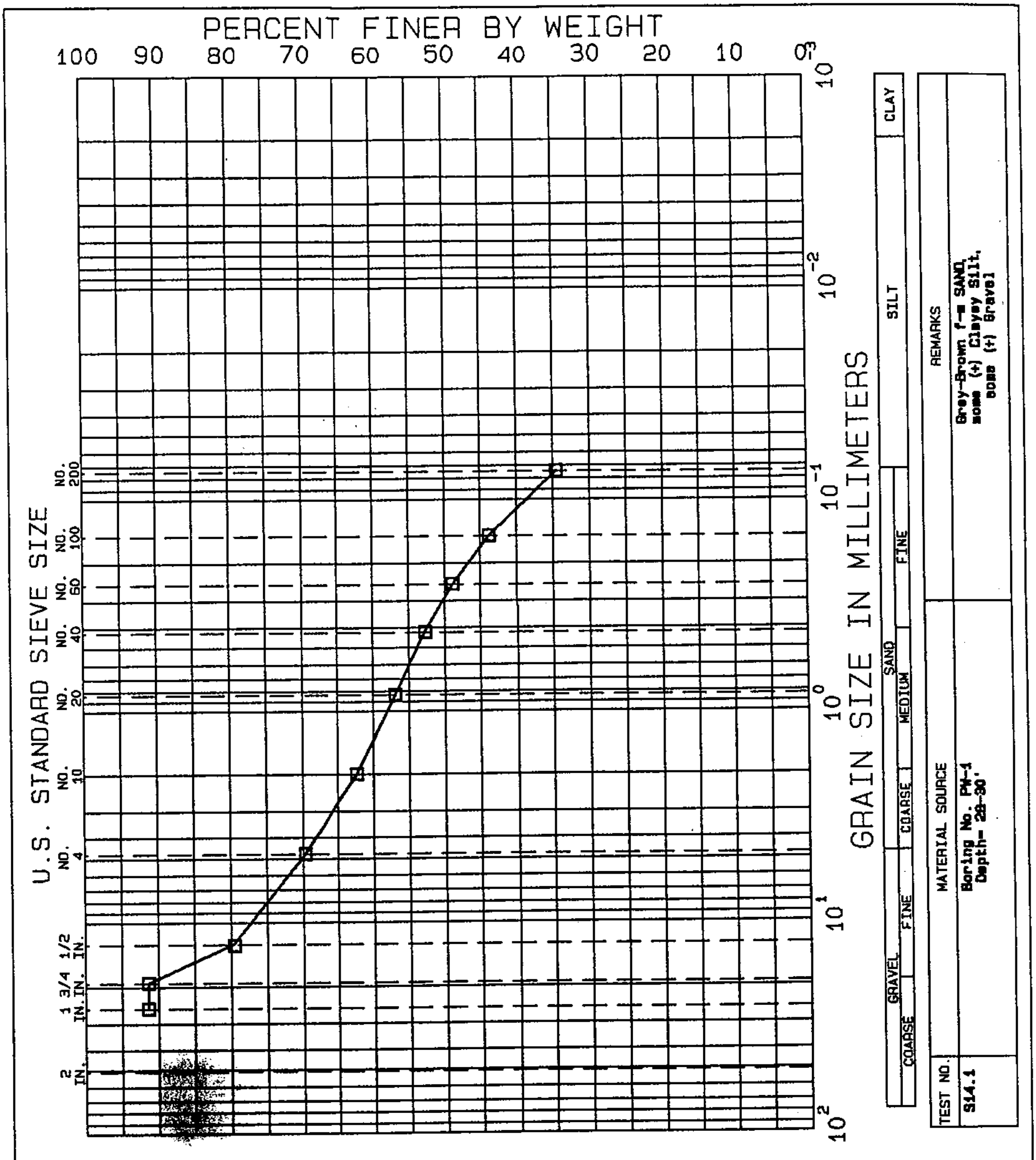


ROCHESTER FIRE ACADEMY
ROCHESTER, N.Y.
GRADATION TESTS

BORING NO. PW-1
SAMPLE
DEPTH 26.5-28'
TECH. BF
REVIEWER DAS

TEST SERIES
NO. 13
DATE Dec. 91

FILE L12783



ROCHESTER FIRE ACADEMY
ROCHESTER, N.Y.
GRADATION TESTS

BORING NO. PW-1
SAMPLE
DEPTH 28-30'
TECH. BF
REVIEWER DAS

TEST SERIES NO. 14
DATE Dec. 91

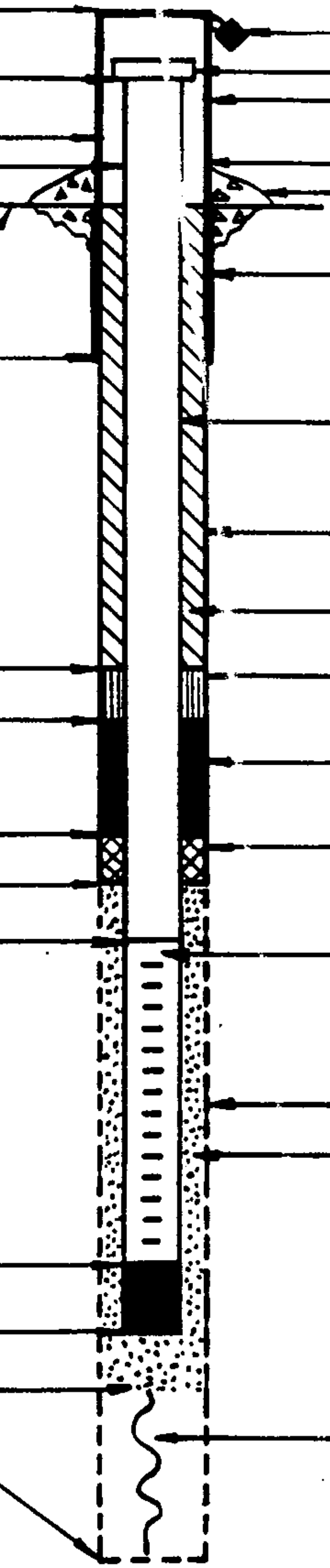
FILE L12783

MALCOLM PIRNIE

B.3 Well Construction Details

MONITORING WELL CONSTRUCTION LOG

PROJECT: Rochester Fire Academy
LOCATION: ______
PROJECT NO.: 0965 071
BORING: LO-1
GROUND ELEV.: 517.19
DATE: 10/29/91
FIELD GEOLOGIST: J.P. Hilton
DRILLER: C. Nicometti
DRILLING METHOD: 4 1/4" HSA
DEVELOPMENT METHOD: Bailing



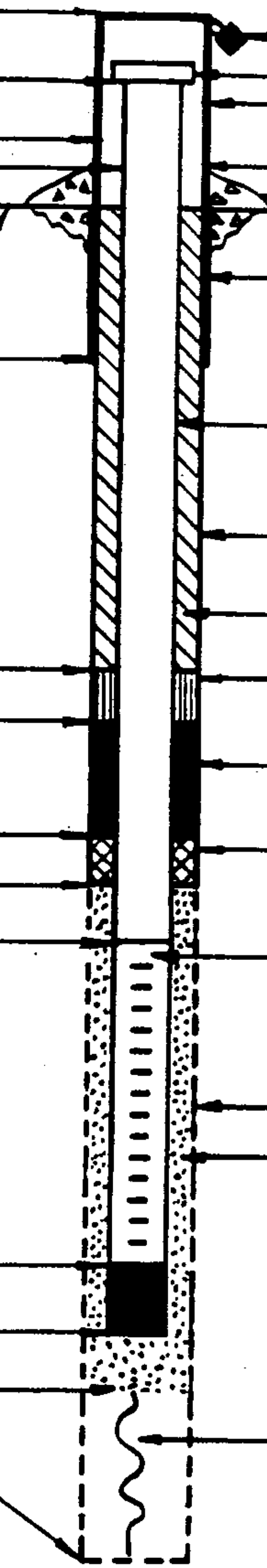
ELEV. OF TOP OF PROTECTIVE CASING: 519.76 ft. AMSL
ELEV. OF TOP OF RISER PIPE: 519.54 ft. AMSL
STICK-UP TOP OF PROTECTIVE CASING: 2.57 ft.
STICK-UP RISER PIPE: 2.35 ft.
GROUND SURFACE ELEV.
DEPTH BOTTOM OF SURFACE CASING: 2.43 ft.
DEPTH TOP OF GROUT INVASION BARRIER: 13 ft.
DEPTH TOP OF SEAL: 13.7 ft.
DEPTH TOP OF SECONDARY SAND PACK: NA ft.
DEPTH TOP OF PRIMARY SAND PACK: 18 ft.
DEPTH TOP OF SCREEN: 19.7 ft.
DEPTH BOTTOM OF SCREEN: 29.7 ft.
DEPTH BOTTOM OF SCREEN CAP: 29.7 ft.
DEPTH BOTTOM OF SAND PACK: 30' ft.
DEPTH OF HOLE: 30' ft.

LOCKING COVER
WELL CAP
I.D. x LENGTH OF PROTECTIVE CASING: 6" x 5' ft.
1/4" WEEP HOLE
TYPE OF SURFACE SEAL: Cement / Bentonite
I.D. OF SURFACE CASING: 6" ft.
TYPE OF SURFACE CASING: Steel
RISER PIPE I.D. 2" ft.
TYPE OF RISER PIPE: Sch 40 PVC
BOREHOLE DIA.: 8" ft.
TYPE OF BACKFILL: cement + Grout
TYPE OF BARRIER: #2 SAND
TYPE OF SEAL: 3/8" Bentonite Pellets
TYPE OF SAND PACK: NA
TYPE OF SCREEN: Sch 40 PVC
SLOT SIZE x LENGTH: .010 x 10' ft.
I.D. OF SCREEN: 2" ft.
BOREHOLE DIA.: 8" ft.
TYPE OF SAND PACK: #2 Q-ROK
TYPE OF BACKFILL BELOW OBSERVATION WELL: #2 Q-ROK

MALCOLM PIRNIE

MONITORING WELL CONSTRUCTION LOG

PROJECT: Rochester Fire Academy
LOCATION: Rochester
DRILLER: K. Huber
PROJECT NO.: 0965 071
BORING: ~~—~~ LO-2
DRILLING METHOD: 4 1/4" HSA
GROUND ELEV.: 520.11
DATE: 10/31/91 * 11/16/91
FIELD GEOLOGIST: J.P. Hilton
DEVELOPMENT METHOD: Bailing
* Re-installed - damaged



ELEV. OF TOP OF PROTECTIVE CASING: 521.97 ft. AMSL

ELEV. OF TOP OF RISER PIPE: 521.74 ft. AMSL

STICK-UP TOP OF PROTECTIVE CASING: 1.86 ft.

STICK-UP RISER PIPE: 1.63 ft.

GROUND SURFACE ELEV.

DEPTH BOTTOM OF SURFACE CASING: 3.~~75~~ ft.

DEPTH TOP OF GROUT INVASION BARRIER: NA ft.

DEPTH TOP OF SEAL: ~~16.0'~~ 18.1 ft.

DEPTH TOP OF SECONDARY SAND PACK: NA ft.

DEPTH TOP OF PRIMARY SAND PACK: ~~20.0~~ 22.5 ft.

DEPTH TOP OF SCREEN ~~21.7~~ 23.5 ft.

DEPTH BOTTOM OF SCREEN: ~~31.7~~ 28.5 ft.

DEPTH BOTTOM OF SCREEN CAP: ~~32.0~~ 21.5 ft.

DEPTH BOTTOM OF SAND PACK: ~~32.3~~ 21.5 ft.

DEPTH OF HOLE: ~~32.5~~ 32 ft.

LOCKING COVER

WELL CAP

I.D. x LENGTH OF PROTECTIVE CASING: 4" X 5' ft.

1/4" WEEP HOLE

TYPE OF SURFACE SEAL: Cement Grout

I.D. OF SURFACE CASING: 4" ft.

TYPE OF SURFACE CASING: Steel

RISER PIPE I.D. 2" ft.

TYPE OF RISER PIPE: Sch 40 PVC

BOREHOLE DIA.: 8" ft.

TYPE OF BACKFILL: Bentonite/Cement Grout

TYPE OF BARRIER: NA

TYPE OF SEAL: 3/8" Bentonite Pellets

TYPE OF SAND PACK: NA

TYPE OF SCREEN: Sch 40 PVC

SLOT SIZE x LENGTH: .010 X 10' ft.

I.D. OF SCREEN: 2" ft.

BOREHOLE DIA.: 8" ft.

TYPE OF SAND PACK: #2 Q-ROK

TYPE OF BACKFILL BELOW OBSERVATION WELL: #2 Q-ROK

MALCOLM PIRNIE

MALCOLM PIRNIE

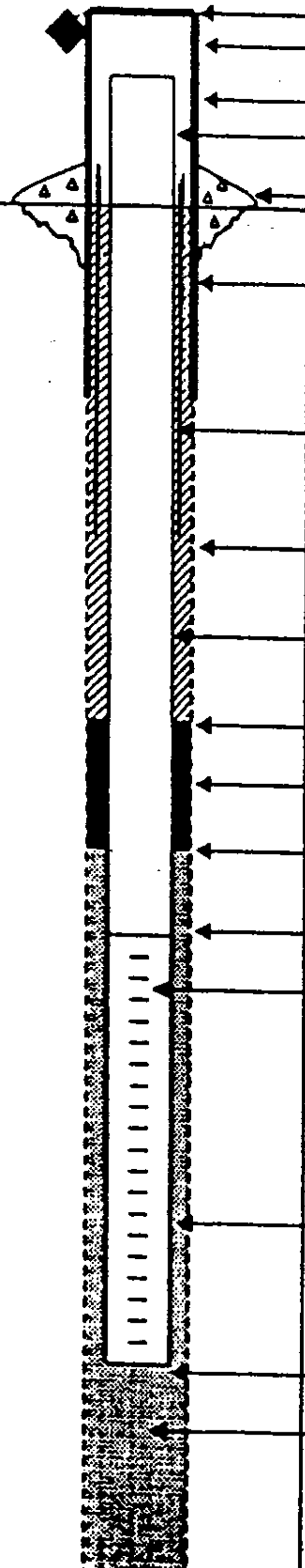
MONITORING WELL SHEET

PROJECT: Supplemental RI
PROJECT NO.: 0965071
ELEVATION: 517.34
FIELD GEOLOGIST: R. Frappa

LOCATION: Fire Academy
BORING: PW-1
DATE: 11/11/91

DRILLER: Buffalo Drilling
DRILLING METHOD: HSA
DEVELOPMENT METHOD: Suction lift pump

GROUND ELEVATION



ELEVATION OF TOP OF SURFACE CASING: 520.16
ELEVATION OF TOP OF RISER PIPE: 520.00
STICK - UP TOP OF SURFACE CASING: 2.82
STICK - UP RISER PIPE: 2.66
TYPE OF SURFACE SEAL: Cement
I.D. OF SURFACE CASING: 6-inch
TYPE OF SURFACE CASING: Steel
I.D. OF OVERBURDEN CASING: N/A
RISER PIPE I.D.: 4-inch
TYPE OF RISER PIPE: SCH-40 PVC
BOREHOLE DIAMETER: 10"
TYPE OF BACKFILL: Cement/Bentonite
DEPTH TOP OF SEAL: 3.5 ft
TYPE OF SEAL: Bentonite Pellets
DEPTH TOP OF SAND PACK: 7.0 ft
DEPTH TOP OF SCREEN: 10 ft
TYPE OF SCREEN: PVC continuous Slot
SLOT SIZE x LENGTH: 10-slot x 10 ft
I.D. OF SCREEN: 4-inch
TYPE OF SAND PACK: #2 Silica Sand
DEPTH BOTTOM OF SCREEN: 20 ft
DEPTH BOTTOM OF SAND PACK: 20.1
TYPE OF BACKFILL BELOW OBSERVATION WELL: Silica Sand
ELEVATION / DEPTH OF HOLE: 20.1

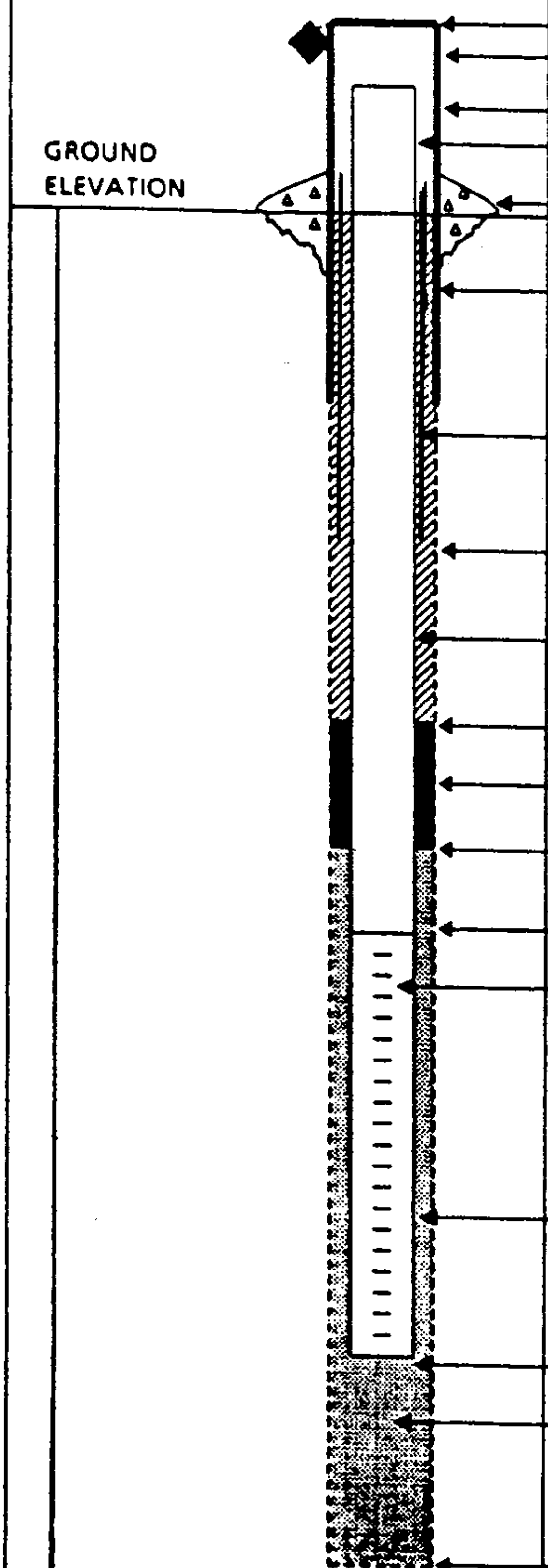
MALCOLM PIRNIE

MONITORING WELL SHEET

PROJECT: Supplemental RI
PROJECT NO.: 0965.07-1
ELEVATION: 519.76
FIELD GEOLOGIST: R. Frappa

LOCATION: South Disposal Area
BORING: PW-2
DATE: 11/8/91 - *11/17/91
* re-drilled
Damaged during installation of LO-2

DRILLER: Buffalo Drilling
DRILLING METHOD: 6 1/4-inch HSA
DEVELOPMENT METHOD: suction lift pump



ELEVATION OF TOP OF SURFACE CASING: 521.77
ELEVATION OF TOP OF RISER PIPE: 521.50

STICK-UP TOP OF SURFACE CASING: 2.01
STICK-UP RISER PIPE: 1.74

TYPE OF SURFACE SEAL: Cement/Bentonite

I.D. OF SURFACE CASING: 6-inch
TYPE OF SURFACE CASING: Steel

I.D. OF OVERBURDEN CASING: N/A
RISER PIPE I.D.: 4-inch
TYPE OF RISER PIPE: SCH40 PVC

BOREHOLE DIAMETER: 10"

TYPE OF BACKFILL: ~~cement~~/Bentonite Silica Sand

DEPTH TOP OF SEAL: 5 ft
TYPE OF SEAL: Bentonite Pellets
DEPTH TOP OF SAND PACK: 9 ft

DEPTH TOP OF SCREEN: 12.5 ~~12~~ ft
TYPE OF SCREEN: PVC Continuous Slot
SLOT SIZE x LENGTH: 10-slot x 10 feet
I.D. OF SCREEN: 4-inch

TYPE OF SAND PACK: #2 Silica Sand

DEPTH BOTTOM OF SCREEN: 22.5 ~~22~~ ft
DEPTH BOTTOM OF SAND PACK: 23.0 ~~22.5~~ ft
TYPE OF BACKFILL BELOW OBSERVATION WELL: #2 silica Sand

ELEVATION / DEPTH OF HOLE: 23.0 ~~22.5~~ ft

MALCOLM PIRNIE

B.4 Well Development Logs

WELL DEVELOPMENT/PURGING LOG

PROJECT TITLE: RFA Supplemental RI

PROJECT NO.: 0965-07-1

STAFF: RHF/RLD

DATE: 11/11-14/91

WELL NO.: PW-1

① TOTAL CASING AND SCREEN LENGTH (FT.): 22'

② CASING INTERNAL DIAMETER (in.): 4"

③ WATER LEVEL BELOW TOP OF CASING (FT.) 8.5 11/14 11/11 8.35

④ VOLUME OF WATER IN CASING (GAL.) ~9 gal

$V = 0.0408\,(②)^2 \times (① - ③) =$ ________ GAL.

WELL I.D.	VOL. GAL./FT.
1"	0.04
2"	0.17
3"	0.38
4"	0.66
5"	1.04
6"	1.50
8"	2.60

PARAMETERS	ACCUMULATED VOLUME PURGED (GALLONS)										
	0	5	12	27	45	95	110				
Clearity (Turbidity NTU)	Gray muddy	Gr/br cloudy >100	√ cloudy >100	Br. cloudy >100	Cloudy >100	22	45				
					*						

COMMENTS: * good improvement

Bailer
+
Suction-lift   Max inflow rate from step test after development
0.25 gpm

MALCOLM PIRNIE

WELL DEVELOPMENT/PURGING LOG

PROJECT TITLE: RFA - Supplemental RI

PROJECT NO.: 0965-07-1

STAFF: RHF/RLD

DATE: 11/11-14/91

WELL NO.: LO-1

① TOTAL CASING AND SCREEN LENGTH (FT.): 30

② CASING INTERNAL DIAMETER (in.): 2"

③ WATER LEVEL BELOW TOP OF CASING (FT.) 11/11 7.4 11/13 7.5

④ VOLUME OF WATER IN CASING (GAL.) ~4

$V = 0.0408 (②)^2 \times (① - ③) =$ ______ GAL.

WELL I.D.	VOL. GAL./FT.
1"	0.04
2"	0.17
3"	0.38
4"	0.66
5"	1.04
6"	1.50
8"	2.60

PARAMETERS	ACCUMULATED VOLUME PURGED (GALLONS)										
	0	5	9	17	25	40					
Turbidity	V. muddy	V. cloudy	V. cloudy	* cloudy	cloudy 60	cloudy/sl. 50					

COMMENTS: * some improvement

Bailer + Suction lift

max inflow rate ~0.3 gpm

MALCOLM PIRNIE

WELL DEVELOPMENT/PURGING LOG

PROJECT TITLE: RFA - Supplemental RI

PROJECT NO.: 0965-074

STAFF: RHF/RLD

DATE: 11/18/98

WELL NO.: PW-2

① TOTAL CASING AND SCREEN LENGTH (FT.): 24'

② CASING INTERNAL DIAMETER (in.): 4"

③ WATER LEVEL BELOW TOP OF CASING (FT.) 9.75

④ VOLUME OF WATER IN CASING (GAL.) ~10.5

$V = 0.0408 (②)^2 \times (① - ③) =$ ______ GAL.

WELL I.D.	VOL. GAL./FT.
1"	0.04
2"	0.17
3"	0.38
4"	0.66
5"	1.04
6"	1.50
8"	2.60

PARAMETERS	ACCUMULATED VOLUME PURGED (GALLONS)										
	0	5	25	100	120						
Turbidity	Gray muddy	Same	Gray cloudy	Cloudy * 90	Clear 25						

COMMENTS:

* Good improvement

Bailer + Suction Lift

Max inflow rate from step test - 0.5 gpm

MALCOLM PIRNIE

WELL DEVELOPMENT/PURGING LOG

PROJECT TITLE: RFA - Supplemental RI

PROJECT NO.: 0965.07-1

STAFF: RHF/RLD

DATE: 11/18/86

WELL NO.: LO-2 (replacement)

① TOTAL CASING AND SCREEN LENGTH (FT.): 30.

② CASING INTERNAL DIAMETER (in.): 2"

③ WATER LEVEL BELOW TOP OF CASING (FT.) 7.97

④ VOLUME OF WATER IN CASING (GAL.) ~4

$V = 0.0408 (②)^2 \times (① - ③) =$ ______ GAL.

WELL I.D.	VOL. GAL./FT.
1"	0.04
2"	0.17
3"	0.38
4"	0.66
5"	1.04
6"	1.50
8"	2.60

PARAMETERS	ACCUMULATED VOLUME PURGED (GALLONS)										
	0	2	10	15							
Turbidity	v. muddy	cloudy	cloudy * 60	cloudy sl. 38							

COMMENTS:
Bailer + suction lift

* good improvement

Recharge rate ~ .1 to .2 gpm

MALCOLM PIRNIE

WELL DEVELOPMENT/PURGING LOG

PROJECT TITLE: Supplemental RI

PROJECT NO.: 0565-0701

STAFF: RHF/RLD/JPH

DATE: 11/18/94

WELL NO.: MW-7S

① TOTAL CASING AND SCREEN LENGTH (FT.): 15

② CASING INTERNAL DIAMETER (in.): 2

③ WATER LEVEL BELOW TOP OF CASING (FT.) 5.52

④ VOLUME OF WATER IN CASING (GAL.) 1.7

$V = 0.0408\,(②)^2 \times (① - ③) =$ ________ GAL.

WELL I.D.	VOL. GAL./FT.
1"	0.04
2"	0.17
3"	0.38
4"	0.66
5"	1.04
6"	1.50
8"	2.60

PARAMETERS	ACCUMULATED VOLUME PURGED (GALLONS)										
	0	7	10								
Turbidity NTU	clear	54	50								

COMMENTS:

Method - Bailer + waterra pump.

* well redeveloped for mini rate pump test

MALCOLM PIRNIE

MALCOLM PIRNIE

B.5 "Mini-Rate" Pump Test Calculations

PERMEABILITY FROM "MINI-RATE" PUMPING TESTS

A greater awareness of ground-water pollution problems has made reliable permeability determinations critical. This article looks at the use of mini-rate pumping tests to derive this information.

by Sanford I. Strausberg

Reliable permeability determinations have increased in importance in the past few years. The need for accurate estimates of quantity and velocity of ground-water flow in fine-grained, unconsolidated materials and tightly fractured rock units has led to widespread usage of in situ "mini-rate" pumping tests, often run at less than 0.06 L/s (1 gpm).

Permeability is a property of the porous medium independent of the fluid. The relationship of permeability to hydraulic conductivity is defined by Freeze and Cherry (1979) and Johnson (1981), who state that hydraulic conductivity is synonymous with "coefficient of field permeability." The latter is used in calculations because of widespread usages in older texts (Ferris and others, 1962; Walton 1970), as well as inferences in newer publications prepared for practical field personnel (Bureau of Reclamation 1977; Powers 1981).

Unconfined conditions and low permeabilities of soil or rock materials generally preclude utilization of all but the well from which water is withdrawn or injected. However, observation wells have been successfully used in some cases. Where permeabilities are very low, in situ aquifer tests, including slug tests, cannot be performed. Laboratory tests must then be utilized (Olson and Daniel 1981; Cedergren 1967).

Bail or injection slug tests (Hendry 1982; Prudic 1982), are often the only types of in situ aquifer tests possible in small-diameter shallow monitoring wells or open boreholes. However, where conditions are favorable, short constant- or declining-rate pumping tests have yielded drawdown and/or recovery data that provide the basis for the most reliable transmissivity estimates for materials in the immediate vicinities of screened or open areas of installations. To derive permeabilities, thicknesses of tested zones have been estimated from:

- Geologic and/or geophysical logs;
- Drilling indications;
- Changes in drawdown and/or recovery patterns;
- The saturated screen or open-hole lengths. Packers have been used in sections of open holes for determining permeabilities of distinct zones.

Where pumping water levels have been deeper than about 7-1/2m (25 ft.), discharges have been augmented by various deep pumping means including rhythmic bailing or pumping with submersible, turbine or air-lift pumps. At shallower depths, these same methods have been used in addition to pumping by suction. Small gasoline-driven suction pumps with rubber hose attachments and small gate valves for discharge control have commonly been used to run many inexpensive constant-rate pumping tests.

Pumping and measuring options vary with well or hole diameters and water-level depths, but pumping tests have been successfully run in wells with casing diameters smaller than 3.2cm (1-1/4 in.). However, because most monitoring wells have casing and screen diameters ranging from 5 to 15cm (2 to 6 in.), there is generally ample room for discharge hose or pipe and measuring probe or tape. Tape measurements made by the author inside a 1.3cm (1/2 in.) air pipe have given good recovery data following air-lift pumping from 61m (200 ft.) deep, 3.2cm (1-1/4 in.) wells screened in fractured coal or silty sand horizons in the Powder River Basin, Wyoming.

Water levels in the pumping well are generally measured to at least the nearest 0.03m (0.1 ft.) by electric tape or transducers. Chalked steel tapes and automatic water-level recorders can be used for measurements to the nearest 0.003m (0.01 ft.) in observation wells.

Low pumping rates usually necessitate volumetric measurements, commonly with 3.8 to 19L (one to five gal.) containers and watches equipped with a second hand. Pumping rates can be kept surprisingly constant with proper planning, design and surveillance. Even at very low rates, variations can be kept to within ±10 percent of the desired flow with the right instrumentation. For example, the author recently directed a 24-hour pumping test in Virginia, at 0.008L/s (0.125 gpm or one pint per minute) when a 0.95L (one quart) bottle was used for flow measurements. Preliminary testing had shown that the maximum inflow rate was 0.0095 to 0.0126L/s (0.15 to 0.20 gpm) when the well was nearly dewatered shortly after pumping commenced. Pumping was accomplished with a genera-

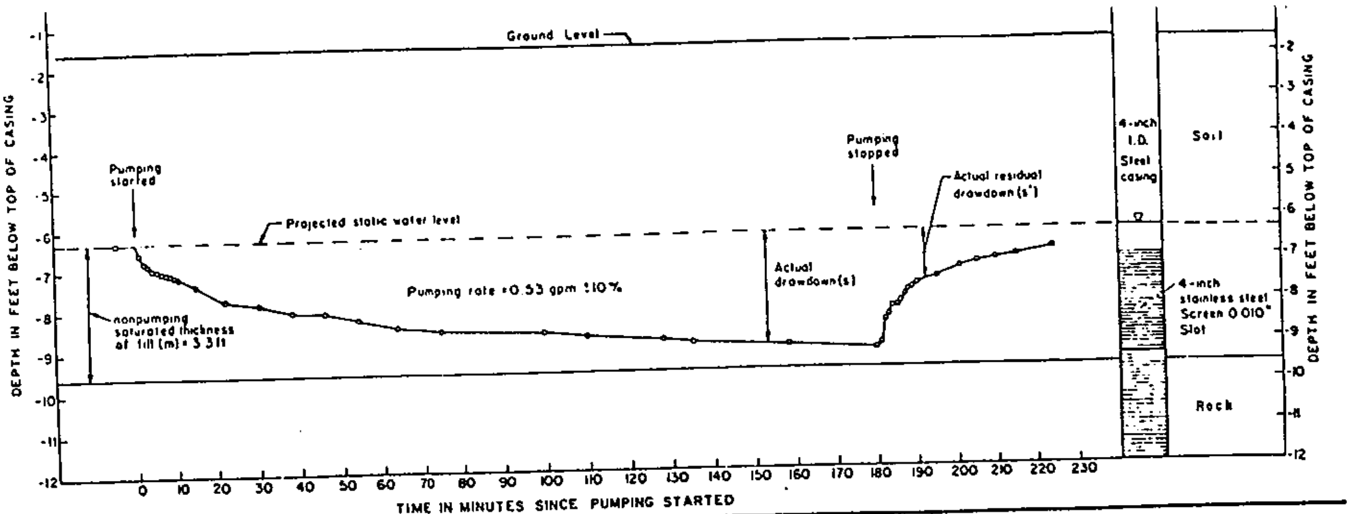


Figure 1. Monitoring well setting and pumping test data.

tor-driven submersible pump set at the bottom of the 3m (10 ft.) long screen in a 5m (16-1/2 ft.) deep, hydraulically efficient monitoring well. PVC screen and casing were 15.2cm (6 in.) in diameter. The column of water in the well stood 3m (10 ft.) above the well bottom prior to pumping. Discharge was closely regulated to within ±10 percent of the desired pumping rate with a valve assembly on 2cm (3/4 in.) tubing. Drawdown and recovery data from electric tape measurements were excellent. The specific capacity was 0.02L/s per m of drawdown (0.1 gpm per ft. of drawdown) at the end of the one-day pumping period. Transmissivity of the 3m (10 ft.) thick, unconfined, silty alluvial horizon tested was calculated from semi-logarithmic plots of drawdown and recovery measurements, at 0.62m^2/day (50 gpd/ft.). Permeability was calculated at 2.4 x 10^{-4}cm/sec (5 gpd/ft.^{2}). These values were similar to those obtained from recovery measurements made following instantaneous removal of measured slugs of water from the same well and other nearby wells screened in the same horizon. However, slug tests were not deemed as reliable as pumping tests primarily because the radius of influence from relatively long-term pumping is far greater than that from a slug.

Maximum Inflow Rate and Recovery Data

Running a constant-rate pumping test in a well or borehole open to materials of low permeability requires that the discharge rate be less than the maximum inflow rate. Consequently, considerable preliminary step-testing and recovery measurements must first be done.

The maximum inflow rate is measured when the potentiometric level at the face of the drill hole or screen of the installation is considerably higher than the pumping water level after the installation has nearly been dewatered by overpumping. After the range of specific capacity and the magnitude of transmissivity have been estimated from preliminary step-testing, the maximum inflow rate may be calculated by suddenly increasing the discharge rate after a protracted period of pumping at a low rate. The pumping is then terminated and the pump is removed. Knowing the casing diameter (I.D.) gives the volume per linear unit and taking timed water-level readings in the first few minutes after pumping ceases gives the maximum inflow rate. In many cases, cascading requires that water levels be measured through a measuring pipe.

If drawdown readings cannot be obtained or utilized, recovery data may be effectively used for transmissivity estimates. Recovery data are often superior to drawdown data because the former are less affected by well losses, flow line distortions and inevitable variations in discharge rate during the pumping period. Additionally, in unconfined situations, later recovery measurements represent thicker sections of the tested material than later drawdown readings due to "aquifer" dewatering during pumping. However, delay of water-level recovery caused by air or other gas entrainment in the dewatered or depressurized sections of tested materials may lead to unrealistic transmissivity determinations. Therefore, wherever possible, it is preferable to obtain both drawdown and recovery data for comparisons.

Casing storage, as well as other factors such as partial penetration, boundaries and delayed gravity drainage must always be considered in analysis of test data (Kruseman and DeRidder 1970).

Maximum inflow rates have also been determined from sumps used for dewatering in quarries. Because of the large diameter of a typical sump, the inflow rate measured immediately after cessation of pumping is analogous to the constant discharge from the aquifer (Q).

Field Example

An estimate of the magnitude of ground-water flow from an industrial plant site in western New York was made by the author in the winter of 1978-79. Results of one of the tests performed are presented here.

The tested material is fill, consisting of loose, silty medium sand. Pumping was accomplished with a small suction (ditch) pump and discharge was measured with a 3.8L (one gal.) bucket. Permeability estimates derived from the drawdown and recovery data were comparable to those derived from two single-bail slug tests performed in a nearby 5cm (2 in.) well screened in the same type of fill material as that open to the 10cm (4 in.) pump-tested well.

Figure 1 shows casing and screen settings of the pump-tested well. The borehole was drilled to an 8-inch diameter and the annulus between the screen and casing assembly was filled with medium sand to within 2 feet of ground level. Also shown in Figure 1 are nonpumping saturated thickness of fill (soil) and pumping test data. Although

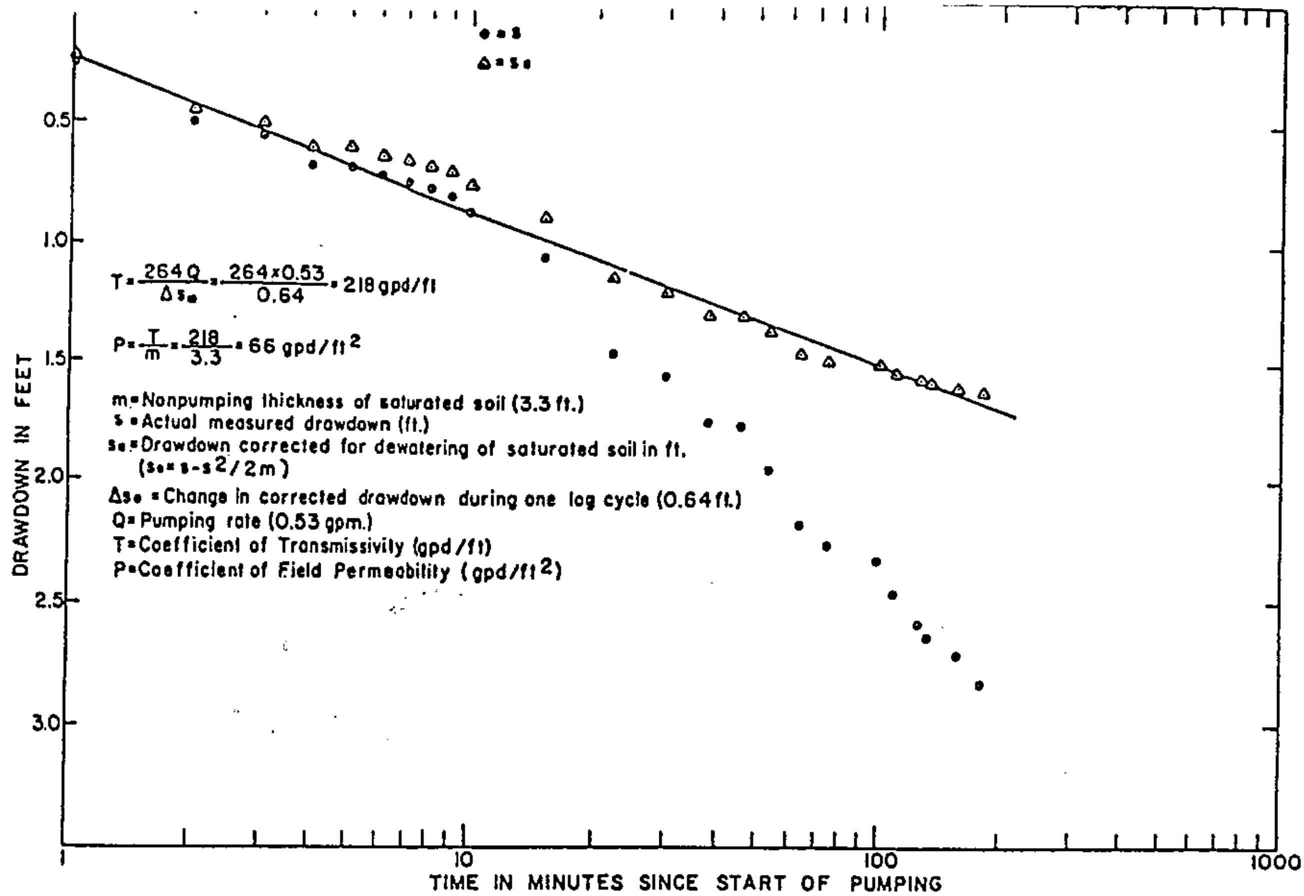


Figure 2. Determination of permeability from semi-logarithmic graph of drawdown during pumping phase.

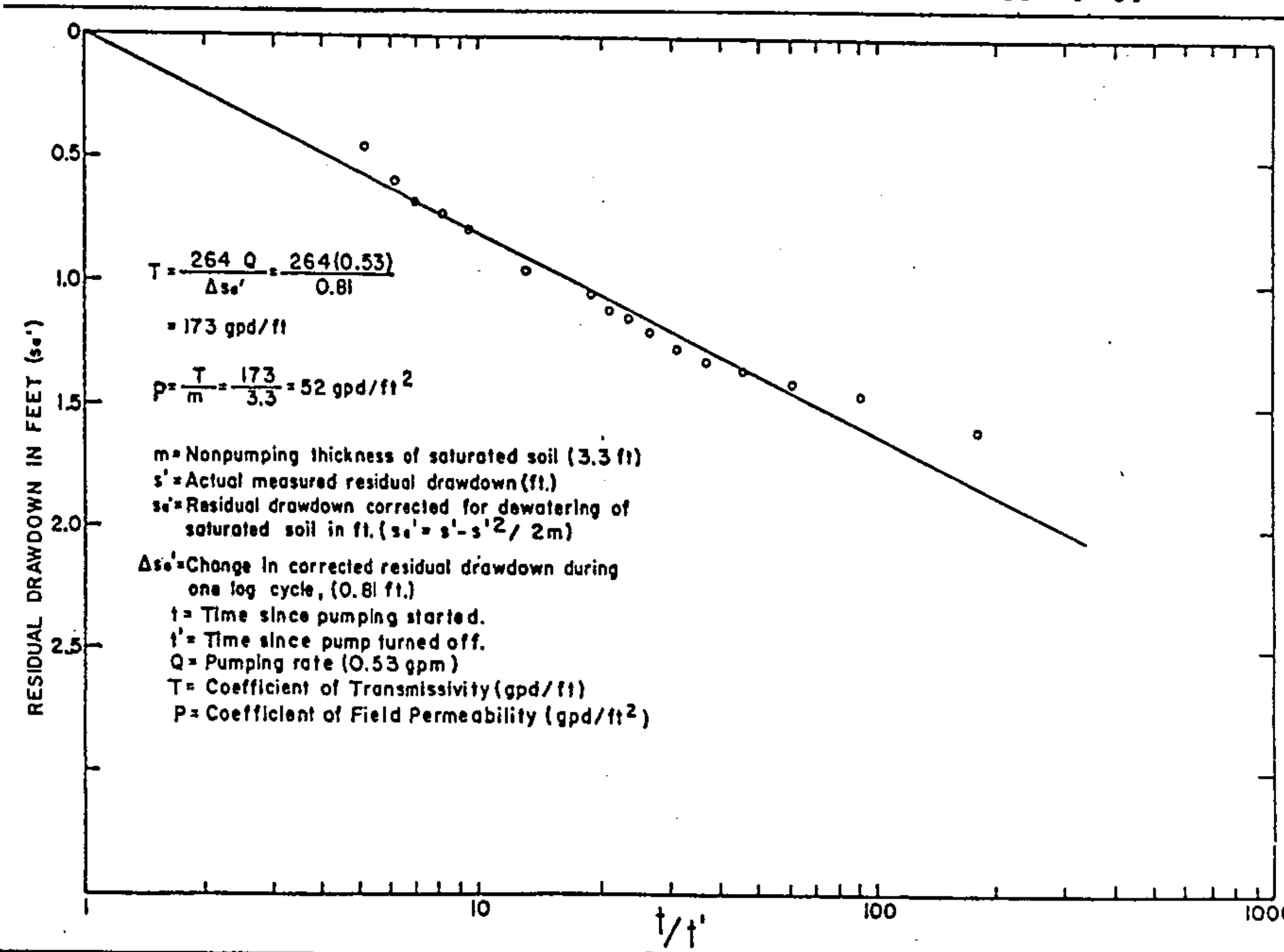


Figure 3. Determination of permeability from semi-logarithmic graph of residual drawdown during recovery phase.

part of the screen is set in rock (consisting of fractured, but unweathered dolomite), data from several nearby wells open exclusively to the rock indicated that the permeability of the fractured rock is one to two orders of magnitude lower than that of the soil at the sites of testing. Consequently, the rock was assumed to be impermeable for the evaluation of test results shown in Figures 2 and 3. Nearby wells could not be used as observation wells because of the combination of unconfined conditions, low transmissivity, short duration of pumping and very low pumping rate. No hydrologic boundaries were expected or observed, and various data showed that the well was hydraulically efficient when 0.03L/s (1/2 gpm) was pumped.

Figure 1 shows that actual drawdown was about 85 percent of the original saturated thickness of the soil after three hours of pumping. Consequently, the actual drawdowns, shown as circles in Figure 2, had to be corrected for aquifer dewatering before an estimate for transmissivity of the nonpumping saturated aquifer zone could be made. The triangles in Figure 2 are corrected drawdowns in accordance with the correction formula indicated. Similarly, recoveries shown in Figure 3 were also corrected for the dewatering because more than 10 percent of the aquifer was still dewatered during the period of recovery measurements.

Transmissivity and permeability calculations are also shown in Figures 2 and 3. Averaging permeability values from the drawdown and recovery portions of the constant-rate pumping test gave 2.8×10^{-3}cm/sec (59 gpd/ft.^{2}) compared to 2.4 x 10^{-3}cm/sec (51 gpd/ft.^{2}) from the two single-bail slug tests run in the nearby 5cm (2 in.) monitoring well. Consequently, the permeability of the fill in the vicinity of the two wells was estimated at 2.6×10^{-3}cm/sec (55 gpd/ft.^{2}).

Using the hydraulic gradient determined from the shallow potentiometric map of the plant site and the estimated cross sectional area of flow (based on visual, geologic, hydrologic and plant structural data), the normal ground-water discharge was then estimated at about 0.013L/s (0.2 gpm). This quantitative estimate compared very well with a qualitative observation of about 0.015L/s (1/4 gpm) made prior to bailing and pumping test operations. The qualitative observation consisted of "eyeballing" the amount of discharge at observed seeps along the face of the line of natural discharge which was a bank intersecting the saturated fill.

Summary

Where conditions permit, constant-rate pumping tests run in properly designed, located, constructed and developed wells, give the most reliable permeability results from drawdown and recovery measurements made in pumping and/or observation wells.

Use should be made of different means to evaluate permeability of distinct hydrogeologic horizons for ground-water flow rate and velocity estimates. If the different methods give comparable "ballpark" numbers, then weighted average values can be used with some degree of confidence.

Acknowledgment

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Biographical Sketch

Sanford L. Strausberg was vice president in the ground-water consulting firm of Leggette, Brashears & Graham Inc., Wilton, Connecticut. He is presently an independent consultant. He received his B.S. in geology from Brooklyn College and his M.S. in geology from the University of Michigan. He has done field and office work on thousands of aquifer tests run in wells, boreholes, trenches, horizontal collectors and sumps, of varying depths for different purposes in virtually every climatic and hydrogeologic setting. Although most of his recent experiences have been in the northeastern U.S., he has also done extensive hydrogeologic field work in most other sections of the U.S. and in several Latin American countries, India, Iran, Papua New Guinea and the Bahamas. His greatest interest throughout his 26-year-career in ground water has been evaluating aquifer test data using derivatives of the Theis nonequilibrium equation.

PW-1

ELAPSED TIME	DRAWDOWN
0	0.1
4	1.16
5	1.28
6	1.39
7	1.48
8	1.54
9	1.62
10	1.67
11	1.66
12	1.62
13	1.48
14	1.59
15	1.81
16	1.91
17	1.99
18	2.07
19	2.16
20	2.23
21	2.3
22	2.35
23	2.45
24	2.46
25	2.5
26	2.5
27	2.52
28	2.54
29	2.54
30	2.57
31	2.57
32	2.59
33	2.61
34	2.68
35	2.77
36	2.87
37	2.96
38	3.02
39	3.09
40	3.11
41	3.18
42	3.15
43	3.16
44	3.18
45	3.23
46	3.36
47	3.46
48	3.53
49	3.62
50	3.69
51	3.76
52	3.83
53	3.9
54	3.96
55	4

PW-2

ELAPSED TIME	DRAWDOWN
0	0.26
1	3.14
2	3.55
3	3.72
4	3.7
5	3.58
6	3.77
7	3.59
8	3.75
9	4.08
10	4.35
11	4.54
12	4.7
13	4.84
14	4.95
15	5.03
16	4.97
17	4.92
18	4.87
19	4.86
20	4.84
21	4.83
22	4.81
23	4.79
24	4.78
25	4.76
26	4.75
27	4.73
28	4.72
29	4.72
30	4.7
31	4.7
32	4.7
33	4.7
34	4.7
35	4.7
36	4.72
37	4.72
38	4.73
39	4.73
40	4.73
41	4.75
42	4.75
43	4.76
44	4.78
45	4.79
46	4.81
47	4.83
48	4.84
49	4.86
50	4.87
51	4.89
52	4.95

PW-1

ELAPSED TIME	DRAWDOWN
56	4.06
57	4.16
58	4.28
59	4.36
60	4.47
61	4.53
62	4.59
63	4.58
64	4.58
65	4.57
66	4.58
67	4.57
68	4.58
69	4.58
70	4.61
71	4.65
72	4.63
73	4.66
74	4.66
75	4.42
76	4.22
77	4.02
78	3.86
79	3.82
80	4.09
81	4.25
82	4.42
83	4.58
84	4.69
85	4.8
86	4.87
87	4.84
88	4.83
89	4.82
90	4.83
91	4.84
92	4.85
93	4.85
94	4.85
95	4.85
96	4.85
97	4.85
98	4.86
99	4.85
100	4.86
101	4.86
102	4.86
103	4.88
104	4.88
105	4.92
106	4.99
107	5.04
108	5.1

PW-2

ELAPSED TIME	DRAWDOWN
53	5.31
54	5.6
55	5.84
56	6.03
57	6.2
58	6.36
59	6.48
60	6.58
61	6.67
62	6.75
63	6.81
64	6.86
65	6.86
66	6.88
67	6.88
68	6.88
69	6.89
70	6.89
71	6.89
72	6.88
73	6.88
74	6.89
75	6.88
76	6.89
77	6.89
78	6.93
79	6.93
80	6.94
81	6.94
82	6.96
83	6.96
84	6.97
85	6.97
86	7.04
87	7.11
88	7.19
89	7.29
90	7.37
91	7.43
92	7.51
93	7.65
94	7.75
95	7.82
96	7.9
97	7.97
98	8.01
99	8.06
100	8.11
101	8.14
102	8.17
103	8.2
104	8.22
105	8.2

PW-1		PW-2	
ELAPSED TIME	DRAWDOWN	ELAPSED TIME	DRAWDOWN
109	5.16	106	8.2
110	5.22	107	8.2
111	5.27	108	8.17
112	5.32	109	8.16
113	5.37	110	8.14
114	5.42	111	8.11
115	5.47	112	8.09
116	5.52	113	8.09
117	5.57	114	8.08
118	5.62	115	8.06
119	5.67	116	8.06
120	5.72	117	8.05
121	5.76	118	8
122	5.8	119	7.95
123	5.84	120	7.9
124	5.89	121	7.86
125	5.93	122	7.9
126	5.96	123	7.95
127	6.01	124	7.95
128	6.05	125	7.95
129	6.11	126	7.94
130	6.15	127	7.94
131	6.19	128	7.92
132	6.24	129	7.92
133	6.28	130	7.92
134	6.32	131	7.92
135	6.36	132	7.94
136	6.4	133	7.94
137	6.43	134	7.92
138	6.47	135	7.94
139	6.51	136	7.92
140	6.54	137	7.92
141	6.58	138	7.92
142	6.61	139	7.92
143	6.65	140	7.9
144	6.68	141	7.87
145	6.71	142	7.95
146	6.74	143	7.92
147	6.77	144	7.9
148	6.81	145	7.89
149	6.84	146	7.89
150	6.87	147	7.86
151	6.89	148	7.84
152	6.92	149	7.82
153	6.96	150	7.84
154	6.99	151	7.82
155	7.02	152	7.82
156	6.94	153	7.82
157	7.18	154	7.82
158	7.14	155	7.81
159	7.15	156	7.81
160	7.16	157	7.84
161	7.17	158	7.86

PW-1

ELAPSED TIME	DRAWDOWN
321	9.97
322	9.99
323	10
324	10.01
325	10.02
326	10.04
327	10.04
328	10.05
329	10.06
330	10.07
331	10.08
332	10.09
333	10.11
334	10.12
335	10.13
336	10.14
337	10.16
338	10.17
339	10.17
340	10.19
341	10.2
342	10.22
343	10.23
344	10.25
345	10.26
346	10.28
347	10.29
348	10.3
349	10.31
350	10.32
351	10.33
352	10.35
353	10.36
354	10.37
355	10.38
356	10.39
357	10.4
358	10.42
359	10.43
360	10.38
361	10.22
362	10.11
363	9.98
364	9.86
365	9.73
366	9.58
367	9.41
368	9.22
369	9.02
370	8.92
371	8.82
372	8.72
373	8.6

PW-2

ELAPSED TIME	DRAWDOWN
318	8.41
319	8.41
320	8.41
321	8.41
322	8.42
323	8.42
324	8.42
325	8.42
326	8.42
327	8.41
328	8.41
329	8.42
330	8.42
331	8.42
332	8.42
333	8.41
334	8.41
335	8.41
336	8.41
337	8.39
338	8.41
339	8.42
340	8.46
341	8.46
342	8.46
343	8.49
344	8.49
345	8.49
346	8.47
347	8.5
348	8.5
349	8.5
350	8.49
351	8.49
352	8.47
353	8.46
354	8.44
355	8.47
356	8.61
357	8.22
358	7.82
359	7.41
360	6.91
361	6.55
362	6.06
363	5.65
364	5.25
365	4.9
366	4.59
367	4.29
368	4.04
369	3.78
370	3.58

PW-1			PW-2	
ELAPSED TIME	DRAWDOWN		ELAPSED TIME	DRAWDOWN
374	8.5		371	3.37
375	8.41		372	3.18
376	8.32		373	3.03
377	8.22		374	2.87
378	8.13		375	2.73
379	8.04		376	2.6
380	7.96		377	2.49
381	7.86		378	2.38
382	7.76		379	2.27
383	7.67		380	2.17
384	7.59		381	2.09
385	7.5		382	2.02
386	7.39		383	1.94
387	7.26		384	1.87
388	7.16		385	1.81
389	7.06		386	1.75
390	6.98		387	1.67
391	6.9		388	1.62
392	6.83		389	1.57
393	6.75		390	1.51
394	6.68		391	1.48
395	6.62		392	1.43
396	6.55		393	1.4
397	6.47		394	1.35
398	6.4		395	1.32
399	6.33		396	1.26
400	6.26		397	1.24
401	6.19		398	1.19
402	6.12		399	1.16
403	6.05		400	1.13
404	5.97		401	1.12
405	5.91		402	1.08
406	5.84		403	1.05
407	5.79		404	1.04
408	5.73		405	1.01
409	5.67		406	0.99
410	5.58		407	0.97
411	5.51		408	0.94
412	5.41		409	0.93
413	5.33		410	0.91
414	5.28		411	0.89
415	5.23		412	0.88
416	5.17		413	0.86
417	5.13		414	0.85
418	5.08		415	0.83
419	5.02		416	0.83
420	4.97		417	0.82
421	4.92		418	0.8
422	4.86		419	0.78
423	4.82		420	0.78
424	4.77		421	0.77
425	4.72		422	0.77
426	4.65		423	0.75

PW-1

ELAPSED TIME	DRAWDOWN
427	4.55
428	4.46
429	4.38
430	4.35
431	4.27
432	4.19
433	4.1
434	4.03
435	3.96
436	3.89
437	3.81
438	3.74
439	3.68
440	3.62
441	3.55
442	3.49
443	3.44
444	3.38
445	3.32
446	3.28
447	3.22
448	3.17
449	3.12
450	3.07
451	3.02
452	2.98
453	2.94
454	2.89
455	2.85
456	2.81
457	2.77
458	2.74
459	2.7
460	2.66
461	2.64
462	2.59
463	2.56
464	2.53
465	2.5
466	2.47
467	2.45
468	2.41
469	2.38
470	2.35
471	2.33
472	2.3
473	2.27
474	2.25
475	2.22
476	2.2
477	2.17
478	2.15
479	2.14

PW-2

ELAPSED TIME	DRAWDOWN
424	0.75
425	0.74
426	0.72
427	0.72
428	0.72
429	0.71
430	0.71
431	0.69
432	0.69
433	0.69
434	0.67
435	0.67
436	0.66
437	0.66
438	0.66
439	0.64
440	0.64
441	0.64
442	0.64
443	0.63
444	0.63
445	0.61
446	0.63
447	0.61
448	0.61
449	0.61
450	0.59
451	0.59
452	0.59
453	0.59
454	0.59
455	0.58
456	0.58
457	0.58
458	0.58
459	0.56
460	0.56
461	0.56
462	0.56
463	0.56
464	0.56
465	0.55
466	0.55
467	0.55
468	0.55
469	0.53
470	0.55
471	0.53
472	0.53
473	0.53
474	0.53
475	0.52
476	0.52

PW-1		PW-2	
ELAPSED TIME	DRAWDOWN	ELAPSED TIME	DRAWDOWN
480	2.1	477	0.52
481	2.09	478	0.52
482	2.06	479	0.52
483	2.05	480	0.52
484	2.03	481	0.5
485	2.01	482	0.5
486	1.98	483	0.5
487	1.96	484	0.5
488	1.94	485	0.5
489	1.93	486	0.5
490	1.9	487	0.5
491	1.89	488	0.5
492	1.87	489	0.5
493	1.85	490	0.5
494	1.83	491	0.48
495	1.82	492	0.48
496	1.8	493	0.48
497	1.78	494	0.48
498	1.76	495	0.48
499	1.75	496	0.48
500	1.74	497	0.48
501	1.72	498	0.48
502	1.7	499	0.48
503	1.69	500	0.48
504	1.68	501	0.48
505	1.66	502	0.48
506	1.64	503	0.47
507	1.63	504	0.47
508	1.62	505	0.47
509	1.6	506	0.47
510	1.59	507	0.47
511	1.58	508	0.47
512	1.56	509	0.47
513	1.56	510	0.47
514	1.54	511	0.47
515	1.53	512	0.47
516	1.52	513	0.47
517	1.51	514	0.47
518	1.5	515	0.47
519	1.49	516	0.45
520	1.48	517	0.45
521	1.47	518	0.45
522	1.45	519	0.45
523	1.44	520	0.45
524	1.44	521	0.45
525	1.43	522	0.45
526	1.41	523	0.45
527	1.41	524	0.45
528	1.4	525	0.45
529	1.39	526	0.45
530	1.38	527	0.44
531	1.37	528	0.44
532	1.36	529	0.44

PW-1

ELAPSED TIME	DRAWDOWN
533	1.35
534	1.34
535	1.33
536	1.32
537	1.31
538	1.3
539	1.3
540	1.29
541	1.27
542	1.27
543	1.26
544	1.26
545	1.24
546	1.23
547	1.23
548	1.22
549	1.22
550	1.21
551	1.2
552	1.19
553	1.18
554	1.17
555	1.17
556	1.16
557	1.16
558	1.15
559	1.14
560	1.14
561	1.13
562	1.12
563	1.12
564	1.12
565	1.11
566	1.1
567	1.09
568	1.09
569	1.08
570	1.07
571	1.07
572	1.06
573	1.06
574	1.05
575	1.04
576	1.05
577	1.03
578	1.02
579	1.02
580	1.02
581	1.02
582	1.01
583	1
584	1
585	0.99

PW-2

ELAPSED TIME	DRAWDOWN
530	0.44
531	0.44
532	0.44
533	0.44
534	0.42
535	0.42
536	0.42
537	0.41
538	0.41
539	0.39
540	0.39
541	0.39
542	0.37
543	0.37
544	0.37
545	0.37
546	0.36
547	0.36
548	0.36
549	0.36
550	0.36
551	0.36
552	0.36
553	0.36
554	0.34
555	0.34
556	0.34
557	0.34
558	0.34
559	0.34
560	0.34
561	0.34
562	0.33
563	0.33
564	0.34
565	0.33
566	0.33
567	0.33
568	0.33
569	0.33
570	0.33
571	0.33
572	0.33
573	0.33
574	0.33
575	0.33
576	0.33
577	0.33
578	0.31
579	0.33
580	0.31
581	0.31
582	0.31

PW-1

ELAPSED TIME	DRAWDOWN
586	0.98
587	0.98
588	0.97
589	0.97
590	0.97
591	0.95
592	0.95
593	0.94
594	0.94
595	0.94
596	0.93
597	0.93
598	0.92
599	0.92
600	0.92
601	0.91
602	0.91
603	0.9
604	0.89
605	0.89
606	0.89
607	0.88
608	0.88
609	0.87
610	0.88
611	0.87
612	0.87
613	0.86
614	0.85
615	0.85
616	0.85
617	0.84
618	0.84
619	0.84
620	0.82
621	0.83
622	0.82
623	0.82
624	0.82
625	0.8
626	0.8
627	0.79
628	0.77
629	0.75
630	0.74
631	0.73
632	0.71
633	0.71
634	0.7
635	0.68
636	0.67
637	0.66
638	0.65

PW-2

ELAPSED TIME	DRAWDOWN
583	0.31
584	0.31
585	0.31
586	0.31
587	0.31
588	0.31
589	0.31
590	0.31
591	0.31
592	0.31
593	0.31
594	0.31
595	0.31
596	0.31
597	0.31
598	0.29
599	0.29
600	0.29
601	0.29
602	0.29
603	0.29
604	0.29
605	0.29
606	0.29
607	0.29
608	0.29
609	0.29
610	0.29
611	0.29
612	0.29
613	0.29
614	0.29
615	0.28
616	0.28
617	0.28
618	0.28
619	0.28
620	0.28
621	0.28
622	0.28
623	0.28
624	0.28
625	0.28
626	0.28
627	0.28
628	0.28
629	0.26
630	0.28
631	0.26
632	0.26
633	0.26
634	0.26
635	0.26

PW-1

ELAPSED TIME	DRAWDOWN
639	0.64
640	0.63
641	0.61
642	0.61
643	0.6
644	0.6
645	0.58
646	0.58
647	0.57

PW-2

ELAPSED TIME	DRAWDOWN
636	0.26
637	0.26
638	0.26
639	0.26
640	0.26
641	0.26
642	0.26
643	0.26
644	0.26
645	0.26
646	0.26
647	0.26
648	0.26
649	0.26
650	0.26
651	0.26
652	0.26
653	0.26
654	0.26
655	0.26
656	0.26
657	0.26
658	0.25
659	0.25
660	0.25
661	0.25
662	0.25
663	0.25
664	0.25
665	0.25
666	0.25
667	0.25
668	0.25
669	0.25
670	0.25
671	0.25
672	0.25
673	0.25

LO-1		LO-2	
ELAPSED TIME	DRAWDOWN	ELAPSED TIME	DRAWDOWN
0	0	0	0.01
4	0.06	1	0.06
5	0.08	2	0.15
6	0.1	3	0.25
7	0.11	4	0.33
8	0.13	5	0.4
9	0.14	6	0.47
10	0.16	7	0.53
11	0.18	8	0.59
12	0.19	9	0.67
13	0.2	10	0.73
14	0.2	11	0.78
15	0.21	12	0.88
16	0.22	13	0.94
17	0.23	14	1.02
18	0.24	15	1.08
19	0.25	16	1.11
20	0.26	17	1.19
21	0.28	18	1.25
22	0.29	19	1.3
23	0.3	20	1.35
24	0.31	21	1.4
25	0.32	22	1.46
26	0.33	23	1.51
27	0.34	24	1.54
28	0.35	25	1.57
29	0.35	26	1.62
30	0.36	27	1.62
31	0.36	28	1.66
32	0.37	29	1.69
33	0.37	30	1.73
34	0.38	31	1.73
35	0.39	32	1.77
36	0.38	33	1.79
37	0.4	34	1.8
38	0.41	35	1.84
39	0.42	36	1.84
40	0.43	37	1.87
41	0.44	38	1.9
42	0.45	39	1.91
43	0.46	40	1.93
44	0.47	41	1.95
45	0.47	42	1.93
46	0.48	43	1.96
47	0.49	44	1.98
48	0.5	45	1.98
49	0.51	46	1.99
50	0.52	47	2.01
51	0.52	48	2.02
52	0.53	49	2.04

LO-1		LO-2	
ELAPSED TIME	DRAWDOWN	ELAPSED TIME	DRAWDOWN
53	0.54	50	2.06
54	0.55	51	2.07
55	0.56	52	2.09
56	0.56	53	2.1
57	0.58	54	2.12
58	0.58	55	2.15
59	0.58	56	2.17
60	0.59	57	2.2
61	0.6	58	2.23
62	0.61	59	2.26
63	0.62	60	2.29
64	0.63	61	2.34
65	0.63	62	2.37
66	0.64	63	2.4
67	0.64	64	2.43
68	0.64	65	2.46
69	0.65	66	2.5
70	0.65	67	2.53
71	0.65	68	2.56
72	0.66	69	2.59
73	0.66	70	2.61
74	0.66	71	2.64
75	0.67	72	2.67
76	0.66	73	2.69
77	0.66	74	2.72
78	0.65	75	2.73
79	0.65	76	2.75
80	0.64	77	2.76
81	0.64	78	2.8
82	0.64	79	2.81
83	0.64	80	2.83
84	0.65	81	2.84
85	0.66	82	2.86
86	0.66	83	2.86
87	0.67	84	2.89
88	0.67	85	2.91
89	0.68	86	2.91
90	0.68	87	2.95
91	0.69	88	2.97
92	0.69	89	2.98
93	0.69	90	3
94	0.69	91	3.02
95	0.7	92	3.03
96	0.7	93	3.05
97	0.7	94	3.05
98	0.7	95	3.08
99	0.7	96	3.09
100	0.71	97	3.13
101	0.71	98	3.14
102	0.71	99	3.16

LO-1

ELAPSED TIME	DRAWDOWN
103	0.7
104	0.71
105	0.71
106	0.71
107	0.71
108	0.71
109	0.72
110	0.72
111	0.72
112	0.73
113	0.73
114	0.74
115	0.74
116	0.75
117	0.75
118	0.75
119	0.76
120	0.76
121	0.76
122	0.76
123	0.77
124	0.78
125	0.77
126	0.78
127	0.78
128	0.78
129	0.79
130	0.8
131	0.8
132	0.8
133	0.8
134	0.8
135	0.8
136	0.81
137	0.81
138	0.81
139	0.81
140	0.82
141	0.82
142	0.82
143	0.83
144	0.83
145	0.83
146	0.84
147	0.85
148	0.85
149	0.86
150	0.86
151	0.86
152	0.86

LO-2

ELAPSED TIME	DRAWDOWN
100	3.19
101	3.19
102	3.2
103	3.22
104	3.24
105	3.25
106	3.27
107	3.28
108	3.31
109	3.31
110	3.33
111	3.35
112	3.36
113	3.36
114	3.38
115	3.41
116	3.41
117	3.42
118	3.42
119	3.42
120	3.44
121	3.44
122	3.44
123	3.44
124	3.44
125	3.46
126	3.46
127	3.46
128	3.46
129	3.47
130	3.47
131	3.47
132	3.47
133	3.47
134	3.47
135	3.47
136	3.49
137	3.49
138	3.49
139	3.49
140	3.49
141	3.49
142	3.49
143	3.49
144	3.49
145	3.47
146	3.47
147	3.49
148	3.49
149	3.49

LO-1		LO-2	
ELAPSED TIME	DRAWDOWN	ELAPSED TIME	DRAWDOWN
153	0.86	150	3.49
154	0.87	151	3.49
155	0.87	152	3.49
156	0.87	153	3.49
157	0.88	154	3.49
158	0.88	155	3.49
159	0.88	156	3.47
160	0.88	157	3.47
161	0.89	158	3.49
162	0.89	159	3.47
163	0.89	160	3.49
164	0.89	161	3.49
165	0.89	162	3.49
166	0.89	163	3.49
167	0.89	164	3.49
168	0.9	165	3.5
169	0.9	166	3.5
170	0.9	167	3.5
171	0.9	168	3.5
172	0.9	169	3.52
173	0.91	170	3.52
174	0.91	171	3.52
175	0.91	172	3.53
176	0.91	173	3.53
177	0.92	174	3.53
178	0.92	175	3.57
179	0.92	176	3.57
180	0.92	177	3.57
181	0.92	178	3.57
182	0.92	179	3.57
183	0.93	180	3.57
184	0.93	181	3.57
185	0.93	182	3.57
186	0.93	183	3.57
187	0.93	184	3.57
188	0.93	185	3.57
189	0.93	186	3.58
190	0.94	187	3.58
191	0.94	188	3.58
192	0.94	189	3.58
193	0.94	190	3.58
194	0.94	191	3.6
195	0.94	192	3.6
196	0.94	193	3.6
197	0.94	194	3.6
198	0.94	195	3.6
199	0.94	196	3.61
200	0.94	197	3.61
201	0.94	198	3.61
202	0.94	199	3.61

LO-1		LO-2	
ELAPSED TIME	DRAWDOWN	ELAPSED TIME	DRAWDOWN
203	0.95	200	3.61
204	0.95	201	3.61
205	0.95	202	3.63
206	0.95	203	3.63
207	0.95	204	3.63
208	0.95	205	3.63
209	0.95	206	3.6
210	0.95	207	3.63
211	0.96	208	3.63
212	0.96	209	3.63
213	0.96	210	3.64
214	0.96	211	3.63
215	0.96	212	3.64
216	0.97	213	3.64
217	0.97	214	3.64
218	0.97	215	3.64
219	0.97	216	3.64
220	0.97	217	3.64
221	0.97	218	3.64
222	0.97	219	3.64
223	0.97	220	3.66
224	0.98	221	3.64
225	0.98	222	3.64
226	0.98	223	3.66
227	0.98	224	3.66
228	0.98	225	3.66
229	0.99	226	3.66
230	0.99	227	3.66
231	0.99	228	3.66
232	0.99	229	3.66
233	0.99	230	3.66
234	0.99	231	3.66
235	1	232	3.66
236	1	233	3.66
237	1	234	3.66
238	1	235	3.64
239	1	236	3.64
240	1	237	3.66
241	1	238	3.66
242	1.01	239	3.66
243	1.01	240	3.66
244	1.01	241	3.68
245	1.01	242	3.68
246	1.01	243	3.68
247	1.01	244	3.68
248	1.01	245	3.69
249	1.01	246	3.69
250	1.01	247	3.69
251	1.01	248	3.69
252	1.02	249	3.69

LO-1 ELAPSED TIME	LO-1 DRAWDOWN	LO-2 ELAPSED TIME	LO-2 DRAWDOWN
253	1.02	250	3.69
254	1.02	251	3.69
255	1.02	252	3.69
256	1.02	253	3.69
257	1.03	254	3.69
258	1.03	255	3.69
259	1.03	256	3.71
260	1.03	257	3.69
261	1.03	258	3.69
262	1.03	259	3.71
263	1.03	260	3.71
264	1.03	261	3.71
265	1.03	262	3.71
266	1.03	263	3.71
267	1.04	264	3.71
268	1.04	265	3.71
269	1.04	266	3.71
270	1.04	267	3.68
271	1.04	268	3.69
272	1.04	269	3.72
273	1.04	270	3.72
274	1.04	271	3.72
275	1.04	272	3.72
276	1.04	273	3.72
277	1.04	274	3.72
278	1.04	275	3.72
279	1.04	276	3.72
280	1.05	277	3.74
281	1.05	278	3.72
282	1.05	279	3.74
283	1.05	280	3.74
284	1.05	281	3.74
285	1.05	282	3.74
286	1.05	283	3.74
287	1.05	284	3.74
288	1.05	285	3.74
289	1.06	286	3.74
290	1.06	287	3.74
291	1.06	288	3.74
292	1.06	289	3.74
293	1.06	290	3.76
294	1.06	291	3.76
295	1.05	292	3.76
296	1.05	293	3.76
297	1.05	294	3.76
298	1.05	295	3.76
299	1.05	296	3.74
300	1.05	297	3.74
301	1.05	298	3.76
302	1.05	299	3.76

LO-1		LO-2	
ELAPSED TIME	DRAWDOWN	ELAPSED TIME	DRAWDOWN
303	1.05	300	3.76
304	1.05	301	3.76
305	1.05	302	3.76
306	1.05	303	3.76
307	1.06	304	3.76
308	1.06	305	3.76
309	1.06	306	3.77
310	1.06	307	3.76
311	1.06	308	3.76
312	1.06	309	3.77
313	1.06	310	3.77
314	1.06	311	3.77
315	1.06	312	3.77
316	1.06	313	3.77
317	1.06	314	3.77
318	1.07	315	3.77
319	1.07	316	3.77
320	1.07	317	3.77
321	1.07	318	3.77
322	1.07	319	3.77
323	1.08	320	3.77
324	1.08	321	3.77
325	1.08	322	3.77
326	1.08	323	3.77
327	1.08	324	3.79
328	1.08	325	3.77
329	1.08	326	3.77
330	1.08	327	3.77
331	1.09	328	3.77
332	1.09	329	3.77
333	1.09	330	3.77
334	1.09	331	3.77
335	1.09	332	3.77
336	1.09	333	3.77
337	1.09	334	3.77
338	1.09	335	3.77
339	1.1	336	3.77
340	1.1	337	3.77
341	1.09	338	3.77
342	1.1	339	3.77
343	1.1	340	3.77
344	1.1	341	3.77
345	1.1	342	3.77
346	1.1	343	3.77
347	1.1	344	3.79
348	1.1	345	3.79
349	1.1	346	3.79
350	1.11	347	3.79
351	1.11	348	3.79
352	1.11	349	3.79

LO-1		LO-2	
ELAPSED TIME	DRAWDOWN	ELAPSED TIME	DRAWDOWN
353	1.11	350	3.79
354	1.11	351	3.79
355	1.11	352	3.79
356	1.11	353	3.8
357	1.11	354	3.8
358	1.11	355	3.79
359	1.11	356	3.82
360	1.1	357	3.8
361	1.1	358	3.79
362	1.11	359	3.79
363	1.11	360	3.76
364	1.11	361	3.72
365	1.11	362	3.69
366	1.11	363	3.66
367	1.1	364	3.63
368	1.1	365	3.57
369	1.09	366	3.52
370	1.09	367	3.46
371	1.08	368	3.39
372	1.08	369	3.33
373	1.07	370	3.25
374	1.07	371	3.19
375	1.07	372	3.13
376	1.06	373	3.05
377	1.05	374	2.97
378	1.04	375	2.89
379	1.04	376	2.84
380	1.03	377	2.76
381	1	378	2.73
382	1.01	379	2.64
383	1	380	2.56
384	1	381	2.51
385	0.99	382	2.45
386	0.99	383	2.39
387	0.98	384	2.32
388	0.97	385	2.26
389	0.96	386	2.21
390	0.96	387	2.15
391	0.95	388	2.12
392	0.94	389	2.06
393	0.94	390	2.01
394	0.93	391	1.96
395	0.93	392	1.91
396	0.92	393	1.87
397	0.92	394	1.82
398	0.9	395	1.77
399	0.9	396	1.73
400	0.9	397	1.69
401	0.89	398	1.63
402	0.89	399	1.6

LO-1		LO-2	
ELAPSED TIME	DRAWDOWN	ELAPSED TIME	DRAWDOWN
403	0.88	400	1.55
404	0.88	401	1.52
405	0.87	402	1.49
406	0.87	403	1.44
407	0.86	404	1.41
408	0.85	405	1.38
409	0.85	406	1.35
410	0.84	407	1.32
411	0.83	408	1.3
412	0.83	409	1.27
413	0.82	410	1.24
414	0.82	411	1.21
415	0.81	412	1.19
416	0.81	413	1.16
417	0.8	414	1.13
418	0.79	415	1.1
419	0.79	416	1.06
420	0.8	417	1.08
421	0.78	418	1.05
422	0.78	419	1.03
423	0.77	420	1.02
424	0.76	421	1
425	0.76	422	0.99
426	0.75	423	0.95
427	0.75	424	0.94
428	0.74	425	0.92
429	0.74	426	0.91
430	0.73	427	0.89
431	0.72	428	0.89
432	0.72	429	0.88
433	0.71	430	0.86
434	0.7	431	0.84
435	0.7	432	0.83
436	0.69	433	0.81
437	0.68	434	0.81
438	0.68	435	0.8
439	0.67	436	0.78
440	0.67	437	0.77
441	0.66	438	0.77
442	0.65	439	0.75
443	0.65	440	0.75
444	0.64	441	0.73
445	0.64	442	0.72
446	0.63	443	0.72
447	0.62	444	0.72
448	0.61	445	0.7
449	0.61	446	0.7
450	0.6	447	0.69
451	0.59	448	0.69
452	0.59	449	0.67

LO-1

ELAPSED TIME	DRAWDOWN
453	0.58
454	0.58
455	0.57
456	0.57
457	0.56
458	0.56
459	0.55
460	0.55
461	0.54
462	0.54
463	0.53
464	0.53
465	0.52
466	0.52
467	0.51
468	0.51
469	0.5
470	0.5
471	0.5
472	0.49
473	0.49
474	0.49
475	0.48
476	0.48
477	0.47
478	0.47
479	0.47
480	0.46
481	0.46
482	0.46
483	0.46
484	0.45
485	0.45
486	0.45
487	0.44
488	0.44
489	0.44
490	0.44
491	0.43
492	0.43
493	0.43
494	0.42
495	0.42
496	0.42
497	0.42
498	0.41
499	0.41
500	0.41
501	0.41
502	0.41

LO-2

ELAPSED TIME	DRAWDOWN
450	0.67
451	0.66
452	0.66
453	0.66
454	0.64
455	0.64
456	0.62
457	0.62
458	0.61
459	0.61
460	0.61
461	0.61
462	0.59
463	0.59
464	0.59
465	0.58
466	0.58
467	0.58
468	0.56
469	0.56
470	0.56
471	0.56
472	0.56
473	0.55
474	0.55
475	0.55
476	0.55
477	0.53
478	0.53
479	0.53
480	0.53
481	0.51
482	0.51
483	0.51
484	0.51
485	0.51
486	0.51
487	0.5
488	0.5
489	0.5
490	0.5
491	0.5
492	0.5
493	0.48
494	0.48
495	0.48
496	0.48
497	0.48
498	0.48
499	0.48

LO-1		LO-2	
ELAPSED TIME	DRAWDOWN	ELAPSED TIME	DRAWDOWN
503	0.4	500	0.47
504	0.4	501	0.47
505	0.4	502	0.47
506	0.39	503	0.47
507	0.39	504	0.47
508	0.39	505	0.47
509	0.38	506	0.47
510	0.38	507	0.48
511	0.38	508	0.47
512	0.38	509	0.47
513	0.38	510	0.47
514	0.37	511	0.47
515	0.37	512	0.47
516	0.37	513	0.45
517	0.37	514	0.45
518	0.36	515	0.45
519	0.36	516	0.45
520	0.36	517	0.45
521	0.36	518	0.45
522	0.35	519	0.45
523	0.35	520	0.45
524	0.35	521	0.44
525	0.35	522	0.45
526	0.35	523	0.44
527	0.35	524	0.44
528	0.35	525	0.44
529	0.35	526	0.44
530	0.35	527	0.44
531	0.35	528	0.44
532	0.35	529	0.44
533	0.34	530	0.44
534	0.34	531	0.44
535	0.34	532	0.44
536	0.34	533	0.44
537	0.34	534	0.44
538	0.34	535	0.42
539	0.34	536	0.42
540	0.33	537	0.42
541	0.33	538	0.42
542	0.33	539	0.42
543	0.33	540	0.42
544	0.33	541	0.42
545	0.33	542	0.4
546	0.33	543	0.4
547	0.32	544	0.4
548	0.32	545	0.4
549	0.32	546	0.4
550	0.32	547	0.4
551	0.32	548	0.4
552	0.32	549	0.4

LO-1

ELAPSED TIME	DRAWDOWN
603	0.25
604	0.25
605	0.25
606	0.25
607	0.25
608	0.25
609	0.25
610	0.25
611	0.24
612	0.24
613	0.24
614	0.24
615	0.24
616	0.24
617	0.24
618	0.24
619	0.24
620	0.24
621	0.24
622	0.24
623	0.23
624	0.23
625	0.23
626	0.23
627	0.23
628	0.23
629	0.23
630	0.23
631	0.23
632	0.23
633	0.23
634	0.23
635	0.23
636	0.23
637	0.22
638	0.22
639	0.22
640	0.22
641	0.22
642	0.22
643	0.22
644	0.21
645	0.21
646	0.19
647	0.21

LO-2

ELAPSED TIME	DRAWDOWN
600	0.33
601	0.33
602	0.33
603	0.33
604	0.33
605	0.33
606	0.33
607	0.33
608	0.33
609	0.33
610	0.33
611	0.33
612	0.33
613	0.33
614	0.33
615	0.33
616	0.31
617	0.31
618	0.31
619	0.31
620	0.31
621	0.31
622	0.31
623	0.31
624	0.31
625	0.31
626	0.31
627	0.31
628	0.31
629	0.31
630	0.31
631	0.31
632	0.31
633	0.31
634	0.31
635	0.29
636	0.29
637	0.29
638	0.29
639	0.29
640	0.29
641	0.29
642	0.29
643	0.29
644	0.29
645	0.29
646	0.29
647	0.29
648	0.29
649	0.29

LO-1

ELAPSED TIME	DRAWDOWN

LO-2

ELAPSED TIME	DRAWDOWN
650	0.29
651	0.29
652	0.29
653	0.29
654	0.29
655	0.29
656	0.29
657	0.29
658	0.29
659	0.29
660	0.29
661	0.28
662	0.29
663	0.28
664	0.28
665	0.28
666	0.28
667	0.28
668	0.28
669	0.28
670	0.28
671	0.28
672	0.29
673	0.28

MW-7S

ELAPSED TIME	DRAWDOWN
0	0.02
1	1.08
2	0.96
3	0.97
4	1.01
5	1.19
6	1.65
7	2.57
8	3.74
9	4.63
10	5.52
11	5.62
12	5.36
13	5.23
14	5.34
15	5.41
16	5.31
17	5.28
18	5.27
19	5.32
20	5.48
21	5.59
22	5.7
23	5.8
24	5.86
25	5.87
26	5.9
27	5.92
28	5.94
29	5.97
30	5.99
31	6
32	6.03
33	6.06
34	6.08
35	6.1
36	6.13
37	6.15
38	6.22
39	6.2
40	6.22
41	6.11
42	6.02
43	5.95
44	5.89
45	5.83
46	5.77
47	5.7
48	5.77

MW-7S

49	5.71
50	5.66
51	5.62
52	5.56
53	5.51
54	5.58
55	5.59
56	6.1
57	6.21
58	6.15
59	6.14
60	6.16
61	6.16
62	6.16
63	6.16
64	6.16
65	6.16
66	6.17
67	6.18
68	6.18
69	6.18
70	6.17
71	6.19
72	6.2
73	6.2
74	6.21
75	6.21
76	6.21
77	6.22
78	6.22
79	6.22
80	6.23
81	6.23
82	6.23
83	6.22
84	6.19
85	6.13
86	6.06
87	6.01
88	5.98
89	5.95
90	5.89
91	5.89
92	6.08
93	6.23
94	6.15
95	6.22
96	6.25
97	6.26
98	6.28
99	6.29
100	6.32
101	6.33

MW-7S

102	6.35
103	6.36
104	6.41
105	6.49
106	6.61
107	6.64
108	6.65
109	6.65
110	6.63
111	6.58
112	6.53
113	6.5
114	6.48
115	6.45
116	6.69
117	6.56
118	6.51
119	6.57
120	6.49
121	6.43
122	6.37
123	6.33
124	6.29
125	6.25
126	6.32
127	6.41
128	6.33
129	6.28
130	6.23
131	6.18
132	6.12
133	6.07
134	6.02
135	5.97
136	5.92
137	5.88
138	5.83
139	5.82
140	6.57
141	6.51
142	6.45
143	6.4
144	6.35
145	6.3
146	6.24
147	6.19
148	6.14
149	6.1
150	6.05
151	6.01
152	5.97
153	5.93
154	5.89

MW-7S

155	5.85
156	5.84
157	6.06
158	6.36
159	6.32
160	6.22
161	6.16
162	6.11
163	6.05
164	5.99
165	5.94
166	6.11
167	6.22
168	6.29
169	6.36
170	6.4
171	6.45
172	6.42
173	6.39
174	6.37
175	6.4
176	6.41
177	6.41
178	6.4
179	6.41
180	6.44
181	6.38
182	6.3
183	6.23
184	6.16
185	6.1
186	6.03
187	5.96
188	5.9
189	5.83
190	5.78
191	5.72
192	5.67
193	5.63
194	5.57
195	5.52
196	5.47
197	5.29
198	5.23
199	5.19
200	5.15
201	5.11
202	5.07
203	5.01
204	4.96
205	4.92
206	4.88
207	4.84

MW-7S

208	4.79
209	4.75
210	4.7
211	4.66
212	4.63
213	4.6
214	4.56
215	4.53
216	4.49
217	4.45
218	4.42
219	4.39
220	4.35
221	4.32
222	4.28
223	4.24
224	4.21
225	4.17
226	4.13
227	4.1
228	4.06
229	4.03
230	3.99
231	3.96
232	3.92
233	3.88
234	3.85
235	3.81
236	3.78
237	3.74
238	3.7
239	3.67
240	3.63
241	3.6
242	3.57
243	3.54
244	3.51
245	3.47
246	3.45
247	3.41
248	3.38
249	3.35
250	3.32
251	3.28
252	3.26
253	3.23
254	3.2
255	3.17
256	3.14
257	3.11
258	3.09
259	3.06
260	3.04

MW-7S

261	3.01
262	2.99
263	2.96
264	2.93
265	2.91
266	2.88
267	2.86
268	2.84
269	2.81
270	2.79
271	2.76
272	2.74
273	2.72
274	2.7
275	2.67
276	2.65
277	2.62
278	2.6
279	2.59
280	2.56
281	2.54
282	2.52
283	2.49
284	2.47
285	2.44
286	2.42
287	2.4
288	2.37
289	2.35
290	2.33
291	2.31
292	2.29
293	2.26
294	2.24
295	2.22
296	2.2
297	2.18
298	2.15
299	2.13
300	2.11
301	2.08
302	2.06
303	2.04
304	2.02
305	2
306	1.98
307	1.96
308	1.95
309	1.93
310	1.91
311	1.89
312	1.88
313	1.86

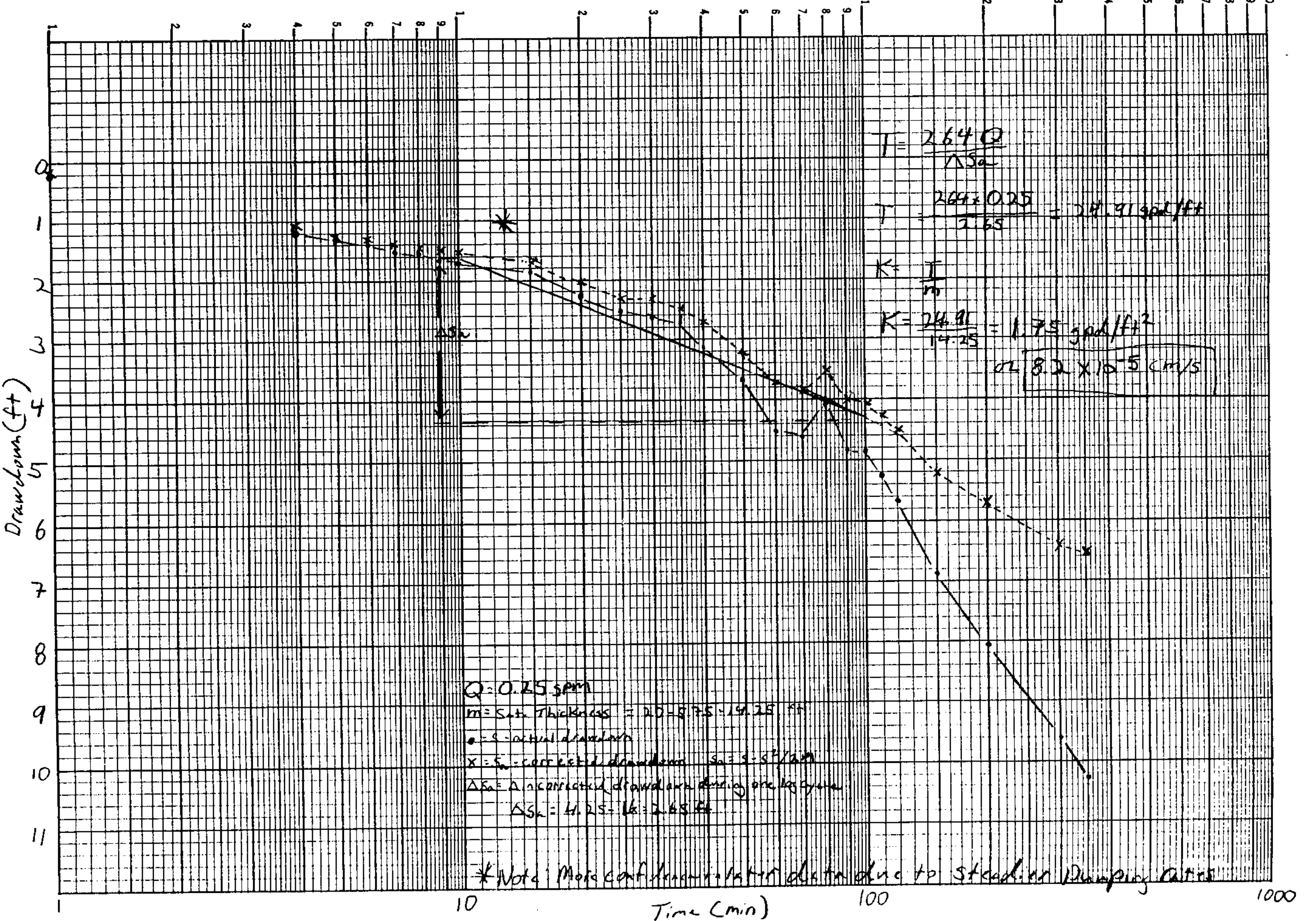
MW-7S

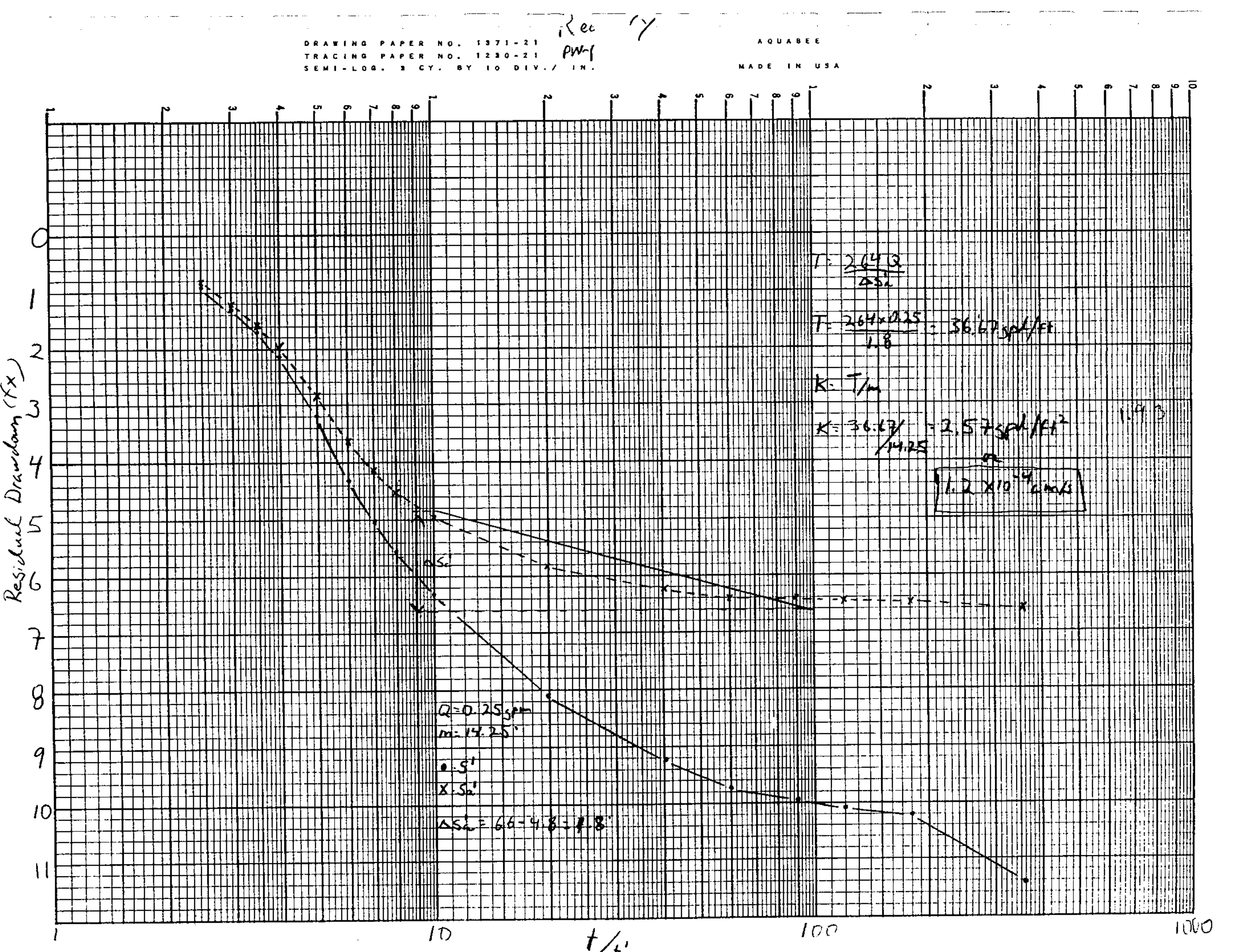
314	1.84
315	1.83
316	1.81
317	1.79
318	1.78
319	1.76
320	1.74
321	1.72
322	1.71
323	1.69
324	1.67
325	1.66
326	1.64
327	1.63
328	1.61
329	1.6
330	1.58
331	1.57
332	1.55
333	1.54
334	1.52
335	1.51
336	1.49
337	1.48
338	1.47
339	1.45
340	1.44
341	1.43
342	1.42
343	1.4
344	1.39
345	1.38
346	1.37
347	1.35
348	1.34
349	1.33
350	1.32
351	1.31
352	1.3
353	1.29
354	1.27
355	1.26
356	1.25
357	1.24
358	1.23
359	1.22
360	1.21
361	1.2
362	1.19
363	1.18

DRAWING PAPER NO. 1371-21
TRACING PAPER NO. 1230-21
SEMI-LOG. 3 CY. BY 10 DIV./ IN.

AQUABEE
MADE IN USA

PW-1



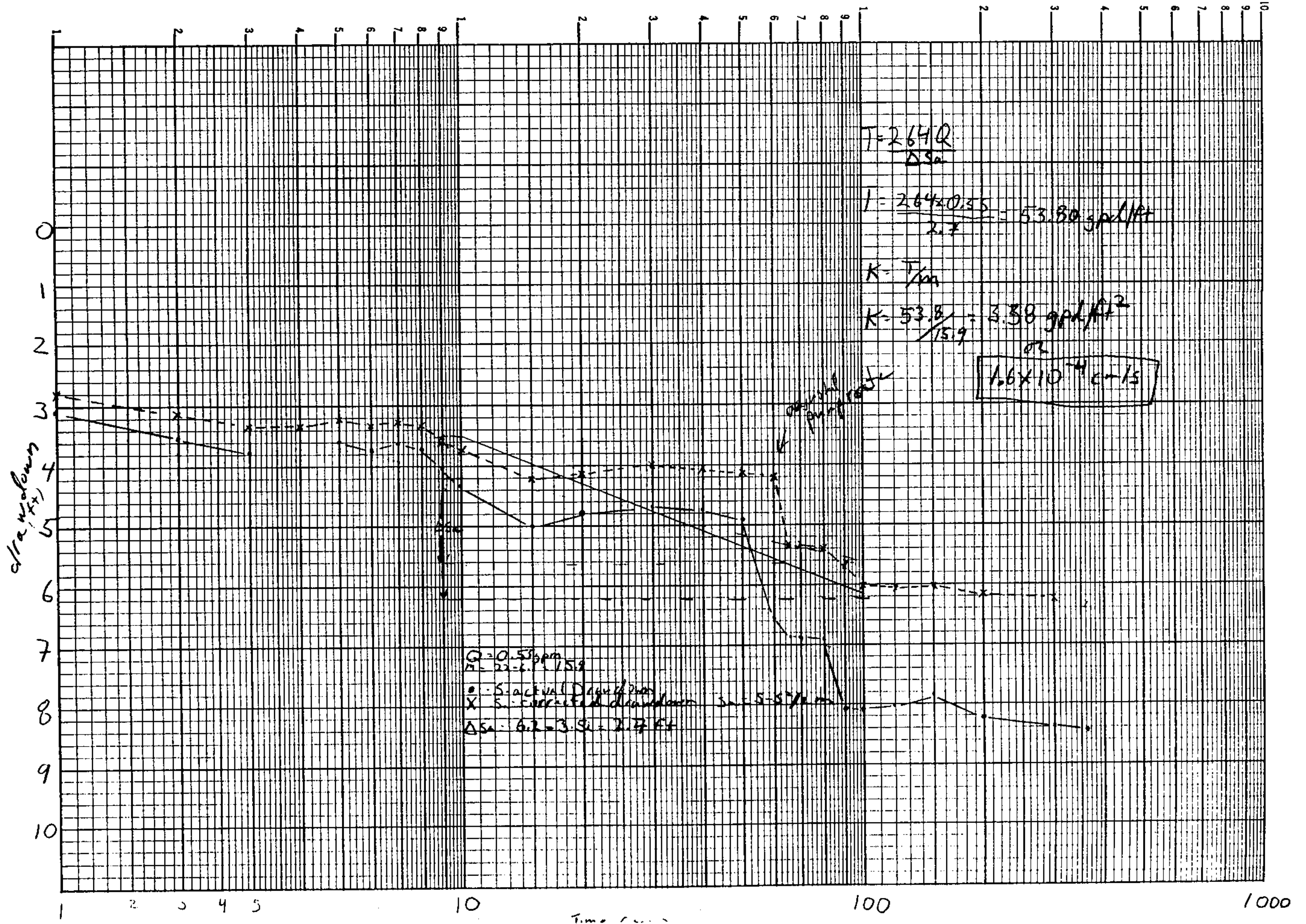


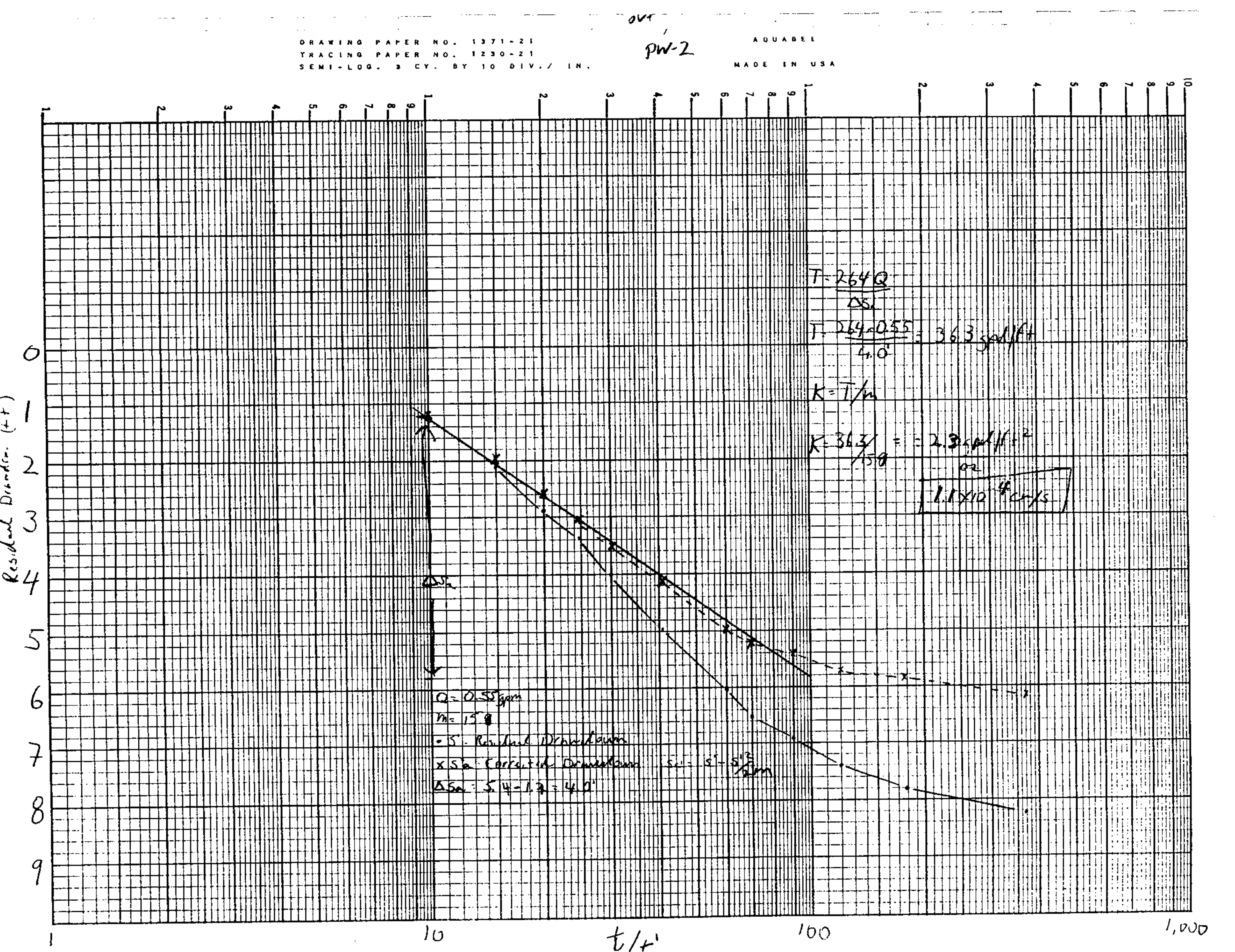
Rec 'Y
PW-1
DRAWING PAPER NO. 1371-21
TRACING PAPER NO. 1230-21
SEMI-LOG. 3 CY. BY 10 DIV./ IN.
AQUABEE
MADE IN USA
T = 264Q / Δs'
T = 264×0.25 / 1.8 = 36.67 gpd/ft
K = T/m
K = 36.67 / 14.25 = 2.57 gpd/ft²
1.2 X10⁻⁴ cm/s
1.93
Δs'
Q = 0.25 gpm
m = 14.25'
• S'
X S₂'
Δs₂' = 6.6 − 4.8 = 1.8'
Residual Drawdown (Ft)
t/t'
1
10
100
1000

DRAWING PAPER NO. 1371-21
TRACING PAPER NO. 1230-21
SEMI-LOG, 3 CY. BY 10 DIV./IN.

PW-2

AQUABEE
MADE IN USA

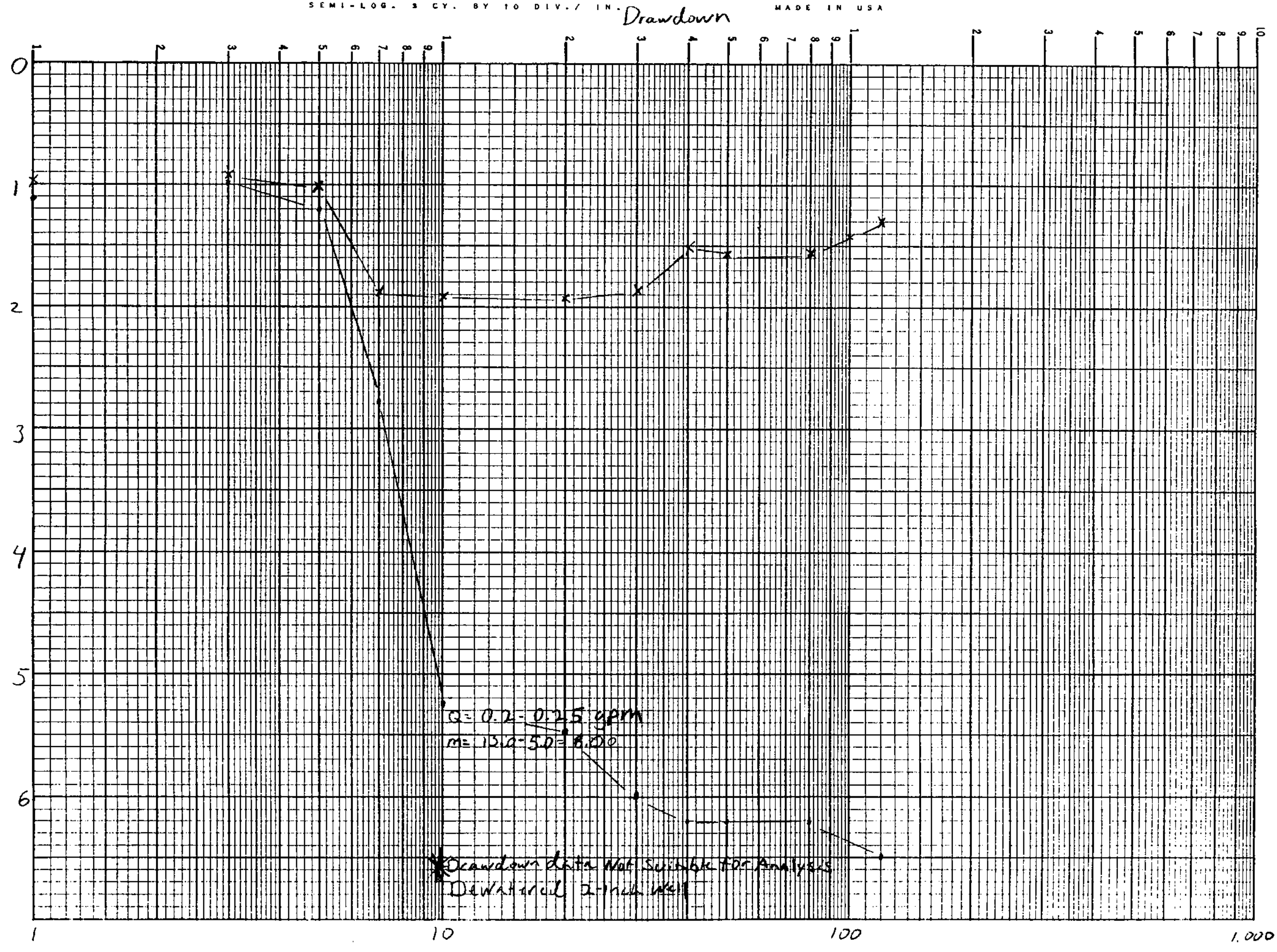


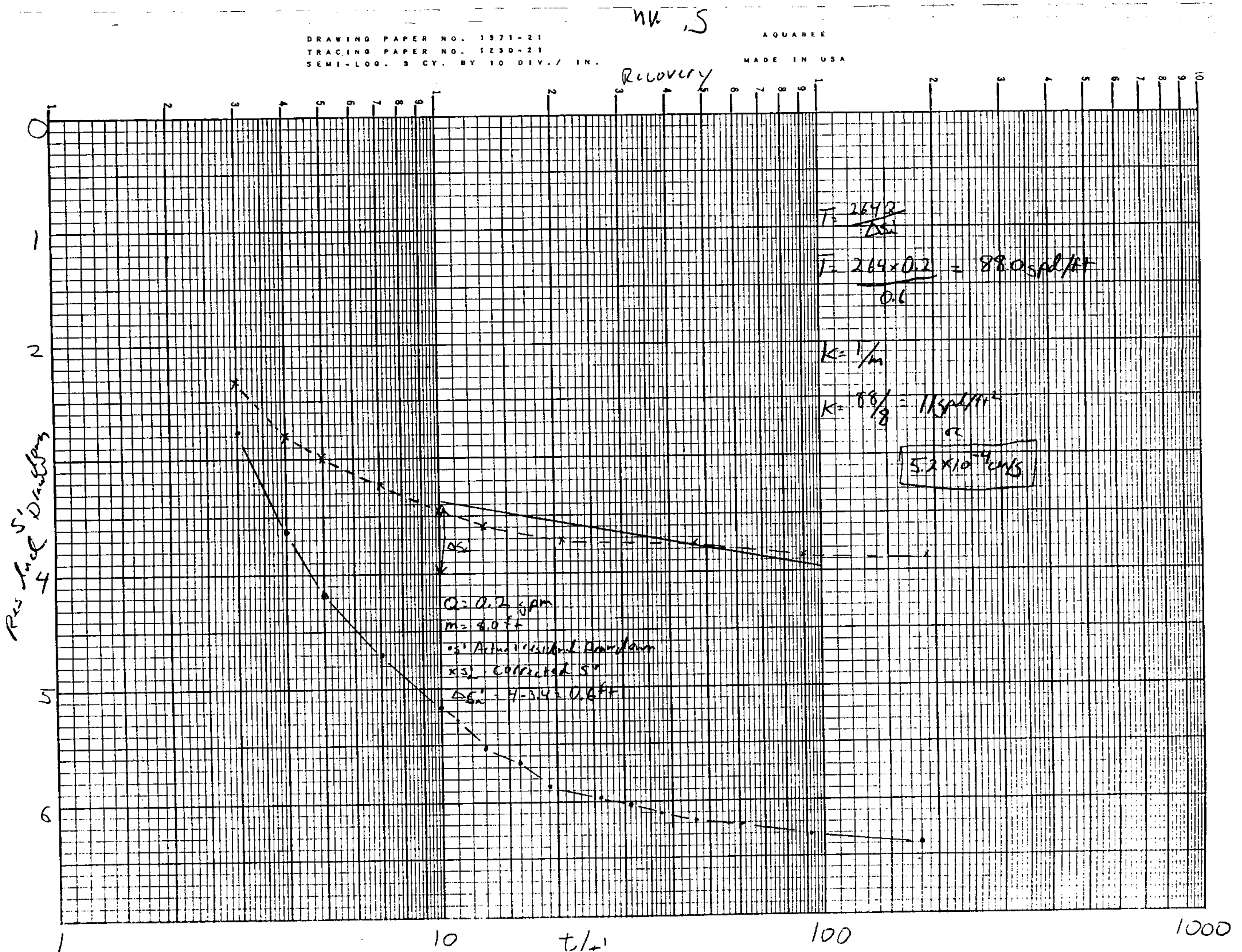


DRAWING PAPER NO. 1371-21
TRACING PAPER NO. 1230-21
SEMI-LOG. 3 CY. BY 10 DIV./ IN.
AQUABEE
MADE IN USA
OUT
PW-2
T = 264Q / ΔS_r
T = 264×0.55 / 4.0' = 36.3 gpd/ft
K = T/m
K = 36.3 / 15.0 = 2.3 gpd/ft²
or
1.1×10⁻⁴ cm/s
ΔS_r
Q = 0.55 gpm
m = 15.0
• S' Residual Drawdown
x S'_c Corrected Drawdown
ΔS_r 5.4 - 1.4 = 4.0'
Residual Drawdown (ft)
t/t'
1
10
100
1,000
0
1
2
3
4
5
6
7
8
9

DRAWING PAPER NO. 1371-21
TRACING PAPER NO. 1230-21
SEMI-LOG. 3 CY. BY 10 DIV./ IN.

AQUABEE
MADE IN USA





MW 5
DRAWING PAPER NO. 1971-21
TRACING PAPER NO. 1230-21
SEMI-LOG. 3 CY. BY 10 DIV./ IN.
AQUABEE
MADE IN USA
Recovery
T = 264Q / Δs'
T = 264×0.2 / 0.6 = 88 gpd/ft
K = T/m
K = 88/8 = 11 gpd/ft²
or
5.2×10⁻⁴ cm/s
Q = 0.2 gpm
m = 8.0 ft
• s' Actual residual drawdown
× s'c corrected s'
Δs'c = 4 - 3.4 = 0.6 ft
Δs'c
Res. and s' Drawdown
0
1
2
4
5
6
1
10
100
1000
t/t'

MALCOLM PIRNIE

B.6 Slug Test Analysis

A Q T E S O L V   R E S U L T S

Version 1.10

12/17/91
11:09:50

TEST DESCRIPTION

Data set........... lo-1slug.in
Data set title..... LO-1 Slug Test
Company............ Malcolm Pirnie, Inc.
Project............ 0965-07-1
Client............. City of Rochester
Location........... Rochester Fire Academy
Test date.......... 11/21/91

Knowns and Constants:
No. of data points................... 17
Radius of well casing............... 0.083
Radius of well...................... 0.416
Aquifer saturated thickness......... 24
Well screen length.................. 10
Static height of water in well...... 24
Log(Re/Rw).......................... 2.895
A, B, C............................. 0.000, 0.000, 1.784

ANALYTICAL METHOD

Bouwer and Rice (unconfined aquifer slug test)

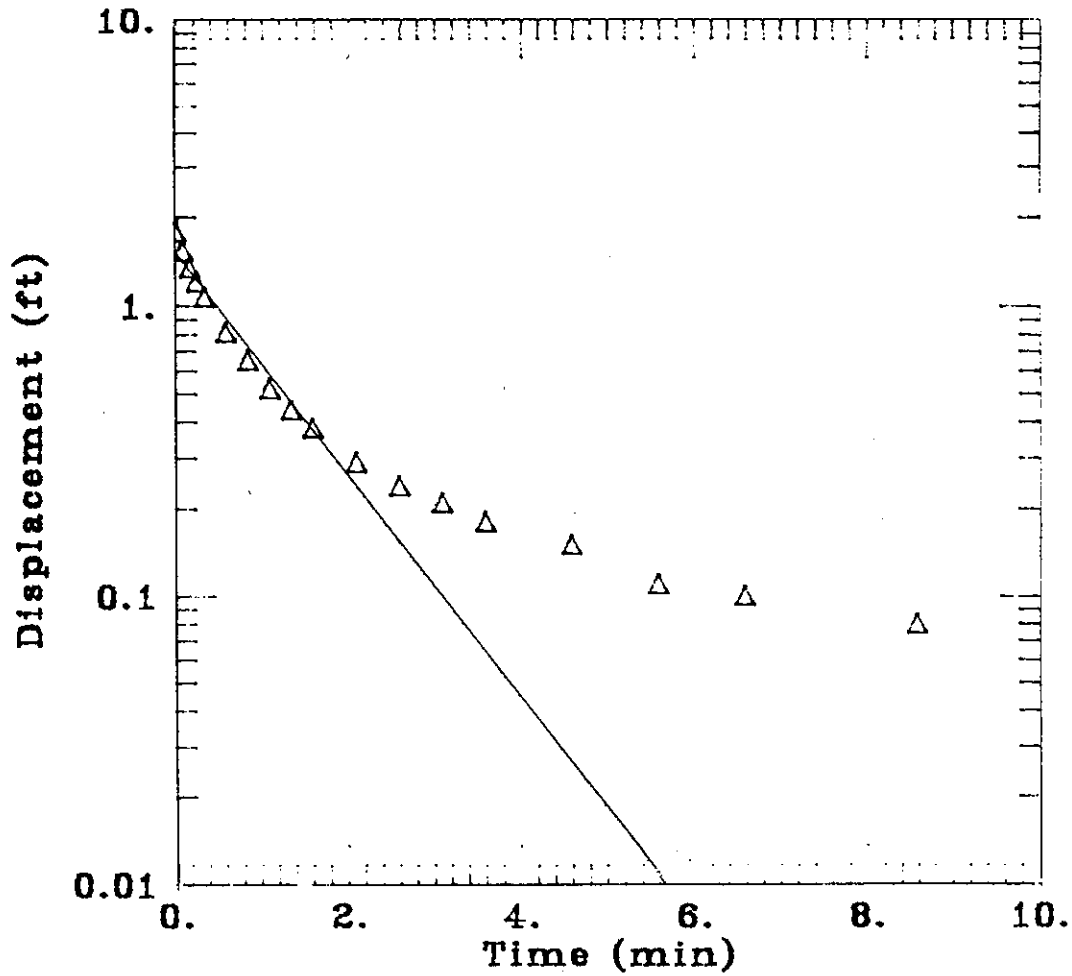
RESULTS FROM STATISTICAL CURVE MATCHING

STATISTICAL MATCH PARAMETER ESTIMATES

	Estimate		Std. Error
K =	8.8481E-004	+/-	7.4567E-005
y0 =	1.5135E+000	+/-	6.2140E-002

Malcolm Pirnie, Inc.	Client: City of Rochester
Project No.: 0965-07-1	Location: Rochester Fire Academy

LO-1 Slug Test



DATA SET:
lo-1slug.in
12/17/91

AQUIFER TYPE:
Unconfined

SOLUTION METHOD:
Bouwer-Rice

TEST DATE:
11/21/91

ESTIMATED PARAMETERS:
K = 0.0008848 ft/min
y0 = 1.513 ft

TEST DATA:
H0 = 1.78 ft
rc = 0.083 ft
rw = 0.416 ft
L = 10. ft
b = 24. ft
H = 24. ft

A Q T E S O L V R E S U L T S

Version 1.10

12/19/91
09:47:10

TEST DESCRIPTION

```
Data set........... lo-2slug.in
Data set title..... LO-2 Slug Test
Company............ Malcolm Pirnie, Inc.
Project............ 0965-07-1
Client............. City of Rochester
Location........... Rochester Fire Academy
Test date.......... 11/21/91

Knowns and Constants:
   No. of data points.................. 11
   Radius of well casing............... 0.089
   Radius of well...................... 0.416
   Aquifer saturated thickness......... 23.5
   Well screen length.................. 5
   Static height of water in well...... 23.5
   Log(Re/Rw).......................... 2.58
   A, B, C.............................  0.000,  0.000,  1.382
```

ANALYTICAL METHOD

Bouwer and Rice (unconfined aquifer slug test)

RESULTS FROM STATISTICAL CURVE MATCHING

STATISTICAL MATCH PARAMETER ESTIMATES

	Estimate		Std. Error
K =	1.7855E-004	+/-	3.7476E-005
y0 =	9.4708E-001	+/-	3.4513E-002

ANALYSIS OF MODEL RESIDUALS

residual = calculated - observed
weighted residual = residual * weight

Weighted Residual Statistics:
Number of residuals.............. 11
Number of estimated parameters.... 2
Degrees of freedom............... 9
Residual mean.................... 0.0004393
Residual standard deviation....... 0.07802
Residual variance................ 0.006087

Model Residuals:

Time	Observed	Calculated	Residual	Weight
0.0166	1.15	0.94571	0.20429	1
0.05	0.94	0.94295	-0.0029522	1
0.2	0.88	0.93067	-0.050673	1
0.45	0.85	0.91056	-0.060563	1
0.7	0.84	0.89089	-0.050887	1
1.2	0.83	0.8528	-0.022802	1
1.45	0.8	0.83437	-0.034374	1
1.95	0.78	0.7987	-0.018705	1
2.95	0.72	0.73188	-0.011875	1
3.95	0.68	0.67064	0.0093622	1
6.95	0.56	0.51599	0.044011	1

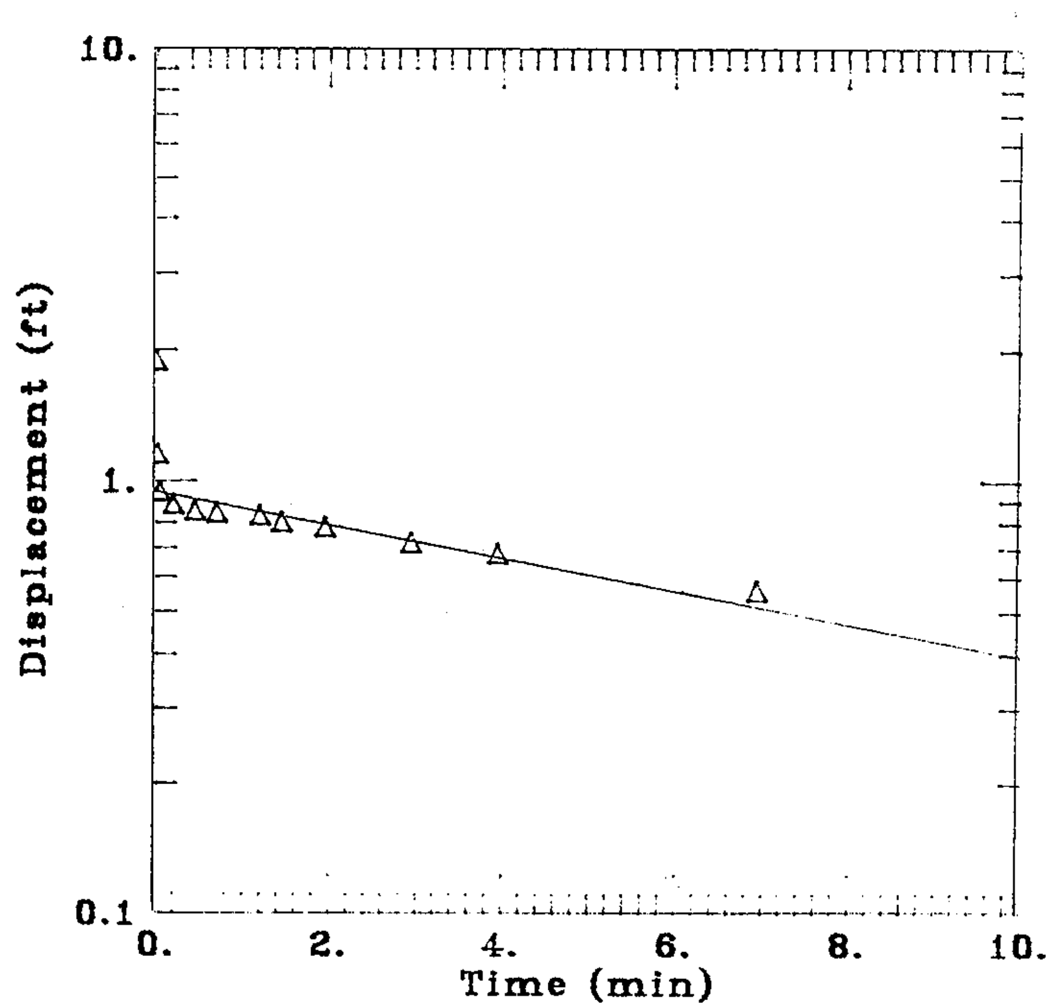
RESULTS FROM VISUAL CURVE MATCHING

VISUAL MATCH PARAMETER ESTIMATES

	Estimate
K =	1.7855E-004
y0 =	9.4708E-001

Malcolm Pirnie, Inc.	Client: **City of Rochester**
Project No.: **0965-07-1**	Location: **Rochester Fire Academy**

LO-2 Slug Test



DATA SET:
lo-2slug.in
12/17/91

AQUIFER TYPE:
Unconfined
SOLUTION METHOD:
Bouwer-Rice
TEST DATE:
11/21/91

ESTIMATED PARAMETERS:
K = 0.0001786 ft/min
y0 = 0.9471 ft

TEST DATA:
H0 = 1.89 ft
rc = 0.088 ft
rw = 0.416 ft
L = 5. ft
b = 23.5 ft
H = 23.5 ft

MALCOLM PIRNIE

B.7 Flow Model Input Parameters

[illegible]
0.5149E+03 0.5146E+03 0.5148E+03 0.5147E+03 0.5148E+03
0.5148E+03 0.5150E+03 0.5151E+03 0.5150E+03 0.5152E+03

0.5142E+03 0.5138E+03 0.5141E+03 0.5142E+03 0.5141E+03
0.5141E+03 0.5140E+03 0.5143E+03 0.5142E+03 0.5144E+03
0.5145E+03 0.5147E+03 0.5149E+03 0.5150E+03 0.5150E+03

0.5140E+03 0.5137E+03 0.5136E+03 0.5136E+03 0.5136E+03
0.5136E+03 0.5136E+03 0.5137E+03 0.5139E+03 0.5140E+03
0.5141E+03 0.5143E+03 0.5146E+03 0.5150E+03 0.5149E+03

0.5132E+03 0.5129E+03 0.5129E+03 0.5129E+03 0.5129E+03
0.5129E+03 0.5130E+03 0.5130E+03 0.5133E+03 0.5134E+03
0.5136E+03 0.5137E+03 0.5139E+03 0.5141E+03 0.5140E+03

0.5120E+03 0.5120E+03 0.5120E+03 0.5120E+03 0.5120E+03
0.5121E+03 0.5120E+03 0.5121E+03 0.5125E+03 0.5125E+03
0.5129E+03 0.5129E+03 0.5131E+03 0.5132E+03 0.5135E+03

0.5120E+03 0.5120E+03 0.5120E+03 0.5120E+03 0.5120E+03
0.5120E+03 0.5120E+03 0.5120E+03 0.5120E+03 0.5120E+03
0.5120E+03 0.5120E+03 0.5120E+03 0.5120E+03 0.5120E+03

0.5120E+03 0.5120E+03 0.5120E+03 0.5120E+03 0.5120E+03
0.5120E+03 0.5120E+03 0.5120E+03 0.5120E+03 0.5120E+03
0.5120E+03 0.5120E+03 0.5120E+03 0.5120E+03 0.5120E+03

TRANSMISSIBILITY IN J-DIRECTION

0.2058E+04 0.2058E+04 0.2058E+04 0.2058E+04 0.2058E+04
0.2058E+04 0.2058E+04 0.2058E+04 0.2058E+04 0.2058E+04
0.2058E+04 0.2058E+04 0.2058E+04 0.2058E+04 0.2058E+04

0.2044E+04 0.2044E+04 0.2044E+04 0.2044E+04 0.2044E+04
0.2044E+04 0.2044E+04 0.2044E+04 0.2044E+04 0.2044E+04
0.2044E+04 0.2044E+04 0.2044E+04 0.2044E+04 0.2044E+04

0.2023E+04 0.2023E+04 0.2023E+04 0.2023E+04 0.2023E+04
0.2023E+04 0.2023E+04 0.2023E+04 0.2023E+04 0.2023E+04
0.2023E+04 0.2023E+04 0.2030E+04 0.2030E+04 0.2100E+04

0.2009E+04 0.2009E+04 0.1435E+03 0.1435E+03 0.1425E+03
0.1435E+03 0.5857E+02 0.5855E+02 0.5843E+02 0.2009E+04
0.2009E+04 0.2009E+04 0.1450E+03 0.1500E+03 0.1500E+03

0.1425E+03 0.1425E+03 0.1425E+03 0.1425E+03 0.1425E+03
0.1425E+03 0.5789E+02 0.5802E+02 0.5834E+02 0.1425E+03
0.1425E+03 0.1425E+03 0.1450E+03 0.1500E+03 0.1500E+03

0.1425E+03 0.1425E+03 0.1425E+03 0.1425E+03 0.1425E+03
0.1425E+03 0.5715E+02 0.5729E+02 0.5746E+02 0.1425E+03
0.1425E+03 0.1425E+03 0.1450E+03 0.1500E+03 0.1500E+03

0.1410E+03 0.1413E+03 0.1413E+03 0.1413E+03 0.1413E+03
0.1413E+03 0.1413E+03 0.1413E+03 0.1413E+03 0.1413E+03
0.1413E+03 0.1413E+03 0.1450E+03 0.1450E+03 0.1450E+03

0.1400E+03 0.1400E+03 0.1400E+03 0.1400E+03 0.1400E+03
0.1400E+03 0.1400E+03 0.1400E+03 0.1400E+03 0.1400E+03
0.1407E+03 0.1416E+03 0.1450E+03 0.1425E+03 0.1400E+03

0.1350E+03 0.1350E+03 0.1350E+03 0.1350E+03 0.1350E+03
[illegible]

```
  Version 3.1 of PLASM
    September 1990

      written by

  Thomas A. Prickett
   6 Oak Bay Drive
   Urbana, Illinois

  Phone(217) 384-0615

This run has the title =

The input data file CALBREV1.PLA has been loaded into RAM

The predictor is turned ON.

Chosen percentage of water  unaccounted for each time step =  2  %

Chosen convergence test error =  1

The name of this PLASM data file for this run is CALBREV1.PLA

                    INTERACTIVE MICROCOMPUTER PLASM

                          INPUT DATA PRINTOUT

System of units used = ENGLISH (gal-day-ft)
Number of time steps= 11
Initial time step= 5.356527  days
Number of rows and columns= 12  13
Allowed error in head between iteration= 1
Unconfined conditions.
Water balance in effect. Cutoff value =  2
Predictor in effect.

                             INITIAL HEAD

 0.5154E+03 0.5154E+03 0.5154E+03 0.5154E+03 0.5154E+03
     0.5154E+03 0.5154E+03 0.5154E+03 0.5154E+03 0.5152E+03
     0.5152E+03 0.5152E+03 0.5152E+03 0.5154E+03 0.5154E+03

 0.5152E+03 0.5152E+03 0.5153E+03 0.5153E+03 0.5153E+03
     0.5153E+03 0.5152E+03 0.5153E+03 0.5153E+03 0.5152E+03
     0.5152E+03 0.5152E+03 0.5152E+03 0.5152E+03 0.5152E+03

 0.5154E+03 0.5151E+03 0.5152E+03 0.5152E+03 0.5153E+03
     0.5153E+03 0.5152E+03 0.5153E+03 0.5153E+03 0.5152E+03
     0.5152E+03 0.5151E+03 0.5151E+03 0.5150E+03 0.5160E+03

 0.5147E+03 0.5149E+03 0.5150E+03 0.5152E+03 0.5153E+03
     0.5153E+03 0.5152E+03 0.5152E+03 0.5152E+03 0.5152E+03
     0.5152E+03 0.5152E+03 0.5152E+03 0.5160E+03 0.5161E+03

 0.5148E+03 0.5149E+03 0.5148E+03 0.5149E+03 0.5149E+03
     0.5149E+03 0.5149E+03 0.5151E+03 0.5152E+03 0.5152E+03
     [illegible]
```

```
      0.4860E+03 0.4860E+03 0.4860E+03 0.4860E+03 0.4860E+03
      0.4860E+03 0.4860E+03 0.4860E+03 0.4860E+03 0.4860E+03

 0.4860E+03 0.4860E+03 0.4860E+03 0.4860E+03 0.4860E+03
      0.4860E+03 0.4860E+03 0.4860E+03 0.4860E+03 0.4860E+03
      0.4860E+03 0.4860E+03 0.4860E+03 0.4860E+03 0.4860E+03

 0.4860E+03 0.4860E+03 0.4860E+03 0.4860E+03 0.4860E+03
      0.4860E+03 0.4860E+03 0.4860E+03 0.4860E+03 0.4860E+03
      0.4860E+03 0.4860E+03 0.4860E+03 0.4860E+03 0.4860E+03

 0.4860E+03 0.4860E+03 0.4860E+03 0.4860E+03 0.4860E+03
      0.4860E+03 0.4860E+03 0.4860E+03 0.4860E+03 0.4860E+03
      0.4860E+03 0.4860E+03 0.4860E+03 0.4860E+03 0.4860E+03

 0.4860E+03 0.4860E+03 0.4860E+03 0.4860E+03 0.4860E+03
      0.4860E+03 0.4860E+03 0.4860E+03 0.4860E+03 0.4860E+03
      0.4860E+03 0.4860E+03 0.4860E+03 0.4860E+03 0.4860E+03

 0.4860E+03 0.4860E+03 0.4860E+03 0.4860E+03 0.4860E+03
      0.4860E+03 0.4860E+03 0.4860E+03 0.4860E+03 0.4860E+03
      0.4860E+03 0.4860E+03 0.4860E+03 0.4860E+03 0.4860E+03

 0.4860E+03 0.4860E+03 0.4860E+03 0.4860E+03 0.4860E+03
      0.4860E+03 0.4860E+03 0.4860E+03 0.4860E+03 0.4860E+03
      0.4860E+03 0.4860E+03 0.4860E+03 0.4860E+03 0.4860E+03

 0.4860E+03 0.4860E+03 0.4860E+03 0.4860E+03 0.4860E+03
      0.4860E+03 0.4860E+03 0.4860E+03 0.4860E+03 0.4860E+03
      0.4860E+03 0.4860E+03 0.4860E+03 0.4860E+03 0.4860E+03
```

These are the DELX values (i.e. column spacing)

The spacing between node 1 and node 2 is 90
The spacing between node 2 and node 3 is 30
The spacing between node 3 and node 4 is 30
The spacing between node 4 and node 5 is 30
The spacing between node 5 and node 6 is 30
The spacing between node 6 and node 7 is 30
The spacing between node 7 and node 8 is 30
The spacing between node 8 and node 9 is 30
The spacing between node 9 and node 10 is 30
The spacing between node 10 and node 11 is 30
The spacing between node 11 and node 12 is 30
The spacing between node 12 and node 13 is 30
The spacing between node 13 and node 14 is 30
The spacing between node 14 and node 15 is 30

These are the DELY values (i.e. row spacing)

The spacing between node 1 and node 2 is 30
The spacing between node 2 and node 3 is 30
The spacing between node 3 and node 4 is 30
The spacing between node 4 and node 5 is 30
The spacing between node 5 and node 6 is 30
The spacing between node 6 and node 7 is 30
The spacing between node 7 and node 8 is 30
The spacing between node 8 and node 9 is 30
The spacing between node 9 and node 10 is 30
The spacing between node 10 and node 11 is 30

[illegible]

```
0.7000E+02 0.7000E+02 0.7000E+02 0.7000E+02 0.7000E+02
     0.7000E+02 0.7000E+02 0.7000E+02 0.7000E+02 0.7000E+02
     0.7000E+02 0.7000E+02 0.7000E+02 0.7000E+02 0.7000E+02

0.7000E+02 0.7000E+02 0.7000E+02 0.7000E+02 0.7000E+02
     0.7000E+02 0.7000E+02 0.7000E+02 0.7000E+02 0.7000E+02
     0.7000E+02 0.7000E+02 0.7000E+02 0.7000E+02 0.7000E+02

0.7000E+02 0.7000E+02 0.5000E+01 0.5000E+01 0.5000E+01
     0.2000E+01 0.2000E+01 0.2000E+01 0.2000E+01 0.7000E+02
     0.7000E+02 0.7000E+02 0.5000E+01 0.5000E+01 0.5000E+01

0.5000E+01 0.5000E+01 0.5000E+01 0.5000E+01 0.5000E+01
     0.5000E+01 0.2000E+01 0.2000E+01 0.2000E+01 0.5000E+01
     0.5000E+01 0.5000E+01 0.5000E+01 0.5000E+01 0.5000E+01

0.5000E+01 0.5000E+01 0.5000E+01 0.5000E+01 0.5000E+01
     0.5000E+01 0.2000E+01 0.2000E+01 0.2000E+01 0.5000E+01
     0.5000E+01 0.5000E+01 0.5000E+01 0.5000E+01 0.5000E+01

0.5000E+01 0.5000E+01 0.5000E+01 0.5000E+01 0.5000E+01
     0.5000E+01 0.5000E+01 0.5000E+01 0.5000E+01 0.5000E+01
     0.5000E+01 0.5000E+01 0.5000E+01 0.5000E+01 0.5000E+01

0.5000E+01 0.5000E+01 0.5000E+01 0.5000E+01 0.5000E+01
     0.5000E+01 0.5000E+01 0.5000E+01 0.5000E+01 0.5000E+01
     0.5000E+01 0.5000E+01 0.5000E+01 0.5000E+01 0.5000E+01

0.5000E+01 0.5000E+01 0.5000E+01 0.5000E+01 0.5000E+01
     0.5000E+01 0.5000E+01 0.5000E+01 0.5000E+01 0.5000E+01
     0.5000E+01 0.5000E+01 0.5000E+01 0.5000E+01 0.5000E+01

0.1000E+03 0.1000E+03 0.1000E+03 0.1000E+03 0.1000E+03
     0.1000E+03 0.1000E+03 0.5000E+01 0.5000E+01 0.5000E+01
     0.5000E+01 0.5000E+01 0.5000E+01 0.5000E+01 0.5000E+01

0.1000E+03 0.1000E+03 0.1000E+03 0.1000E+03 0.1000E+03
     0.1000E+03 0.1000E+03 0.1000E+03 0.1000E+03 0.1000E+03
     0.1000E+03 0.1000E+03 0.1000E+03 0.1000E+03 0.1000E+03

0.1000E+03 0.1000E+03 0.1000E+03 0.1000E+03 0.1000E+03
     0.1000E+03 0.1000E+03 0.1000E+03 0.1000E+03 0.1000E+03
     0.1000E+03 0.1000E+03 0.1000E+03 0.1000E+03 0.1000E+03
```

ELEVATION OF BOTTOM OF AQUIFER

```
0.4860E+03 0.4860E+03 0.4860E+03 0.4860E+03 0.4860E+03
     0.4860E+03 0.4860E+03 0.4860E+03 0.4860E+03 0.4860E+03
     0.4860E+03 0.4860E+03 0.4860E+03 0.4860E+03 0.4860E+03

0.4860E+03 0.4860E+03 0.4860E+03 0.4860E+03 0.4860E+03
     0.4860E+03 0.4860E+03 0.4860E+03 0.4860E+03 0.4860E+03
     0.4860E+03 0.4860E+03 0.4860E+03 0.4860E+03 0.4860E+03

0.4860E+03 0.4860E+03 0.4860E+03 0.4860E+03 0.4860E+03
     0.4860E+03 0.4860E+03 0.4860E+03 0.4860E+03 0.4860E+03
     0.4860E+03 0.4860E+03 0.4860E+03 0.4860E+03 0.4860E+03

0.4860E+03 0.4860E+03 0.4860E+03 0.4860E+03 0.4860E+03
     0.4860E+03 0.4860E+03 0.4860E+03 0.4860E+03 0.4860E+03
```

[illegible]

[illegible]

0.0000E+00 0.0000E+00 0.5000E-03 0.0000E-01 0.0000E-01
0.0000E-01 0.1000E-00 0.5000E-03 0.0000E-01 0.0000E-01
0.0000E+00 0.0000E+00 0.0000E+00 0.0000E-00 0.0000E-00

HYDRAULIC CONDUCTIVITY IN THE I DIRECTION
(unadjusted)

0.7000E-02 0.7000E-02 0.7000E-02 0.7000E+02 0.7000E-02
0.7000E+02 0.7000E+02 0.7000E-02 0.7000E-02 0.7000E-02
0.7000E+02 0.7000E-02 0.7000E-02 0.7000E+02 0.7000E-02

0.7000E+02 0.7000E-02 0.7000E-02 0.7000E-02 0.7000E-02
0.7000E+02 0.7000E+02 0.7000E+02 0.7000E+02 0.7000E-02
0.7000E-02 0.7000E-02 0.7000E-02 0.7000E+02 0.7000E-02

0.7000E+02 0.7000E-02 0.7000E+02 0.7000E+02 0.7000E+02
0.7000E+02 0.7000E+02 0.7000E-02 0.7000E+02 0.7000E-02
0.7000E+02 0.7000E+02 0.7000E-02 0.7000E+02 0.7000E-02

0.7000E+02 0.7000E-02 0.5000E+01 0.5000E+01 0.5000E-01
0.5000E+01 0.2000E+01 0.2000E+01 0.2000E+01 0.7000E-02
0.7000E-02 0.7000E-02 0.5000E+01 0.5000E+01 0.5000E-01

0.5000E+01 0.5000E+01 0.5000E+01 0.5000E+01 0.5000E-01
0.5000E-01 0.2000E+01 0.2000E+01 0.2000E+01 0.5000E+01
0.5000E-01 0.5000E+01 0.5000E+01 0.5000E+01 0.5000E-01

0.5000E+01 0.5000E+01 0.5000E+01 0.5000E-01 0.5000E+01
0.5000E+01 0.2000E+01 0.2000E+01 0.2000E+01 0.5000E+01
0.5000E+01 0.5000E+01 0.5000E+01 0.5000E+01 0.5000E+01

0.5000E+01 0.5000E+01 0.5000E+01 0.5000E+01 0.5000E+01
0.5000E+01 0.5000E+01 0.5000E+01 0.5000E+01 0.5000E+01
0.5000E+01 0.5000E+01 0.5000E+01 0.5000E+01 0.5000E+01

0.5000E-01 0.5000E-01 0.5000E+01 0.5000E-01 0.5000E+01
0.5000E+01 0.5000E+01 0.5000E-01 0.5000E+01 0.5000E+01
0.5000E+01 0.5000E+01 0.5000E+01 0.5000E+01 0.5000E+01

0.5000E-01 0.5000E+01 0.5000E+01 0.5000E+01 0.5000E-01
0.5000E+01 0.5000E+01 0.5000E+01 0.5000E+01 0.5000E+01
0.5000E+01 0.5000E+01 0.5000E+01 0.5000E+01 0.5000E+01

0.1000E+03 0.1000E+03 0.1000E+03 0.1000E+03 0.1000E+03
0.1000E+03 0.1000E+03 0.5000E+01 0.5000E+01 0.5000E+01
0.5000E+01 0.5000E+01 0.5000E+01 0.5000E+01 0.5000E+01

0.1000E+03 0.1000E+03 0.1000E-03 0.1000E-03 0.1000E+03
0.1000E-03 0.1000E+03 0.1000E+03 0.1000E+03 0.1000E+03
0.1000E+03 0.1000E+03 0.1000E-03 0.1000E+03 0.1000E+03

0.1000E+03 0.1000E+03 0.1000E+03 0.1000E-03 0.1000E+03
0.1000E+03 0.1000E+03 0.1000E+03 0.1000E+03 0.1000E+03
0.1000E+03 0.1000E+03 0.1000E+03 0.1000E+03 0.1000E-03

HYDRAULIC CONDUCTIVITY IN THE J DIRECTION
(unadjusted)

(5)

[illegible]

```
0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
     0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
     0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00

0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
     0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
     0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00

0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
     0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
     0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00

0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
     0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
     0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00

0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
     0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
     0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
```

CONFINING BED BOTTOM

```
0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
     0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
     0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00

0.0000E+00 0.5080E+03 0.5080E+03 0.5080E+03 0.5080E+03
     0.5080E+03 0.5080E+03 0.5080E+03 0.5080E+03 0.5080E+03
     0.5080E+03 0.5080E+03 0.5080E+03 0.5080E+03 0.0000E+00

0.0000E+00 0.5080E+03 0.5080E+03 0.5080E+03 0.5080E+03
     0.5080E+03 0.5080E+03 0.5080E+03 0.5080E+03 0.5080E+03
     0.5080E+03 0.5080E+03 0.5080E+03 0.5080E+03 0.0000E+00

0.0000E+00 0.5100E+03 0.5100E+03 0.5100E+03 0.5100E+03
     0.5100E+03 0.5100E+03 0.5100E+03 0.5100E+03 0.5100E+03
     0.5100E+03 0.5100E+03 0.5100E+03 0.5100E+03 0.0000E+00

0.0000E+00 0.5120E+03 0.5120E+03 0.5120E+03 0.5120E+03
     0.5120E+03 0.5120E+03 0.5120E+03 0.5120E+03 0.5120E+03
     0.5120E+03 0.5120E+03 0.5120E+03 0.5120E+03 0.0000E+00

0.0000E+00 0.5140E+03 0.5140E+03 0.5140E+03 0.5140E+03
     0.5140E+03 0.5140E+03 0.5140E+03 0.5140E+03 0.5140E+03
     0.5140E+03 0.5140E+03 0.5140E+03 0.5140E+03 0.0000E+00

0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
     0.5140E+03 0.0000E+00 0.0000E+00 0.5140E+03 0.5140E+03
     0.5140E+03 0.5140E+03 0.5140E+03 0.5140E+03 0.0000E+00

0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
     0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
     0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00

0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
     0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
     0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00

0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
     0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
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MALCOLM PIRNIE

APPENDIX C

TREATABILITY TESTING

MALCOLM PIRNIE

C.1 Air Guide 1 Analysis

ROCHESTER FIRE ACADEMY - SOUTH DISPOSAL AREA SHALLOW OVERBURDEN
COMPARISON OF ANTICIPATED STACK CONCENTRATIONS TO
DRAFT AIR GUIDE 1 LIMITS AT A
STEADY-STATE PRODUCTION RATE OF 15 gpm

CONTAMINANT	INFLUENT WATER CONC. (mg/l)	EFFLUENT WATER CONC. (mg/l)	NET (mg/l)	MAX WATER FLOW RATE (GPM)	MASS TRANSFER TO AIR (mg/min)	BLOWER CAP. (cfm)	STACK AIR CONC. (mg/cu m)	MASS TRANSFER TO AIR (lbs/hr)
1,1-Dichloroethene	0.12	0.0012	0.1188	15	6.75	600	0.40	0.0009
1,1-Dichloroethane	1	0.01	0.99	15	56.25	600	3.31	0.0074
1,2-Dichloroethene	30	0.3	29.7	15	1687.50	600	99.28	0.2232
Chloroform	0.008	0.00008	0.00792	15	0.45	600	0.03	0.0001
1,2-Dichloroethane	0.046	0.00046	0.04554	15	2.59	600	0.15	0.0003
Vinyl Chloride	0.22	0.0022	0.2178	15	12.37	600	0.73	0.0016
Acetone	1.6	0.016	1.584	15	90.00	600	5.30	0.0119
Methylene Chloride	0.58	0.0058	0.5742	15	32.62	600	1.92	0.0043
2-Butanone	0.15	0.0015	0.1485	15	8.44	600	0.50	0.0011
1,1,1-Trichloroethane	7.9	0.079	7.821	15	444.38	600	26.14	0.0588
Bromodichloromethane	0.009	0.00009	0.00891	15	0.51	600	0.03	0.0001
Trichloroethene	0.94	0.0094	0.9306	15	52.88	600	3.11	0.0070
Benzene	0.009	0.00009	0.00891	15	0.51	600	0.03	0.0001
4-methyl-2-pentanone	0.16	0.0016	0.1584	15	9.00	600	0.53	0.0012
Tetrachloroethene	0.088	0.00088	0.08712	15	4.95	600	0.29	0.0007
Toluene	0.91	0.0091	0.9009	15	51.19	600	3.01	0.0068
Chlorobenzene	0.008	0.00008	0.00792	15	0.45	600	0.03	0.0001
Ethylbenzene	0.34	0.0034	0.3366	15	19.13	600	1.13	0.0025
Total Xylenes	2.3	0.023	2.277	15	129.37	600	7.61	0.0171

ROCHESTER FIRE ACADEMY - SOUTH DISPOSAL AREA SHALLOW OVERBURDEN
COMPARISON OF ANTICIPATED STACK CONCENTRATIONS TO
DRAFT AIR GUIDE 1 LIMITS AT A
STEADY-STATE PRODUCTION RATE OF 15 gpm

CONTAMINANT	STACK ELEVATION (FT)	MAX. ACTUAL ANNUAL IMPACT (ug/cu. m)	MAX. POTENTIAL ANNUAL IMPACT (ug/cu. m)	MAX. SHORT-TERM IMPACT (ug/cu. m)	ANNUAL GUIDANCE CONC. (AGC) (ug/cu. m)	SHORT-TERM GUIDANCE CONC. (SGC) (ug/cu. m)
1,1-Dichloroethene	15	0.011	0.011	4.56	NA	NA
1,1-Dichloroethane	15	0.091	0.090	37.98	500	190000
1,2-Dichloroethene	15	2.716	2.713	1139.53	1900	190000
Chloroform	15	0.001	0.001	0.30	23	980
1,2-Dichloroethane	15	0.004	0.004	1.75	0.039	950
Vinyl Chloride	15	0.020	0.020	8.36	0.02	1300
Acetone	15	0.145	0.145	60.78	14000	140000
Methylene Chloride	15	0.053	0.052	22.03	27	41000
2-Butanone	15	0.014	0.014	5.70	300	140000
1,1,1-Trichloroethane	15	0.715	0.714	300.08	1000	450000
Bromodichloromethane	15	0.001	0.001	0.34	0.02	NA
Trichloroethene	15	0.085	0.085	35.71	0.45	33000
Benzene	15	0.001	0.001	0.34	0.12	30
4-methyl-2-pentanone	15	0.014	0.014	6.08	480	48000
Tetrachloroethene	15	0.008	0.008	3.34	0.075	81000
Toluene	15	0.082	0.082	34.57	0.1	NA
Chlorobenzene	15	0.001	0.001	0.30	20	11000
Ethylbenzene	15	0.031	0.031	12.91	1000	100000
Total Xylenes	15	0.208	0.208	87.36	300	100000

ROCHESTER FIRE ACADEMY - SOUTH DISPOSAL AREA SHALLOW OVERBURDEN
COMPARISON OF ANTICIPATED STACK CONCENTRATIONS TO
DRAFT AIR GUIDE 1 LIMITS AT A
START-UP PRODUCTION RATE OF 40 gpm

CONTAMINANT	INFLUENT WATER CONC. (mg/l)	EFFLUENT WATER CONC. (mg/l)	NET (mg/l)	MAX WATER FLOW RATE (GPM)	MASS TRANSFER TO AIR (mg/min)	BLOWER CAP. (cfm)	STACK AIR CONC. (mg/cu m)	MASS TRANSFER TO AIR (lbs/hr)
1,1-Dichloroethene	0.12	0.0012	0.1188	40	18.00	600	1.06	0.0024
1,1-Dichloroethane	1	0.01	0.99	40	150.00	600	8.83	0.0198
1,2-Dichloroethene	30	0.3	29.7	40	4500.00	600	264.75	0.5952
Chloroform	0.008	0.00008	0.00792	40	1.20	600	0.07	0.0002
1,2-Dichloroethane	0.046	0.00046	0.04554	40	6.90	600	0.41	0.0009
Vinyl Chloride	0.22	0.0022	0.2178	40	33.00	600	1.94	0.0044
Acetone	1.6	0.016	1.584	40	240.00	600	14.12	0.0317
Methylene Chloride	0.58	0.0058	0.5742	40	87.00	600	5.12	0.0115
2-Butanone	0.15	0.0015	0.1485	40	22.50	600	1.32	0.0030
1,1,1-Trichloroethane	7.9	0.079	7.821	40	1185.00	600	69.72	0.1567
Bromodichloromethane	0.009	0.00009	0.00891	40	1.35	600	0.08	0.0002
Trichloroethene	0.94	0.0094	0.9306	40	141.00	600	8.30	0.0187
Benzene	0.009	0.00009	0.00891	40	1.35	600	0.08	0.0002
4-methyl-2-pentanone	0.16	0.0016	0.1584	40	24.00	600	1.41	0.0032
Tetrachloroethene	0.088	0.00088	0.08712	40	13.20	600	0.78	0.0017
Toluene	0.91	0.0091	0.9009	40	136.50	600	8.03	0.0181
Chlorobenzene	0.008	0.00008	0.00792	40	1.20	600	0.07	0.0002
Ethylbenzene	0.34	0.0034	0.3366	40	51.00	600	3.00	0.0067
Total Xylenes	2.3	0.023	2.277	40	345.00	600	20.30	0.0456

ROCHESTER FIRE ACADEMY - SOUTH DISPOSAL AREA SHALLOW OVERBURDEN
COMPARISON OF ANTICIPATED STACK CONCENTRATIONS TO
DRAFT AIR GUIDE 1 LIMITS AT A
START-UP PRODUCTION RATE OF 40 gpm

CONTAMINANT	STACK ELEVATION (FT)	MAX. ACTUAL ANNUAL IMPACT (ug/cu. m)	MAX. POTENTIAL ANNUAL IMPACT (ug/cu. m)	MAX. SHORT-TERM IMPACT (ug/cu. m)	ANNUAL GUIDANCE CONC. (AGC) (ug/cu. m)	SHORT-TERM GUIDANCE CONC. (SGC) (ug/cu. m)
1,1-Dichloroethene	24	0.010	0.010	4.40	NA	NA
1,1-Dichloroethane	24	0.087	0.087	36.70	500	190000
1,2-Dichloroethene	24	2.624	2.621	1101.02	1900	190000
Chloroform	24	0.001	0.001	0.29	23	980
1,2-Dichloroethane	24	0.004	0.004	1.69	0.039	950
Vinyl Chloride	24	0.019	0.019	8.07	0.02	1300
Acetone	24	0.140	0.140	58.72	14000	140000
Methylene Chloride	24	0.051	0.051	21.29	27	41000
2-Butanone	24	0.013	0.013	5.51	300	140000
1,1,1-Trichloroethane	24	0.691	0.690	289.94	1000	450000
Bromodichloromethane	24	0.001	0.001	0.33	0.02	NA
Trichloroethene	24	0.082	0.082	34.50	0.45	33000
Benzene	24	0.001	0.001	0.33	0.12	30
4-methyl-2-pentanone	24	0.014	0.014	5.87	480	48000
Tetrachloroethene	24	0.008	0.008	3.23	0.075	81000
Toluene	24	0.080	0.080	33.40	0.1	NA
Chlorobenzene	24	0.001	0.001	0.29	20	11000
Ethylbenzene	24	0.030	0.030	12.48	1000	100000
Total Xylenes	24	0.201	0.201	84.41	300	100000

MALCOLM PIRNIE

C.2 Packed Tower Stack Height Analysis

DESIGN FOR : Malcolm Pirnie, Inc.
Thomas Forbes

TOWER DESIGN :
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Air Flow Rate -> 320 CFM
Water Flow Rate -> 40.00 gpm
Air:Water -> 60.00 (CFM/CFM)
Tower Diameter -> 2.0 ft
Liquid Loading -> 12.74 gpm/ft^2
Pressure Drop Across Packed Bed -> .36 in W.C
Packing 3.5 LANPAC
Packing Volume -> 78.6 cu ft
Removal Efficiency -> 99.000 %
Packing Height -> 25.0 ft
Water And Air Temperature 50.00, 70.00 oF

TOWER ANALYSIS :

Component	NTU	HTU	H (atm)	Vc (gm/cc)
1,1-Dichloroethane	4.87	3.38	326.00	240.00
1,2-Dichloroethylene	4.83	3.33	373.00	230.00
Chloroform	5.14	3.37	170.00	239.00
1,2-Dichloroethane	6.95	3.28	54.30	220.00
Vinyl Chloride	4.61	3.02	*******	169.00
Methylene Chloride	5.30	3.15	136.00	193.00
1,1,1-Trichloroethane	4.80	3.64	444.00	304.00
Bromodichloromethane	5.77	3.46	89.00	259.00
Trichloroethylene	4.76	3.44	550.00	256.00
Benzene	4.97	2.42	240.00	259.00
Tetrachloroethylene	4.68	3.58	1100.00	290.00
Toluene	4.87	2.58	330.00	316.00
Chlorobenzene	5.07	2.56	192.00	308.00
Ethylbenzene	4.79	2.72	469.00	374.00
Total Xylene	4.82	2.72	389.00	375.00

WATER AND AIR ANALYSIS FOR THE TOWER :

Component	C1 water PPB	C2 water PPB	C AIR #/day
1,1-Dichloroethane	.10E+04	.10E+02	.48E+00
1,2-Dichloroethylene	.30E+05	.30E+03	.14E+02
Chloroform	.80E+01	.80E-01	.38E-02
1,2-Dichloroethane	.46E+02	.46E+00	.22E-01
Vinyl Chloride	.22E+03	.22E+01	.10E+00
Methylene Chloride	.58E+03	.58E+01	.28E+00
1,1,1-Trichloroethane	.79E+04	.79E+02	.38E+01
Bromodichloromethane	.90E+01	.90E-01	.43E-02
Trichloroethylene	.94E+03	.94E+01	.45E+00
Benzene	.90E+01	.90E-01	.43E-02
Tetrachloroethylene	.88E+02	.88E+00	.42E-01

Toluene	.89E+03	.89E+01	.42E+00
Chlorobenzene	.80E+01	.80E-01	.38E-02
Ethylbenzene	.17E+03	.17E+01	.81E-01
Total Xylene	.86E+03	.86E+01	.41E+00

TOTAL VOC In AIR = 20.30 #/day
==================================

* C1 water : inffluent concentration in water
C2 water : effluent concentration in water
C AIR : effluent concentration in air

MALCOLM PIRNIE

C.3 Peroxidation Systems Report

CONFIDENTIAL PROCESS ASSESSMENT REPORT

PROCESS ASSESSMENT OF THE perox-pure™ PROCESS FOR THE DESTRUCTION OF ORGANIC CONTAMINANTS IN GROUNDWATER

prepared for

Malcolm Pirnie, Inc.
Buffalo, New York
Purchase Order No. 0965-071
PSI Project No. NAO-19203-08524-0194

by

Peroxidation Systems, Inc.
5151 E. Broadway, Suite 600
Tucson, Arizona 85711

January 2, 1992

TABLE OF CONTENTS

EXECUTIVE SUMMARY

Peroxidation Systems Inc. (PSI) has performed a laboratory investigation to evaluate the effectiveness of the **perox-pure**™ Process for Malcolm Pirnie, Inc. (Malcolm Pirnie) on treatment of contaminated groundwater from the Rochester site.

The **perox-pure**™ system provides effective treatment of the contaminated groundwater at the Rochester site. The unique difference between the **perox-pure**™ organic destruction process and other systems is its ability to actually destroy organics to non-detectable levels. It does this by combining the effects of ultraviolet light (UV) and hydrogen peroxide (H_2O_2) in a closed reactor. The UV light cleaves the H_2O_2 forming powerful hydroxyl radicals -- which in turn oxidize the organics to carbon dioxide and water. Any halogens present are converted to halides.

The treatment of the groundwater, as defined by Malcolm Pirnie, included the destruction of chloroform, methylene chloride ($MeCl_2$), acetone, 1,1,1-trichloroethane (1,1,1-TCA), 1,2-dichloroethane (1,2-DCA), and 1,1-dichloroethane (1,1-DCA) to the limits specified for three (3) different cases, summarized in Table 4, Section 3.1.1. At a 20 gpm flow rate, the treatment levels specified for Cases I and II can be achieved with the chemical oxidation process using a **perox-pure**™ Model LEBX-270. The capital cost for this system is $315,000. Including electricity, hydrogen peroxide, labor and maintenance, the estimated monthly treatment cost is $12,820. The treatment levels specified for Case III can be achieved using a **perox-pure**™ Model LSB-60. The capital cost of this unit is $96,850. Including electricity, hydrogen peroxide, labor and maintenance, the estimated monthly treatment cost is $3,590.

As an alternative, PSI can offer the **perox-pure**™ Process on a Full Service Agreement with no capital investment or for purchase with a separate service agreement available. The Full Service Agreement includes all maintenance, parts and labor, emergency service, and regular site visits. Further, PSI guarantees that the system will meet the agreed upon specification as determined by these tests. A Full Service Agreement for this groundwater is available for $21,900/month for the LEBX-270 (Cases I and II), and $7,310/month for the LSB-60 (Case III).

The **perox-pure**™ Process offers the advantages of a proven, cost-effective treatment system that creates no air emissions, or generation of secondary waste products. The equipment typically is available within 12 weeks of order.

1.0 INTRODUCTION

The **perox-pure**™ Process destroys dissolved organic contaminants in water by means of chemical oxidation. Ultraviolet (UV) light catalyzes the chemical oxidation of organic contaminants in water by its combined effect upon the organic contaminants and its reaction with hydrogen peroxide (H_2O_2). Many organic contaminants absorb UV light and may undergo a change in their chemical structure or may become more reactive with chemical oxidants. More importantly, UV light at less than 400 nm wavelength reacts with H_2O_2 molecules to form hydroxyl radicals. These powerful chemical oxidants then react with the organic contaminants in the water. If carried to completion the reaction products of hydrocarbon oxidation with the **perox-pure**™ Process are carbon dioxide and water.

Peroxidation Systems, Inc. (PSI) was contracted by Malcolm Pirnie, Inc. (Malcolm Pirnie) to perform a treatability study on contaminated groundwater using the **perox-pure**™ Process. The groundwater reportedly contained 8 μg/l of chloroform, 580 μg/l of methylene chloride ($MeCl_2$), 1600 μg/l of acetone, 7,900 μg/l of 1,1,1-trichloroethane (1,1,1-TCA), 21 μg/l of 1,2-dichloroethane (1,2-DCA), and 690 μg/l of 1,1-dichloroethane (1,1-DCA). Malcolm Pirnie specified three (3) treatment cases as described in Table 4, Section 3.1.1.

A bench-scale **perox-pure**™ treatability study was performed on the groundwater during December of 1991 at the PSI Testing Laboratory in Tucson, Arizona. These tests were designed to provide a range of data from which full-scale treatment criteria and costs would be projected.

2.0 BENCH-SCALE LABORATORY TESTING

2.1 Testing Procedures

2.1.1 Description of Groundwater

On November 20, 1991, 13-gallons of groundwater were received from Malcolm Pirnie at the PSI Laboratory in Tucson, Arizona. The water was contained in 4-liter bottles with minimal headspace.

Characterization of the water sample was performed by PSI to determine parameters of importance for **perox-pure**™ treatment. The raw water required filtration prior to testing. The characterization results are shown in Table 1.

Table 1

Sample Characterization Results
for the Malcolm Pirnie Groundwater

	Filtered	Raw
Color:	Clear	Turbid
Visual Appearance:	Colorless	Pale Yellow
pH:	7.2	7.2
Iron (mg/l):	0.8	1.2
Chloride (mg/l):	----	87
Chemical Oxygen Demand (mg/l):	----	30
Total Organic Carbon (mg/l):	----	12
Total Dissolved Solids (mg/l):	----	<5
Total Suspended Solids (mg/l):	<5	340
Alkalinity (mg/l):	----	386
Turbidity (FTU):	<5	21

2.1.2 Testing Protocol

2.1.2.1 perox-pure™

The bench-scale **perox-pure**™ test unit was charged by filtering an aliquot of the water into a recycle reservoir. A pump was started which circulated the solution through the reactor and back into the reservoir providing continual mixing in the closed system. At this time, pH adjustment and/or chemical spiking (i.e. 1,1,1-TCA, acetone, and methylene chloride) were performed as required. The UV lamp was illuminated to start a test, and H_2O_2 was added as required to maintain a constant concentration in solution. All materials in contact with the solution were glass, quartz, stainless steel, viton or teflon.

After the appropriate retention times, samples of the treated water were collected in 40 ml septum vials. An untreated sample was also collected in the same way. These samples were analyzed for volatile contaminants using EPA Methods 601/602.

2.1.2.2 Filtration

Filtration of the raw groundwater was performed by pumping the water through a 3 micron filter cartridge.

2.2 Testing Results

Five (5) **perox-pure™** treatment tests were performed by PSI on the Malcolm Pirnie groundwater. These tests were designed to determine the effects of pH, and H_2O_2 dosage on the rate of contaminant destruction. The H_2O_2 dosage was varied between 25 and 100 mg/l. In Tests 4 and 5, the initial pH was adjusted to 5. The as-received groundwater contained lower than expected concentrations of the contaminants, 1,1,1-TCA, acetone, and methylene chloride. Therefore, the water was spiked with these compounds to the levels reported by Malcolm Pirnie prior to performing Test 5.

Table 2

Bench-Scale **perox-pure™** Treatment Conditions
for the Malcolm Pirnie Groundwater

Test	H_2O_2 in Solution (mg/l)	Initial pH	Spiking
1	25	7.0	----
2	50	7.0	----
3	100	7.0	----
4	50	5.0	----
5	100	5.0	Acetone, TCA, $MeCl_2$

The test results are shown in Table 3.

Table 3

Bench-Scale **perox-pure™** Treatment Results
for the Malcolm Pirnie Groundwater

Contaminant Concentration (μg/l)	Full-Scale Oxidation Times (min.) 0	0.7	1.4	2.8	4.2
TEST 1					
1,1-DCA	793	86	10	<2	<2
1,1,1-TCA	274	90	38	10	<2
1,2-DCA	55	<2	<2	<2	<2
Acetone	371	202	55	16	<5
Chloroform	<20	<2	<2	<2	<2
$MeCl_2$	<20	<2	<2	<2	<2
TEST 2					
1,1-DCA	777	116	14	<2	<2
1,1,1-TCA	264	95	47	12	<2
1,2-DCA	55	5	<2	<2	<2
Acetone	551	290	66	11	<5
Chloroform	<20	<2	<2	<2	<2
$MeCl_2$	<20	<2	<2	<2	<2

Table 3 (cont'd)

Bench-Scale perox-pure™ Treatment Results
for the Malcolm Pirnie Groundwater

Contaminant Concentration (μg/l)	Full-Scale Oxidation Times (min.) 0	0.7	1.4	2.8	4.2
TEST 3					
1,1-DCA	809	153	27	<2	<2
1,1,1-TCA	273	103	42	7	<2
1,2-DCA	50	6	<2	<2	<2
Acetone	339	276	<5	<5	<5
Chloroform	<20	<2	<2	<2	<2
$MeCl_2$	<20	<2	<2	<2	<2
TEST 4					
1,1-DCA	575	62	<2	<2	<2
1,1,1-TCA	184	72	25	5	<2
1,2-DCA	41	3	<2	<2	<2
Acetone	233	123	<5	<5	<5
Chloroform	<20	<2	<2	<2	<2
$MeCl_2$	<20	<2	<2	<2	<2
TEST 5					
1,1-DCA	649	50	<2	<2	<2
1,1,1-TCA	4,800	1,504	507	102	15
1,2-DCA	168	36	7	<2	<2
Acetone	3,133	345	4	<5	<5
Chloroform	<20	<2	<2	<2	<2
$MeCl_2$	497	103	6	<2	<2

Analytical test results for Tests 1 through 5 are shown in Table 3. Analyses for the contaminants shown were performed by PSI. In all tests, 1,1-DCA, 1,2-DCA and methylene chloride were destroyed to below the analytical detection limit of 2 μg/l in under 2.8 minutes of oxidation time. The initial chloroform and methylene chloride concentrations were below the analytical detection limit in each of the tests performed. 1,1,1-TCA was determined to be the rate limiting compound in Tests 1 through 5.

As shown in Figure 1, increasing the H_2O_2 dosage from 25 mg/l (Test 1) to 100 mg/l (Test 3) generated an approximate 2 fold increase in the acetone destruction rate. In Test 3 acetone was destroyed to less than 5 μg/l in under 1.4 minutes of oxidation time. Similar improvements in the destruction rates for other contaminants were not observed by increasing the H_2O_2 dosage.

The acetone destruction results from Tests 2 and 4, performed using a H_2O_2 dosage of 50 mg/l, are depicted graphically in Figure 2. Adjusting the pH to 5 in Test 4 produced an approximate 1.5 times increase in the acetone destruction rate as compared to Test 2. The destruction rates of the other contaminants increased somewhat (Figure 3).

Test 5 was performed on spiked groundwater using a H_2O_2 dosage of 100 mg/l at an initial pH of 5. The contaminant destruction rates observed in Test 5 were similar to the rates achieved in Test 4, except that the initial acetone destruction rate increased approximately 3 times. In Test 5, each of the contaminants was destroyed to below detection limits in under 2.8 minutes of oxidation time, except for 1,1,1-TCA which was destroyed to 15 μg/l in 4.2 minutes.

FIGURE 1

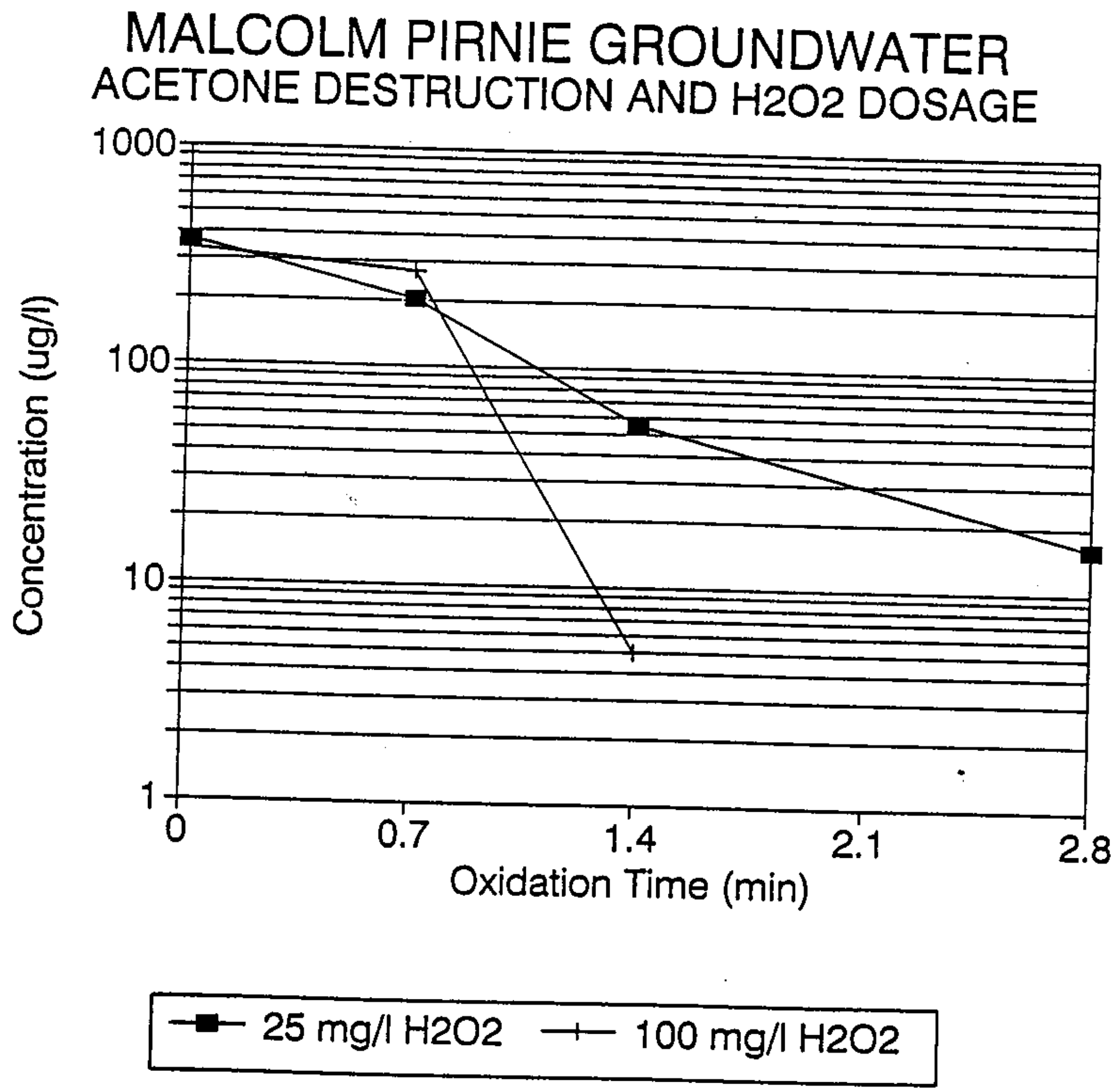

MALCOLM PIRNIE GROUNDWATER
ACETONE DESTRUCTION AND H2O2 DOSAGE
1000
100
10
1
Concentration (ug/l)
0
0.7
1.4
2.1
2.8
Oxidation Time (min)
25 mg/l H2O2
100 mg/l H2O2

FIGURE 2

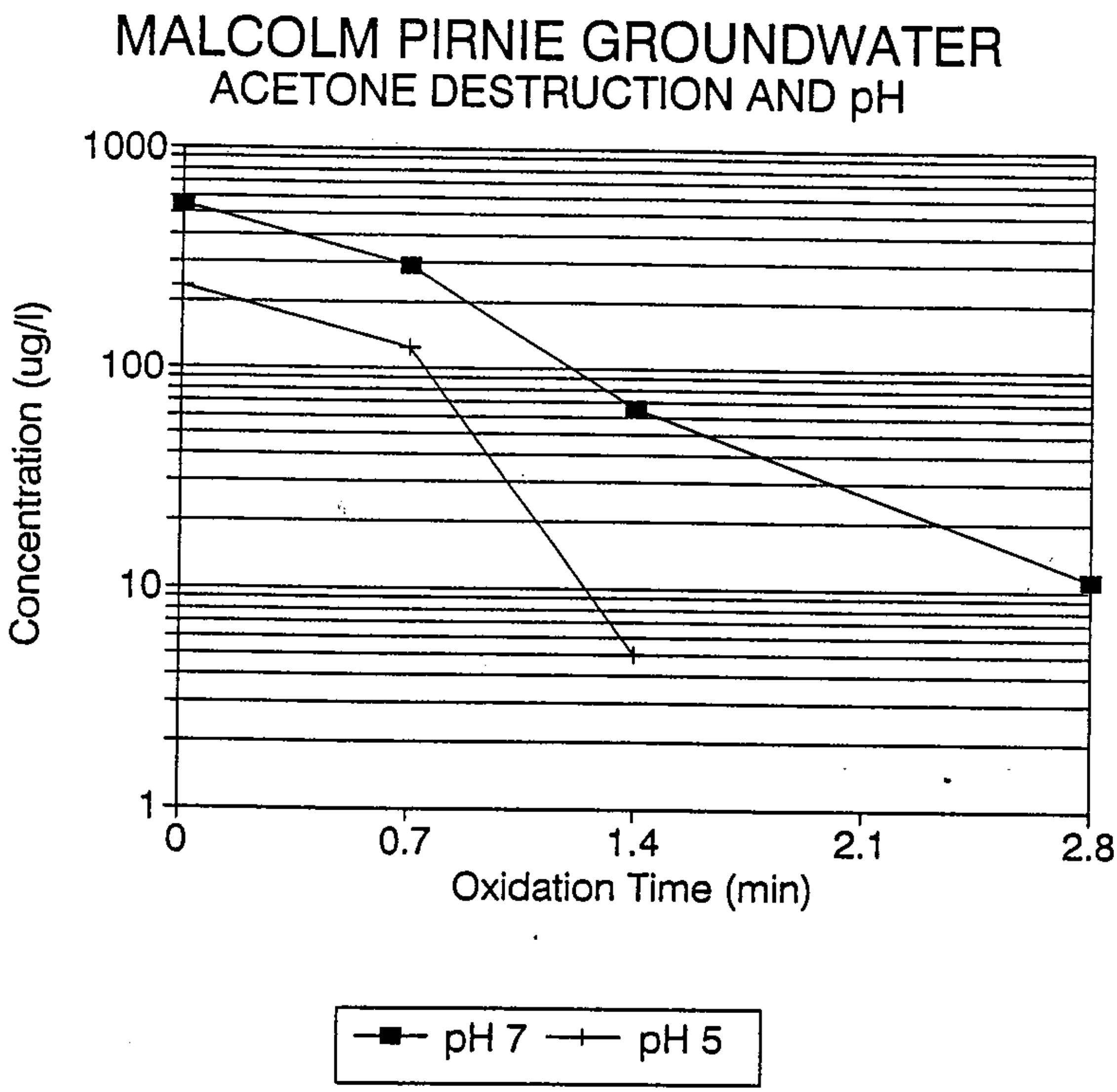
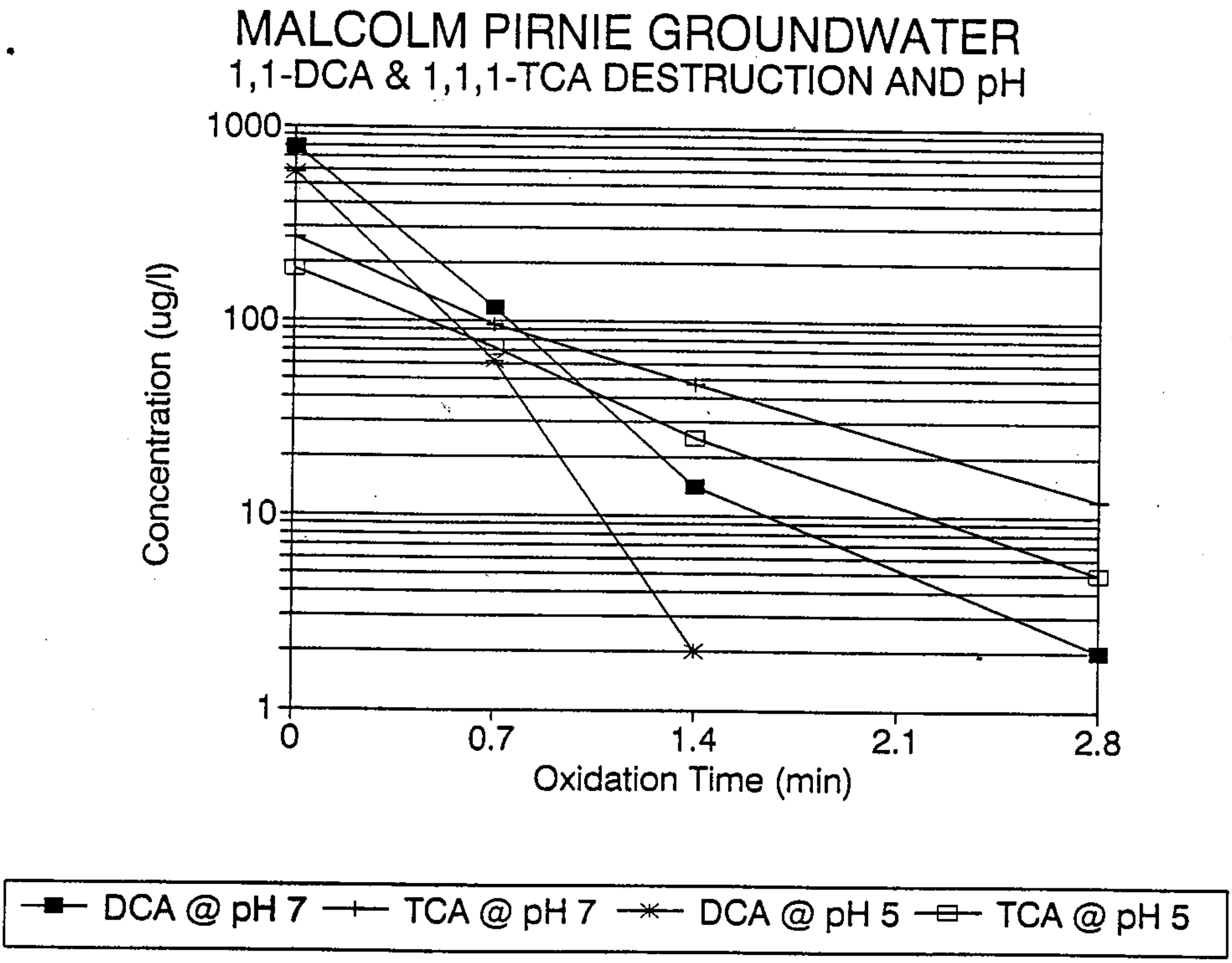

MALCOLM PIRNIE GROUNDWATER
ACETONE DESTRUCTION AND pH
Concentration (ug/l)
1000
100
10
1
0
0.7
1.4
2.1
2.8
Oxidation Time (min)
pH 7
pH 5

FIGURE 3


MALCOLM PIRNIE GROUNDWATER
1,1-DCA & 1,1,1-TCA DESTRUCTION AND pH
1000
100
10
1
Concentration (ug/l)
0
0.7
1.4
2.1
2.8
Oxidation Time (min)
DCA @ pH 7
TCA @ pH 7
DCA @ pH 5
TCA @ pH 5

2.3 Discussion

The objective of the treatability study discussed herein was to determine the treatment conditions necessary to treat the groundwater to the required effluent criteria.

In Test 4, the pH was lowered to determine the effects of alkalinity on contaminant destruction rates. Overall destruction rates for the target compounds increased significantly by lowering the pH to about 5.

Based on treatment results for both the as received and spiked groundwater concentrations, the best overall contaminant destruction rates were achieved using a H_2O_2 dosage of 100 mg/l and an initial pH of 5. Under these conditions, oxidation rates were determined for each of the contaminants. The rate limiting contaminant was 1,1,1-TCA with a rate constant of 1.37 min^{-1}. The destruction rate constant for the total organic component was determined to be 2.16 min^{-1}.

2.4 Laboratory Testing Summary

This bench-scale testing program has demonstrated that the **perox-pure™** Process is an effective method of treating the contaminated groundwater to meet the required treatment objectives. Specific test results and treatment conditions are as follows:

1) The as-received groundwater contained approximately 790 μg/l of 1,1-DCA, 260 μg/l of 1,1,1-TCA, 55 μg/l of 1,2-DCA, and 400 μg/l of acetone. No chloroform or methylene chloride was detected. Because the 1,1,1-TCA, acetone and methylene chloride were below the expected concentrations, one test (Test 5) was performed using groundwater spiked with TCA, acetone, and methylene chloride to the levels reported by Malcolm Pirnie.

2) In each of the Tests 1 through 5, the raw water was filtered prior to performing bench-scale testing.

3) Five (5) bench-scale **perox-pure™** tests were performed on the groundwater evaluating the effects of varying H_2O_2 dosage and pH.

4) For both the as-received and spiked groundwaters, the best destruction rates were achieved using a H_2O_2 dosage of 100 mg/l at a pH of 5.0. The rate limiting compound was determined to be 1,1,1-TCA with a rate constant of 1.37 min^{-1}. Overall, the destruction rate for the total organic component of the groundwater was determined to be 2.16 min^{-1}.

3.0 PROCESS ASSESSMENT

3.1 Full-Scale Treatment Conditions

3.1.1 Treatment Criteria

The criteria used to project full-scale treatment conditions for the **perox-pure**™ Process are summarized in Table 4. These criteria were specified by Malcolm Pirnie.

Table 4

Criteria for Full-Scale Treatment of the Contaminated Groundwater

Flow rate (gpm)		20	
Influent Contaminants (μg/l)			
Chloroform		8	
Methylene Chloride		580	
Acetone		1,600	
1,1,1-TCA		7,900	
1,2-DCA		21	
1,1-DCA		690	
Effluent Contaminants (μg/l)	Case I	Case II [1]	Case III
Chloroform	100	5	
Methylene Chloride	5	5	
Acetone	----	50	<1,800[2]
1,1,1-TCA	5	5	
1,2-DCA	5	5	
1,1-DCA	5	5	

[1]Detection limits for contaminants using EPA Method 624 obtained from Golden State Analytical Laboratories (Van Nuys, California)

[2]The sum of all volatile organic compounds based on an assumption by Malcolm Pirnie that semi-volatile organic compounds will contribute approximately 0.2 ppm to the ultimate criteria of 2.0 ppm total organics.

3.1.2 Recommended Process Conditions

Full-scale **perox-pure**™ Process conditions are projected in Table 5 for the three (3) cases specified by Malcolm Pirnie. Treatment criteria from Table 4 was used along with the rate constant for 1,1,1-TCA determined from Test 5 to calculate the oxidation times for Cases I and II. The same treatment criteria was also used along with the destruction rate determined for the total organic component of the groundwater (Test 5) to calculate the oxidation time for Case III in Table 5. These oxidation times were then used with the specified flow rate to determine required power demands.

The H_2O_2 listed in Table 5 was calculated from the H_2O_2 concentration used in Test 5.

Table 5

Full-Scale **perox-pure**™ Process Conditions
for Treatment of the Contaminated Groundwater

	Case I	Case II	Case III
Oxidation Time (min.)	5.4	5.4	~0.83
Power Demand (kW)	216	216	33
50% H_2O_2 Dosage (lbs/1000 gal)	0.8	0.8	0.8

3.2 Equipment Selection

The bench-scale testing indicates that the target contaminants in the groundwater are oxidized to below the Case I and II effluent levels specified by Malcolm Pirnie within 5.4 minutes in an EX reactor using 216 kW of power to the UV lamp. Because the UV light source requires 30 kW per lamp, the power usage would be 240 kW when operating. At a maximum flow rate of 20 gpm, the **perox-pure**™ unit which can best accommodate the Case I and II treatment requirements is an LEBX-270. For the Case III treatment requirements, only 0.83 minutes of oxidation time is required to oxidize the contaminants of concern. The **perox-pure**™ unit which can best accommodate the Case III treatment objectives is a Model LSB-60.

A hydrogen peroxide dosage of 0.8 lb/1000 gallons was used in the Test 5 bench-scale test. This results in a peroxide usage of 70 gal/month for all three cases. PSI therefore recommends that a 500 gallon hydrogen peroxide storage tank and dosing module be used to support the **perox-pure**™ unit. Assuming continuous operation, this would result in delivery of hydrogen peroxide to the site approximately every 7 months.

The utilities required include potable water for the safety shower and equipment cleaning, and 300 amps of 3 phase, 60 cycle, 480 volt electrical power for the LEBX-270 unit. The LSB-60 unit would require 80 amps.

PSI's **perox-pure**™ system is a complete skid mounted system with all required controls enclosed. Only a minimal foundation with containment dike, and electrical and plumbing connections are necessary. The equipment can operate with infrequent attention from the operator. It does require occasional servicing which PSI can provide under several service agreement options.

3.3 Discussion of Investment Options

PSI offers the **perox-pure™** system under either a Full Service Agreement with no capital cost or through direct purchase.

Option I - Full Service Agreement

PSI will provide the **perox-pure™** system under its Full Service Agreement program, which includes the **perox-pure™** unit and hydrogen peroxide feed module, maintenance, replacement parts, emergency service, and regular service/maintenance visits. PSI guarantees that the performance of the system will meet the agreed upon effluent specifications.

Our qualified technical personnel will visit the site on a regular basis to monitor the operation, perform necessary maintenance and provide a monthly report on the system. Other operator attention is not normally required.

All of these services are included in one monthly service fee. In addition, if the process conditions change, such as either an increasing or decreasing flow, or organic contaminant level, the customer can request equipment replacement. In this way, the facility is always provided with an optimum size unit, providing minimum operating costs for current site conditions.

Option II - Equipment Purchase

Alternatively, we can supply the **perox-pure™** treatment system through equipment purchase with a separate Maintenance Technical Services Agreement. The Services Agreement provides a program which includes hydrogen peroxide storage and feed module, maintenance, replacement parts, emergency service and regular maintenance visits.

Our qualified technical personnel will visit the site on a regular basis to monitor the operation, perform necessary maintenance, and provide a monthly report on the system. Other operator attention is not normally necessary.

3.4 Investment - Cases I and II

3.4.1 Capital Investment - perox-pure™

The budgetary capital investment for both a customer owned system and a PSI owned system with a PSI Full Service Agreement are shown below. The capital investment is based on the 20 gpm flow rate. The customer is responsible for freight costs, site preparation and foundation, power to the battery limit, influent/effluent pipes, pretreatment or post-treatment equipment, taxes, special permits, pumps and tanks.

	PSI Owned System with Full Service Contract	Customer Owned System
Capital Investment (LEBX-270)	Included	$ 315,000
H_2O_2 Storage and Feed System[1]	Included	Included
Start-up & Training	$ 7,500	10,000
TOTALS	$ 7,500	$ 325,000

[1]No capital investment when H_2O_2 is purchased from PSI.

3.4.2 Treatment Cost - perox-pure™

The projected costs for **perox-pure**™ treatment of the groundwater are shown below. The energy cost assumed is $0.06/kWh. The maintenance fee represents costs for repair/replacement parts and labor, and is estimated to be 8% of the capital cost per year. Acid costs for pH adjustment are considered negligible.

	perox-pure™ Operating Costs ($/Month)
Hydrogen Peroxide (700 lb @ $0.50/lb)	$ 350
Electrical (240 kW @ $0.06/kWh)	10,370
Maintenance	2,100
TOTAL	$ 12,820/Mo.

3.4.3 Full Service Agreement - perox-pure™

Alternatively, PSI will provide the **perox-pure™** system under its Full Service Agreement program, which includes the **perox-pure™** unit and hydrogen peroxide feed module, maintenance, replacement parts, emergency service, and regular service/maintenance visits. PSI guarantees that the performance of the system will meet the agreed upon effluent specifications.

The Full Service Agreement offers guaranteed performance at a guaranteed monthly cost.

	PSI Owned System ($/Month)
Full Service Agreement Fee	$ 11,180
Hydrogen Peroxide (700 lb @ $0.50/lb)	350
Electrical (240 kW @ $0.06/kWh)	10,370
TOTAL	$ 21,900/Mo.

3.5 Investment - Case III

3.5.1 Capital Investment - perox-pure™

The budgetary capital investment for both a customer owned system and a PSI owned system with a PSI Full Service Agreement are shown below. The capital investment is based on the 20 gpm flow rate. The customer is responsible for freight costs, site preparation and foundation, power to the battery limit, influent/effluent pipes, pretreatment or post-treatment equipment, taxes, special permits, pumps and tanks.

	PSI Owned System with Full Service Contract	Customer Owned System
Capital Investment (LSB-60)	Included	\$ 96,850
H_2O_2 Storage and Feed System[1]	Included	Included
Start-up & Training	\$ 5,000	7,500
TOTALS	\$ 5,000	\$ 104,350

[1]No capital investment when H_2O_2 is purchased from PSI.

3.5.2 Treatment Cost - perox-pure™

The projected costs for **perox-pure™** treatment of the groundwater are shown below. The energy cost assumed is \$0.06/kWh. The maintenance fee represents costs for repair/ replacement parts and labor, and is estimated to be 8% of the capital cost per year. Acid costs for pH adjustment are considered negligible.

	perox-pure™ Operating Costs (\$/Month)
Hydrogen Peroxide (700 lb @ \$0.50/lb)	\$ 350
Electrical (60 kW @ \$0.06/kWh)	2,590
Maintenance	650
TOTAL	\$ 3,590/Mo.

3.5.3 Full Service Agreement - perox-pure™

PSI will provide the **perox-pure**™ system under its Full Service Agreement program, which includes the **perox-pure**™ unit and hydrogen peroxide feed module, maintenance, replacement parts, emergency service, and regular service/maintenance visits. PSI guarantees that the performance of the system will meet the agreed upon effluent specifications.

The Full Service Agreement offers guaranteed performance at a guaranteed monthly cost.

	PSI Owned System ($/Month)
Full Service Agreement Fee	$ 4,370
Hydrogen Peroxide (700 lb @ $0.50/lb)	350
Electrical (60 kW @ $0.06/kWh)	2,590
TOTAL	$ 7,310 /Mo.

3.6 Conclusion

The **perox-pure**™ Process can provide effective treatment of the contaminated groundwater to the limits specified by Malcolm Pirnie as determined in the treatability study and process assessment presented above. The **perox-pure**™ Process offers the advantages of a proven, cost-effective treatment system that creates no air emissions, or generation of secondary waste products and is available for reasonable costs under purchase or lease arrangements.

MALCOLM PIRNIE

APPENDIX D

LABORATORY DATA AND REPORT DOCUMENTATION PACKAGE

MALCOLM PIRNIE

Due to their large volume, the Laboratory Data Reports and Documentation Packages for the Supplemental RI and DEC Confirmation Sampling were previously submitted to the NYSDEC under separate cover.

The sampling and Analytical Report for DOH soil samples collected in the Police Firing Range/Obstacle Course Area is enclosed herein.

City of Rochester

Department of Environmental Services

Office of the Commissioner

City Hall
30 Church Street
Rochester, New York 14614

October 16, 1991

Mr. Dave Napier, Regional Toxics Coordinator
New York State Department of Health
42 South Washington Street
Rochester, New York 14608

Re: SWAT Team Obstacle Course - Composite Soil Sample Results

Dear Dave:

Enclosed are the soil sample results and the sampling report for the area of the Rochester Police Department's planned obstacle course for the SWAT team. As we discussed on the telephone yesterday, no PCB's were detected and the level of metals are within the common range of concentrations found in natural soils. Although lead and cadmium are somewhat elevated above the site background, you indicated that the results satisfy your concerns regarding the potential for exposure to PCB's or high levels of metals.

Thank you for your assistance.

Sincerely,

Mark Gregor
Environmental Specialist

MG:dm
Atts.
(0496M)

xc: Mike Burkow, Police Dept.
Greg Johnson, Municipal Facilities
Gerard Burke, NYS-DEC
Joe Albert, MC-DOH
Ann Marie McManus, MPI

LOZIER LABORATORIES, INC.
909 CULVER ROAD
ROCHESTER, NEW YORK 14609
716-654-6350

NEW YORK STATE
APPROVED
ENVIRONMENTAL LABORATORY

October 11, 1991

Mark Gregor
City of Rochester
30 Church Street
Rochester, New York 14614

Re : Fire/Police Academy: Soil Analysis, O Course

Dear Mr. Gregor :

Please find enclosed analytical results concerning a composite of two soil samples taken from location O-Course by City of Rochester personnel, and submitted to Lozier Laboratories, Inc. on October 4, 1991 for heavy metals and PCB analyses. All analyses were performed by EPA approved methodologies.

It has been a pleasure to perform environmental analysis for the City of Rochester.

Please feel free to contact the laboratory if you have any questions or require additional information.

Sincerely,

Dennis M. Ciehomski

Dennis M. Ciehomski
Laboratory Coordinator

DMC/slp
Enclosure

LOZIER LABORATORIES, INC.
909 CULVER ROAD
ROCHESTER, NEW YORK 14609
716-654-6350

NEW YORK STATE
APPROVED
ENVIRONMENTAL LABORATORY

CLIENT: CITY OF ROCHESTER
30 CHURCH STREET
ROCHESTER, NEW YRK 14614

DATE REC'D : 10/04/91
LABORATORY NO. : 91104419
REPORT DATE : 10/11/91

ATTN : MARK GREGOR

RE : FIRE/POLICE ACADEMY

SAMPLE INFORMATION

SAMPLE DATE :	10/04/91	LOCATION :	SEE REFERENCE
SAMPLE TIME :	11:15 AM	TYPE OF SAMPLE :	SOIL
NUMBER OF SAMPLES :	1	SAMPLER :	CLIENT

POLYCHLORINATED BIPHENYLS

PARAMETER	SOIL - O COURSE	UNITS
PCB 1221	<0.02	mg/kg
PCB 1232	<0.02	mg/kg
PCB 1016	<0.02	mg/kg
PCB 1242	<0.02	mg/kg
PCB 1248	<0.02	mg/kg
PCB 1254	<0.02	mg/kg
PCB 1260	<0.02	mg/kg
PCB 1262	<0.02	mg/kg
PCB 1268	<0.02	mg/kg
TOTAL PCB'S	<0.02	mg/kg

Performed by Method 3540/8080.

NYSDOH LAB ID # 10390

LABORATORY DIRECTOR

LOZIER LABORATORIES, INC.
909 CULVER ROAD
ROCHESTER, NEW YORK 14609
716-654-6350

NEW YORK STATE
APPROVED
ENVIRONMENTAL LABORATORY

CITY OF ROCHESTER / LAB # 91104398

LABORATORY REPORT

PARAMETER	SOIL - D COURSE	UNITS	METHOD NUMBER	DATE ANALYZED
TOTAL METALS :				
LEAD	66.6	mg/kg	3050/7420	10/08
CADMIUM	0.67	mg/kg	3050/7130	10/08
COPPER	17.2	mg/kg	3050/7210	10/08
SILVER	0.66	mg/kg	3050/7760	10/08
ZINC	5.38	mg/kg	3050/7950	10/09
MERCURY	0.05	mg/kg	3050/7471	10/11
ARSENIC	5.44	mg/kg	3050/7060	10/10

* Method reference : EPA SW 846, "Test Methods for Evaluating Solid Waste", 3rd Edition.

NYSDOH LAB ID # 10390

LABORATORY DIRECTOR

MALCOLM PIRNIE

ENVIRONMENTAL SERVICES

91 OCT -8 AM 10: 23

MALCOLM PIRNIE, INC.
ENVIRONMENTAL ENGINEERS, SCIENTISTS & PLANNERS

October 7, 1991

Mr. Mark Gregor
City of Rochester
Department of Environmental Services
City Hall
30 Church Street
Rochester, New York 14614

Re: Fire Academy Soil Sampling
City of Rochester

Dear Mark:

On Friday morning, October 4, 1991, Malcolm Pirnie personnel accompanied you and Mr. Dave Napier of the New York State Department of Health to the City of Rochester Fire Training Academy on Scottsville Road. The purpose of the visit was to extract four (4) surface soil samples from the proposed obstacle course construction area. Four (4) grab samples were taken from 2"-4" at the locations indicated on the attached figure and blended into one composite sample.

The soil sample was then hand delivered to Lozier Laboratories for the following analysis:

- PCB (Method SW846-8080)
- Metals, Total:
  - Lead
  - Cadmium
  - Mercury
  - Silver
  - Arsenic
  - Zinc

Turnaround time from the laboratory is expected to be no longer than seven (7) calendar days, or by Friday, October 11. Should you have any questions regarding this submission please contact me. Thank you.

Very truly yours,

MALCOLM PIRNIE, INC.

Nicholas J. Harding
Project Engineer

Attachment
096505-1-143

1000 PITTSFORD - VICTOR RD. PITTSFORD, NY 14534-3822 716-248-5161 FAX: 716-248-2332

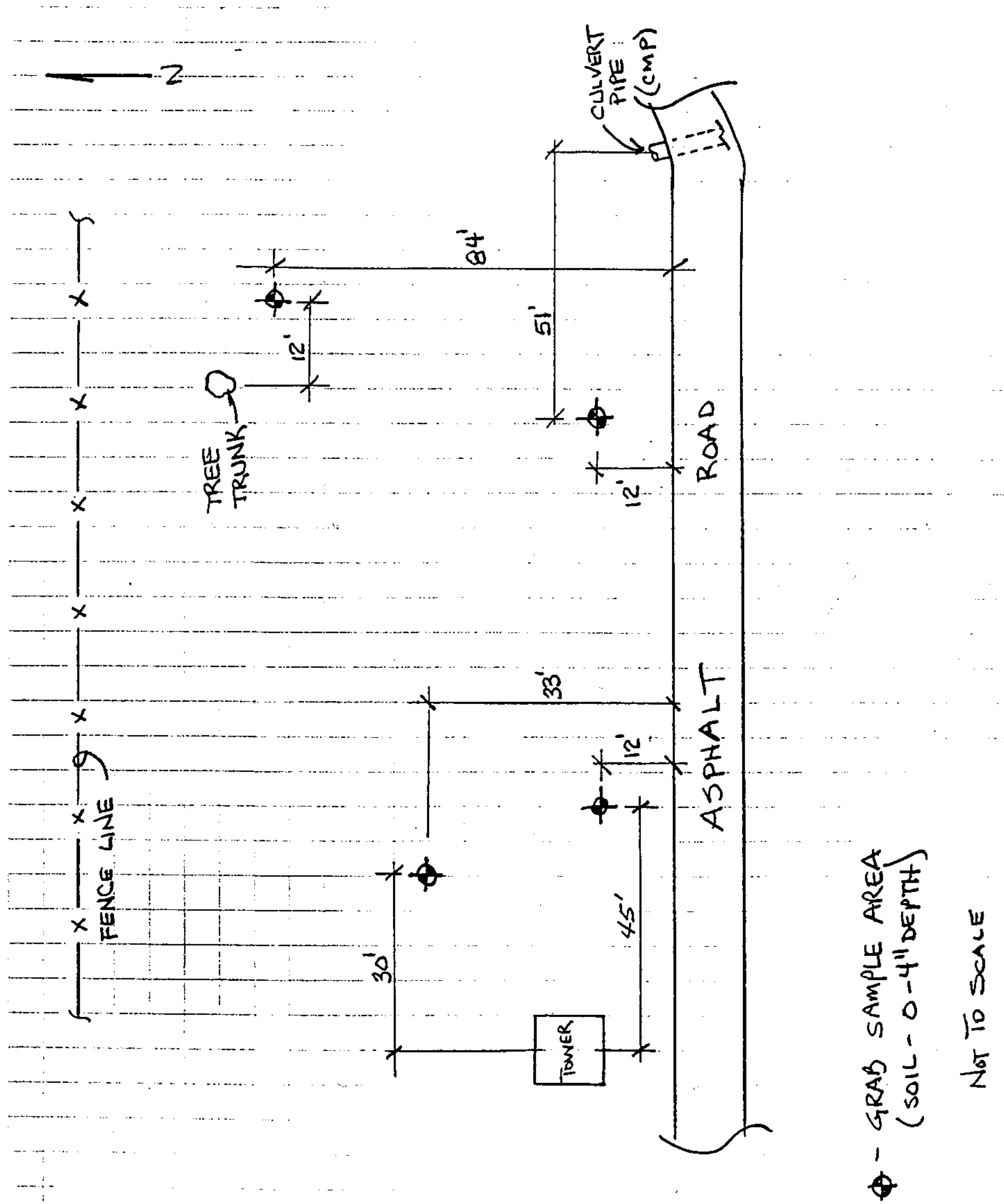
MALCOLM PIRNIE

MALCOLM PIRNIE, INC.

BY NH DATE 10/4/91 SHEET NO. 1 OF 1

CHKD. BY .... DATE .... JOB NO. 0965-05-1-

SUBJECT FIRE ACADEMY SOIL SAMPLING



[redacted]

LOZIER LABORATORIES

CHAIN OF CUSTODY RECORD

654-6350

SEE PAUL

Client Name: [redacted]

Mailing Address: CITY HALL

Project Name: FIRE/POLICE ACADEMY

SAMPLE NUMBER	DATE	TIME	LOCATION	SAMPLE TYPE	ANALYSIS: PCB	ANALYSIS: METALS	NUMBER OF CONTAINERS	REMARK
#3 - 32oz AMBER	10/[illegible]/91	1115 hrs	O COURSE	SOIL	X		1	> SAME SAMPLE
#14 - 4oz CLEAR	10/4/91	1115	O COURSE	SOIL		X	2	

SAMPLED BY: Nicholas J. Hardin (SIGN)

RELINQUISHED BY:
1. SIGN: Nicholas J. Hardin — DATE: 10/4/91 — TIME: 1400 hrs.
2. SIGN: ____ DATE: ____ TIME: ____
3. SIGN: ____ DATE: ____ TIME: ____
4. SIGN: ____ DATE: ____ TIME: ____

RECEIVED BY:
1. SIGN: ____ DATE: ____ TIME: ____
2. SIGN: ____ DATE: ____ TIME: ____
3. SIGN: ____ DATE: ____ TIME: ____
4. SIGN: ____ DATE: ____ TIME: ____

METHOD OF SHIPMENT: ____ SIGN: ____

RECEIVED FOR LABORATORY BY: W. A. Richards (SIGN) — DATE: 10/4/91 — TIME: 14:00

2

MALCOLM PIRNIE

APPENDIX E

LABORATORY DATA VALIDATION

1.0 INTRODUCTION

The following discussion details Malcolm Pirnie's analytical data assessment and validation of results reported by Energy and Environmental Engineering (E3I) for soil samples collected at the Rochester Fire Academy Site. Each sample was analyzed for polychlorinated biphenyls (PCBs) and the inorganic elements: arsenic, cadmium, lead, mercury, silver and zinc. The assessment of analytical data included a review of data consistency and data completeness; adherence to accuracy and precision criteria; and review of anomalously high and low parameter values.

The validation is based on laboratory compliance with Method 8080 (for PCBs) and the 200-CLP series methods (for inorganics) as contained in the 1989 NYSDEC Analytical Services Protocol (ASP). In addition, federal guidelines (the guidelines for evaluating organic and inorganic analytical data), were consulted. Data were evaluated as indicated in the following table:

Data Type	Criteria
All Data	holding times, calibrations, blanks, matrix spike/matrix spike duplicate (MS/MSD) recoveries, field duplicate precision, and data completeness.
Organic (PCB) Data	surrogate recoveries, chromatography resolution, retention time windows/retention time shift, evaluation standard mixes, and matrix spike blank (MSB) recoveries.
Inorganic Data	contract required detection limit (CRDL) standards for ICP and AA, laboratory control sample (LCS), ICP interference check sample (ICS), ICP serial dilution analysis, and furnace AA QC analysis.

2.0 ORGANIC (PCBs) ANALYSES

The following sections detail the evaluation of analytical results for all samples analyzed for PCBs with respect to Method 8080 as contained in the 1989 NYSDEC ASP.

2.1 Sample Holding Time

According to the ASP the following maximum holding times for soil samples are recommended for PCBs: extract within five days of the verified time of sample receipt (VTSR), and analyze within 40 days of VTSR.

Comparison of the dates of sample receipt (from the laboratory chain-of-custody forms) to the dates of sample extraction/analysis (from the laboratory preparation records and Form I's) indicated that all samples were extracted and analyzed prior to expiration of the recommended holding time. Therefore, no qualification of the data due to holding time exceedance is necessary.

2.2 PCB Instrument (GC) Performance and Calibration

2.2.1 Retention Time Criteria

Prior to sample analysis, retention time windows must be established for each PCB to be analyzed. The retention time windows are used to make tentative identification of the PCBs during sample analysis; since PCBs are "multi-response" compounds, pattern recognition is also relied upon for identification of the particular PCBs. In addition, the instrument (GC) operating conditions (packed columns) must be adjusted such that the retention time shift for dibutylchlorendate (DBC) between initial and subsequent standards is less than 2.0% (1.5% for wide bore capillary columns).

Review of the PCB data indicated that most PCBs identified and quantitated on the 3% OV-1 packed column were within established retention time windows. However, some PCBs were slightly outside of established windows and pattern recognition by the analyst was relied upon for identification. In addition, some PCBs were quantitated using the confirmatory column (SP2250/2401) due to co-elution of peaks. This method of identification and quantification has no impact on the analytical results reported for PCBs.

Review of the retention time shift criteria for DBC indicated that criteria were met for all samples with the exception of the following samples contained in SDG1B06: 1A06DL, 1A612DL, 1B612DL, 1C06DL, 1D06DL, 1DE612, 1DE1218, 1DE1824DL, and 1E06DL.

The laboratory reported that phthalate ester contamination "masked" the elution of DBC, thereby causing exceedance of the retention time shift criteria. However, the reported results for PCBs are not impacted by this exceedance.

2.2.2 Evaluation Standard Mixture

Evaluation standards are analyzed to determine the percent breakdown of DDT and Endrin which may occur over time due to active sites in the injection port of the instrument. The evaluation standards are also used to assess the linearity of the instrument calibration.

According to the ASP, the percent breakdown of endrin and/or DDT must not exceed 20% during a quantitation run and the percent relative standard deviation (% RSD) between evaluation mixtures must not exceed 10%. A review of the standards data indicates that the criteria were met.

An additional check on the linearity of the instrument calibration includes the analysis of standards at various intervals (specified in the ASP) throughout a 72-hour time period. The calibration factor for each standard is calculated and must not exceed 15% difference during a quantitation run or 20% during a confirmatory run. Review of the calibration data indicated that criteria were met with the exception of the Aroclor 1254 standard (#2) analyzed on 11/28/91. The % difference was calculated as 15.1%. However, the analytical results are not impacted by this minor exceedance.

2.3 Blank Analyses

Laboratory method blanks were analyzed with each batch of samples analyzed/extracted to determine the existence and/or extent of contamination which may have potentially been introduced during preparation of sample containers, sample collection, sample storage and/or sample analysis. It was noted that no contaminants were detected in any of the blanks submitted for PCBs analyses.

2.4 Surrogate Spike Recovery

To evaluate laboratory performance in terms of accuracy, all samples submitted for PCBs analyses, as well as all blanks, standards and matrix spikes, were spiked with the surrogate compound, dibutylchlorendate (DBC), prior to sample preparation. All surrogate recoveries were within advisory limits (20-150%) with the exception of the following: 1A06DL, 1E06DL, 1A612DL, 3B06DL, 1BC612DL, SD5DL, 1C06DL, SD6DL, 1D06DL, SDB21824.

The laboratory reported 0% recovery for DBC in the samples listed above due to necessary dilutions and/or co-elution problems. No qualification to the PCB results in these samples is necessary as the recovery limits listed above are for advisory purposes only.

2.5 Matrix Spike/Matrix Spike Duplicate (MS/MSD) and Matrix Spike Blank (MSB) Analyses

MS/MSD data are generated to determine the effect of the sample matrix on precision and accuracy of the analytical method. In addition, a matrix spike blank (MSB) is analyzed to substantiate that any deviations in spike recovery are due to matrix effects and not improper spiking solutions. In general, the MS/MSD data alone cannot be used to evaluate the precision and accuracy of individual samples. In addition, the EPA and NYSDEC have not established recovery limits for PCBs. Review of all MS/MSD/MSB data indicated the following recoveries:

Sample	Analyte	% REC	% RPD
2AB1824 MS 2AB1824 MSD MSB	aroclor 1254 aroclor 1254 aroclor 1254	131 160 105	19.8
GP1 MS GP1 MSD MSB	aroclor 1254 aroclor 1254 aroclor 1254	133 118 124	8.1
SDB206 MS SDB206 MSD MSB	aroclor 1254 aroclor 1254 aroclor 1254	136 161 91	13.3
SDB106 MS SDB106 MSD MSB	aroclor 1254 aroclor 1254 aroclor 1254	191 191 97	0
SD1 MS SD1 MSD MSB	aroclor 1254 aroclor 1254 aroclor 1254	91 103 109	9.3

The recoveries listed above indicate a potential high bias in the reported results for Aroclor 1254 in samples 2AB1824, SDB206 and SDB106.

2.6 Field Duplicate Samples

Field duplicate analysis is an indicator of the precision of sample collection and a measure of laboratory performance. Field duplicates of the following samples were submitted "blind" to the laboratory:

Sample ID	Duplicate Sample ID
2A06	BLINDD
SD5	BLDUP
SDB206	DUP1121
GP2	BLDUP

In general, the duplicate results exhibited good reproducibility indicating satisfactory sampling and analytical precision.

3.0 INORGANIC ANALYSES

The following sections detail the evaluation results for soil samples analyzed for inorganic elements (200-CLP series methodology, as contained in the 1989 NYS DEC ASP).

3.1 Sample Holding Time

According to the ASP, CLP Methodology, the following maximum holding times for soil samples are recommended for the specified analyses:

Analytes	**Recommended Holding Time**
Mercury	Prepare and analyze within 26 days of VTSR.
Metals	Prepare and analyze within 180 days of VTSR.

Comparison of the dates of sample receipt (from the laboratory chain-of-custody forms) to the dates of sample preparation and analysis (from the laboratory preparation logs and Form XIVs) indicated that all samples were prepared/analyzed prior to expiration of the recommended holding time. Therefore, no qualification of the data due to holding time exceedance is necessary.

3.2 Instrument Calibration

Initial calibrations of the atomic absorption (AA), inductively coupled plasma (ICP), and mercury cold vapor (CV) systems are accomplished via the analysis of standards at concentrations which define the working range of the particular instrument. To verify the accuracy of the initial calibration for each analyte, an EPA initial calibration verification (ICV) solution must be analyzed at each wavelength that is used for sample analyses. Recoveries of each analyte contained in the ICV solution should be within the control limits established by the EPA. In addition, the correlation coefficient for the initial calibration curve must be >0.995 for AA analyses. To ensure calibration accuracy during each analytical run, a continuing calibration verification (CCV) solution must be analyzed at each wavelength that is used for sample analyses. The CCV solution must be analyzed at a frequency of 10% or every two (2) hours (whichever is more frequent) during an analytical run. The CCV solution must also be analyzed at the beginning of the analytical run and after the last analytical sample. In addition, recoveries of each analyte in the CCV solution should be within the control limits established by the EPA.

As assessment of the calibration data for all inorganic analyses indicated that the proper number of calibration standards were analyzed at the beginning of each analytical run and at the appropriate frequency throughout the analytical run. In addition, the recoveries of each analyte contained in the ICV and CCV solutions were within criteria, and the correlation coefficients for AA data were greater than 0.995.

3.3 Contract Required Detection Limit (CRDL) Standards for ICP and AA

To verify the linearity near the CRDL for ICP analysis, an ICP standard must be analyzed at a concentration of two (2) times the CRDL [or at the CRDL for AA], or two (2) times the instrument detection limit (IDL), whichever is greater. The standard must be analyzed at the beginning and end of each sample analysis run, or a minimum of twice per eight (8) hour shift, whichever is more frequent (but not before the ICV). To verify linearity near the CRDL for AA analysis, an AA standard must be analyzed at the CRDL or the IDL, whichever is greater. The standard must be analyzed at the beginning of each sample analysis run, but not before the ICV. A review of the analysis run logs (Form XIVs) and the raw data indicated that the CRDL standards for both ICP and AA met these criteria.

3.4 Blank Analyses

As previously stated, the results of blank analyses are used to determine the existence and magnitude of contamination which can be introduced during preparation of sample containers, sample collection, sample storage, and/or sample analysis. For inorganic analyses, initial calibration blanks, (ICBs), continuing calibration blanks (CCBs), and preparation blanks (PBs), are analyzed to make this determination. Ideally, no contaminants should be detected in any of the blanks and no contaminants should be detected in the preparation blanks or ICBs at concentrations greater than the CRDL. In addition, when more than one blank is associated with a given sample, qualification is based on a comparison with the associated blank having the highest concentration of a contaminant. An assessment of all blank analytical data indicated that no contaminants were detected at concentrations greater than the CRDL.

3.5 ICP Interference Check Sample (ICS)

To verify inter-element and background correction factors, an ICS is analyzed at the beginning and end of each analytical run (or a minimum of twice per eight-hour work shift). The ICS consists of two solutions, A and AB. Solution A contains the interferents and solution AB contains the analytes mixed with the interferents. The solutions are analyzed consecutively. A review of the ICS analyses results indicated that no substantial effect on the ICP analyses from interferents was exhibited. In addition, the ICS solutions were analyzed at the proper frequency.

3.6 Matrix Spike (MS) Analysis

The analysis of an inorganic matrix spike sample provides the data user with information regarding sample matrix effects on the digestion procedure and analytical methodology. Matrix spike recoveries for inorganic elements must be within the 75% to 125% recovery "window" unless the sample concentration exceeds the spike concentration by a factor of four (4) or more. If the recovery of an analyte does not fall within this "window", a post-digestion spike must be analyzed for each element (except silver) which did not meet criteria.

The MS data for analytes outside of criteria are summarized in the following table:

Sample	Analyte	% Recovery
SDB106S	Copper Lead (ICP)	74.9 72.0
GP1S	Lead (AA) Mercury	203.1 132.9
SD1S	Lead (AA)	188
2AB1824S	Lead (AA) Mercury	171.7 164.9
SDB206S	Cadmium	65.8

It was noted that post-digestion spikes were analyzed for those analytes which did not meet matrix spike recovery criteria. According to the guidelines, positive results for the analytes listed above should be estimated and qualified with a "J" as a high or low bias may have been imparted on the analyses. The metals data have been qualified accordingly.

3.7 Duplicate Analyses

Laboratory duplicate analysis is an indicator of the precision of sample results and a measure of laboratory performance. A control limit of 20% RPD is used for soil sample results which are greater than five (5) times the CRDL, and a control limit of +/- the CRDL is used for soil sample results which are less than five (5) times the CRDL.

A review of the laboratory duplicate results indicated the following analytes outside of criteria:

Sample	Analyte	Criteria
SDB106D	Cadmium Copper Lead (ICP)	29.9% RPD 35.5% RPD 75.0% RPD
SD1D	Lead (ICP)	46.3% RPD
2AB1824D	Lead (ICP)	24.6% RPD
SDB206D	Copper Lead (AA)	37.4% 32.4%

According to the guidelines, positive results for these analytes are estimated and qualified with a "J". The metals data have been qualified accordingly.

3.8 Laboratory Control Sample (LCS) Analysis

As an additional measure of accuracy, the ASP requires that a soil LCS be prepared and analyzed for every group of soil samples in a sample delivery group (SDG), or for each batch of samples digested, whichever is more frequent. The percent recovery for analytes contained in the LCS must fall within the control limits established by the EPA. Review of the LCS data indicated that all criteria were met.

3.9 Furnace Atomic Absorption (AA) QC Analyses

All furnace AA analyses require duplicate injections. For concentrations greater than the CRDL, the duplicate injection results must agree within 20% RSD. If the results do not agree to within 20% RSD, the sample must be rerun. In addition, analysis of a post-digestion spike is required for each sample. The recovery of the analyte in each post-digestion spike must be within the control limit, (i.e., 85-115%). If the recovery of the analyte is outside of this criteria, the analyte may be quantitated using the Method of

Standard Addition (MSA), depending on sample absorbance. A review of the raw furnace atomic absorption data indicated that no samples required MSA for quantitation, and the above-stated criteria were met.

4.0 INDUCTIVELY COUPLED PLASMA (ICP) SERIAL DILUTION ANALYSIS

If the concentration of an analyte in a sample is sufficiently high (a minimum of 50 times the IDL), a five-fold dilution of the sample is analyzed to determine whether significant physical or chemical interferences exist. The results of the dilution must agree to within 10% difference (%D) of the original results.

A review of the ICP serial dilution results indicated that zinc did not meet this criteria in the following samples:

Sample	% Difference
SDB106L	29.4
GP1L	12.6
SD1L	18.2
2AB1824L	22.4
SDB206L	11.7

According to the guidelines, positive results for zinc are therefore estimated and qualified with a "J". The zinc data has been qualified accordingly.

5.0 CONCLUSION

Laboratory compliance with specific analytical methodology, reporting and deliverable requirements stipulated in the 1989 NYSDEC ASP, was carefully scrutinized. All procedures were conducted in accordance with the specific methodology. In addition, appropriate corrective actions were taken when necessary.

Based on this evaluation, the analytical data generated for soil samples collected during the Supplemental Remedial Investigation are considered to be valid and useful for the purpose of completing the investigation. It is recommended that the analytical data be accepted with the specific qualifications noted herein.

TABLE 1a

CITY OF ROCHESTER
ROCHESTER FIRE ACADEMY SUPPLEMENTAL RI

TRAINING GROUNDS AREA

PESTICIDES/PCBs (ug/kg)

Sample #	Aroclor-1248	Aroclor-1254	Aroclor-1260
1A06		16000 J	9400 J
1A1218	150	390	170 J
1A1824	260	120 J	
1A612		7500 J	6700 J
1B06		260 J	370
1BC1218	65 J	100 J	
1BC1824	150	53 J	
1BC612	26,000	59,000	
1C06		25,000 J	20,000 J
1D06			7300 J
1DE1218		330 J	2700
1DE1824		9300	
1DE612		1400	2400
1E06		4800 J	4400 J
2A06	50 J	170 J	73 J
Blind D	91 J	190 J	120 J
2AB612		52 J	
2AB1218		79 J	
2AB1824	150		
2B06	42 J		160 J
2C06	54 J	210	170 J
2C1218		72 J	
2C1824		74 J	33 J
2C612	63 J	150 J	560
3A06	74 J	58 J	
3A1218		56 J	
3A1824	150		
3A612		82 J	

TABLE 1a

CITY OF ROCHESTER
ROCHESTER FIRE ACADEMY SUPPLEMENTAL RI

TRAINING GROUNDS AREA

PESTICIDES/PCBs (ug/kg)

Sample #	Aroclor-1248	Aroclor-1254	Aroclor-1260
3B06		42,000	
3B1218		88 J	
3B1824			
3B612		580	

TABLE 1b

CITY OF ROCHESTER
ROCHESTER FIRE ACADEMY
SUPPLEMENTAL RI

GENESEE PARK AREA

PESTICIDES/PCBs (ug/kg)

Sample #	Aroclor-1254	Aroclor-1260
GP1	200	
GP2	140 J	
Bldup	250	
GP3	140 J	
GP4		
GP5	540 J	350 J
GP6	140 J	220
GP7		
GP8	190 J	
GP9	1200 J	740 J

TABLE 1c

CITY OF ROCHESTER
ROCHESTER FIRE ACADEMY SUPPLEMENTAL RI

NORTH DISPOSAL AREA

PESTICIDES/PCBs (ug/kg)

Sample #	Aroclor-1248	Aroclor-1254	Aroclor-1260
ND1			270
ND2			1900
ND3			1200
ND4		260	
ND5		160 J	
ND6		160 J	
NDB106			
NDB11218			
NDB11824			
NDB1612			
NDB206		100 J	
NDB21218	10 J		
NDB21824	46 J		
NDB2612			
NDB306	33 J		

TABLE 1d

CITY OF ROCHESTER
ROCHESTER FIRE ACADEMY SUPPLEMENTAL RI

SOUTH DISPOSAL AREA

PESTICIDES/PCBs (ug/kg)

Sample #	Aroclor-1254	Aroclor-1260
SD1	110 J	
SD2		310
SD3		31 J
SD4	81 J	
SD5	83,000	
BLDDUP	87,000	
SD6	17,000 J	8800 J
SD7	130 J	
SD8	17 J	
SD9	31J	70 J
SD10	38 J	
SDB106	570 J	380 J
SDB11218	71 J	
SDB11824	55 J	92 J
SDB1612	120 J	83 J
SDB206	110 J	
DUP1121	110 J	
SDB21218	32 J	
SDB21824		
SDB2612	68 J	

TABLE 1e

CITY OF ROCHESTER
ROCHESTER FIRE ACADEMY SUPPLEMENTAL RI

POLICE FIRING RANGE AREA

PESTICIDES/PCBs (ug/kg)

Sample #	Aroclor-1254	Aroclor-1260
PF1	58 J	
PF2	250 J	420 J
PF3		
PF4		

TABLE 2a

CITY OF ROCHESTER
ROCHESTER FIRE ACADEMY SUPPLEMENTAL RI

TRAINING GROUNDS AREA

INORGANIC ELEMENTS (mg/kg)

Sample #	Arsenic	Cadmium	Copper	Lead	Mercury	Silver	Zinc
1A06	5.50	3.90	87.7	1210 J	0.17 J	0.89 B	196 J
1A1218	5.10		10.0	13.2 J			49 J
1A1824	4.20		11.9	6.5 J			61.4 J
1A612	5.70	9.10	38.3	205 J	0.11 J		126 J
1B06	4.80		18.0	64.2 J			32.8 J
1BC1218	6.20		12.5	19.6 J			48.9 J
1BC1824	6.70		13.6	14.2 J			53.3 J
1BC612	3.60	3.20	30.8	4380 J			74.7 J
1C06	3.50	2.80	21.5	154 J	0.17 J		70.2 J
1D06	5.20	4.00	65.5	558 J	0.19 J		111 J
1DE1218	4.90		25.8	18.3 J			91.0 J
1DE1824	8.30		27.4	154 J			73.1 J
1DE612	4.10	1.90	41.4	77.8 J	0.50 J		75.0 J
1E06	6.20	4.60	297	390 J	0.59 J	0.86 B	368 J
2A06	2.70		9.20	32.7			38.1 J
Blind D	2.80	1.40	9.30	37.4			36.7 J
2AB612	5.20		7.80	28.5			30.3 J
2AB1218	5.00		9.00	13.9 J			33.5 J
2AB1824	5.10		11.2	13.3 J			42.9 J
2B06	3.60	1.80	21.1	52.4			74.2 J
2C06	3.60	1.60	71.1	178 J			71.8 J
2C1218	4.60		12.2	7.8 J			50.1 J
2C1824				12.6 J			49.7 J
2C612	7.90		13.2	15.3 J			42.9 J
	5.40		17.5				
3A06	2.00	0.95	3.40 B	15.1			10.9 J
3A1218	4.90		10.0	15.9			44.1 J
3A1824	5.80		11.3	19.6			50.1 J
3A612	4.70		5.50	26.7			8.50 J

(continued)

TABLE 2a

CITY OF ROCHESTER
ROCHESTER FIRE ACADEMY SUPPLEMENTAL RI

TRAINING GROUNDS AREA

INORGANIC ELEMENTS (mg/kg)

Sample #	Arsenic	Cadmium	Copper	Lead	Mercury	Silver	Zinc
3B06	2.50	1.50	8.40	34.9			23.2 J
3B1218	5.60	0.75B	9.90	13.7			30.9 J
3B1824	4.10		12.1	13.3			50.4 J
3B612	3.70		48.6	29.0			45.5 J
BS1	5.20		14.2	9.00		1.20 B	57.9
BS2	4.90		7.40	23.7			47.4
DB11218	2.80		14.6 J	5.30			30.9 J
DB11824	3.70		13.0 J	6.30			34.3 J
DB21218	5.30		16.9 J	7.40 J			43.4 J
DB21824	5.10		16.0 J	7.90 J			43.3 J

TABLE 2b

CITY OF ROCHESTER
ROCHESTER FIRE ACADEMY SUPPLEMENTAL RI

GENESEE PARK AREA

INORGANIC ELEMENTS (mg/kg)

Sample #	Arsenic	Cadmium	Copper	Lead	Mercury	Silver	Zinc
GP1	7.50		25.9	51.1		0.67 B	75.4 J
GP2	7.50		17.4	39.9			70.7 J
Bldup	7.90		17.2	32.6			70.2 J
GP3	3.50		11.8	19.3			39.9 J
GP4	5.90		15.3 J	32.5			50.6 J
GP5	14.3	17.4 J	37.3 J	83.5			84.2 J
GP6	15.0	5.40 J	18.1 J	32.7			59.0 J
GP7	6.3		10.9 J	19.0			45.5 J
GP8	6.80		12.3 J	30.5		0.66 B	54.7 J
GP9	6.20	12.4 J	35.7 J	47.2			73.8 J

TABLE 2c

CITY OF ROCHESTER
ROCHESTER FIRE ACADEMY SUPPLEMENTAL RI

NORTH DISPOSAL AREA

INORGANIC ELEMENTS (mg/kg)

Sample #	Arsenic	Cadmium	Copper	Lead	Mercury	Silver	Zinc
ND1	9.00		22.4	60.1			97.2J
ND2	14.4		24.0	55.1		1.10B	140 J
ND3	16.9	1.10 B	31.4	102	0.25 J	1.70 B	198 J
ND4	11.1		32.5	59.6		1.50 B	143 J
ND5	9.40		18.3	48.3		0.93 B	88.2 J
ND6	6.40		36.7	59.9			120 J
NDB106	10.5		11.5	17.3		1.20 B	94.0 J
NDB11218	10.8		19.1	15.6		1.20 B	86.8 J
NDB11824	6.60		9.30	10.7		0.84 B	63.3 J
NDB1612	15.3		9.80	18.4		1.30 B	9.10 J
NDB206	8.70		21.4	154 J			148 J
NDB21218	7.20	1.00 B	14.4	13.0		0.92 B	67.7 J
NDB21824	6.90		17.2	11.1		0.82 B	59.5 J
NDB2612	8.90		15.1	38.0		1.30 B	216 J
NDB306	5.60		14.2	8.60			49.7 J

TABLE 2d

CITY OF ROCHESTER
ROCHESTER FIRE ACADEMY SUPPLEMENTAL RI

SOUTH DISPOSAL AREA

INORGANIC ELEMENTS (mg/kg)

Sample #	Arsenic	Cadmium	Copper	Lead	Mercury	Silver	Zinc
SD1	4.80		18.1	38.7		0.76 B	69.5 J
SD2	5.10		15.7	45.7			64.3 J
SD3	4.32		16.9	194 J		0.68 B	54.7 J
SD4	4.00		7.70	38.2		0.82 B	51.7 J
SD5	21.7	31.4 J	273 J	2260 J	0.11 B		252 J
BLDDUP	40.4	33.8 J	400 J	1920 J	0.11 B	0.75 B	450 J
SD6	5.40	20.4 J	140 J	394 J	0.15	0.80 B	498 J
SD7	5.20		36.2 J	73.8 J			73.7 J
SD8	6.90		14.7 J	140 J	0.15		64.6 J
SD9	6.00		17.3 J	47.6	0.12	0.70 B	96.0 J
SD10	6.00		29.6 J	51.0 J			62.9 J
SDB106	2.90	4.90 J	29.0 J	12.6			36.9 J
SDB1612	4.10		25.9 J	6.10			29.9 J
SDB206	6.20		30.0 J	11.9 J		0.71 B	64.2 J
DUP1121	5.40		27.2 J	10.4			64.5 J
SDB2612	5.90		21.2 J	11.2 J			52.7 J

TABLE 2e

CITY OF ROCHESTER
ROCHESTER FIRE ACADEMY SUPPLEMENTAL RI

POLICE FIRING RANGE AREA

INORGANIC ELEMENTS (mg/kg)

Sample #	Arsenic	Cadmium	Copper	Lead	Mercury	Silver	Zinc
PF1	2.40		8.50	32.2			25.4 J
PF2	5.60	6.20	23.6	72.8		0.62 B	58.5 J
PF3	4.30	0.77B	12.8	38.9			43.8 J
PF4	3.80		18.0	27.9			49.6 J

MALCOLM PIRNIE

APPENDIX F

1990 RI SOIL SAMPLING RESULTS

CITY OF ROCHESTER, ROCHESTER FIRE ACADEMY, RI/FS
SUMMARY OF ANALYTES DETECTED IN SURFICAL AND SUBSURFACE SOILS OF NORTH DISPOSAL AREA

SAMPLE NUMBER	SS-1	SS-2	SS-3	SS-4	TP-1	TP-2	TP-3	TP-3A	TP-4	TP-5	B-1
SAMPLE DEPTH (1)	0-.5'	0-.3'	0-.4'	0-.3'	1.5'	2.5'	2'	2'	1.4'	2'	0-4'
PARAMETER (2) (3) (4)											
Volatiles (mg/kg)											
Methylene Chloride	0.006 B	0.007 B	0.007 B	0.006 B	0.013 B	0.017 B	0.013 B	0.031 B	0.023 B	0.026 B	0.006 B
Acetone	0.012 B	0.013 B	0.013 B	0.012 B	0.018 B	0.020 B	0.030 B	0.011 B	0.050 B	0.014 B	0.017 B
1,1-Dichloroethane	0.010								0.002 J		
1,2-Dichloroethene (total)	0.041						0.002 J				0.005 J
Chloroform									0.002 J		
1,2-Dichloroethane	0.001 J										
1,1,1-Trichloroethane	0.004 J					0.002 J	0.001 J		0.006 J	0.002 J	
Trichloroethene			0.004 J	0.014		0.042	0.063	0.020	0.021	0.009	0.019
Benzene											
Tetrachloroethene	0.005 J		0.007 J	0.006 J		0.036	0.10	0.039	0.004 J	0.012	0.004 J
1,1,2,2-Tetrachloroethane						0.001 J	0.001 J				
Toluene	0.002 J					0.002 J				0.012	0.003 J
Chlorobenzene						0.001 J					
Semi-Volatiles (mg/kg)											
bis(2-chloroisopropyl)ether						0.12 J	0.28 J			0.34 J	
Isophorone										0.17 J	
Benzoic Acid					0.25 J	0.20 J					
Naphthalene						0.18 J	0.30 J	0.035 J		0.41 J	
2-Methylnaphthalene				0.26 J		0.17 J	0.61 J	0.053 J		1.7	
Dimethylphthalate				0.15 J							
4-Nitrophenol						0.16 J					
Diethylphthalate				0.094 J		0.23 J		0.54 J			0.040 J
Phenanthrene		0.19 J	0.10 J	0.22 J		0.94		0.32		0.42 J	
Anthracene				0.24 J		0.15					
Di-n-butylphthalate				0.64		3.0		0.26 J	0.12 J		0.39 B
Fluoranthene		0.42 J	0.20 J	0.27 J		0.88					
Pyrene		0.31 J	0.13 J	0.29 J		1.2				0.13 J	
Butylbenzylphthalate				0.68	0.11 J	1.3		0.54 J			
Benzo(a)anthracene		0.21 J		0.14 J							
Chrysene		0.26 J	0.10 J	0.21 J		0.59					
Bis(2-ethylhexyl)phthalate	0.43 B	0.49 B	0.47 B	2.1	0.41 B	7.3		1.5 B	0.57 B	0.98 B	0.39 B
Di-n-octylphthalate										0.15 J	
Benzo(b)fluoranthene				0.16		0.24 J					
Benzo(k)fluoranthene				0.20 J		0.50					
Benzo(a)pyrene		0.17 J				0.50					

CITY OF ROCHESTER, ROCHESTER FIRE ACADEMY, RI/FS
SUMMARY OF ANALYTES DETECTED IN SURFICAL AND SUBSURFACE SOILS OF NORTH DISPOSAL AREA

SAMPLE NUMBER	SS-1	SS-2	SS-3	SS-4	TP-1	TP-2	TP-3	TP-3A	TP-4	TP-5	B-1
SAMPLE DEPTH (1)	0-.5'	0-.3'	0-.4'	0-.3'	1.5'	2.5'	2'	2'	1.4'	2'	0-4'
PARAMETER (2) (3) (4)											
Pesticide/PCBs (mg/kg)											
Aroclor-1254				10							
Aroclor-1260		0.162				7.4	4.1	9.7			0.49
Inorganic Elements (mg/kg)											
Aluminum	15300	7950	11200	4280	12800	9310	3430		8750	11000	13900
Antimony				12		22.8 J					17 J
Arsenic	5.9	12.4	15.5	41.9	5.8	14.6	8.3		50	69	18.6
Barium	75.4	1220	4160	490	49.9	1170	286		1690	787	581 J
Beryllium	0.54 J		412		0.50 J					0.41 J	0.48 J
Cadmium	0.33	2.6 J	5.1 J	19.7 J		20.1 J	3.6 J		3.8 J	3.2 J	9.4
Calcium	2080	49200	54300	32600	761 J	59600	27900		67900	36800	25000
Chromium	17	36.1	37.5	340	15.1	227	105		42.2	41.4	46.8
Cobalt	11.3 J	7.7 J	50	5.80 J	11.3 J	9.7 J	4.2 J		8.50 J	9.1 J	21
Copper	14.7	426	51700	56	12.7	14000	29.8		167	110	156
Iron	23700 J	32000 J	26100 J	10300 J	21900 J	38800 J	8540 J		19800 J	22800 J	106000
Lead	16.2	3220	7860	3080		4260	830		4310	3160	1470
Magnesium	3740	11500	13200	11700	3680	16000	6800		14400	12200	7090
Manganese	384 J	443 J	449 J	248 J	381 J	624 J	287 J		443 J	664 J	1070 J
Mercury	0.43	0.39	0.30	0.49	0.12	1.6	0.16		0.73	0.30	0.66 J
Nickel	20.8	15.9	28.9	10.3	20.4	48.4	8.5		26	22.8	46
Potassium	1090 J	1300 J	1650	894 J	951 J	874 J	659 J		1700	1450	1950
Selenium		1.0	3.2	8.1		4.90 J	1.0 J		0.62 J		1.1
Silver			47.6	5.3		2.4 J	3.1				1.30 J
Sodium	67.9 J	349 J	537 J	123 J	52.3 J	308 J	99 J		345 J	258 J	180 J
Thallium									0.55 J		
Vanadium	23.8	24	34.4	11 J	20.7	25.1	10.6		32.8	33.1	31.7
Zinc	68 J	1690 J	6190 J	470 J	54.4 J	3750 J	246 J		2020 J	1000 J	672 J

CITY OF ROCHESTER, ROCHESTER FIRE ACADEMY, RI/FS
SUMMARY OF ANALYTES DETECTED IN SURFICAL AND SUBSURFACE SOILS OF TRAINING GROUNDS

SAMPLE NUMBER	SS-5	SS-6	SS-7	SS-8	SS-10	SS-11	SS-12	TP-6	TP-8	B-2	B-4	MW-13S*	MW-14S*
SAMPLE DEPTH (1)	0-.3'	0-.3'	0-.3'	0-.3'	0-1'	0-1'	0-1'	0-2'	0-3'	0-2'	0-2'	0-2'	0-4'
PARAMETER (2) (3) (4)													
<u>Volatiles (mg/kg)</u>													
Methylene Chloride	0.006 B	1.6 B	0.006 B	0.10 B	0.011 B	0.006 B	0.010 B	0.023 B	0.007 B	7.0 B	0.79 B		1.9 B
Acetone	0.013 B		0.013 B		0.031 B	0.096 B	0.012 B	0.055 B		14.0 B		0.029 B	
1,1-Dichloroethane			0.019										
1,2-Dichloroethene (total)			0.007										
Chloroform			0.002 J										
2-Butanone						0.011 J			0.01 J				
Trichloroethene						0.001 J							
Benzene		0.89 J											
Tetrachloroethene							0.001 J						
Toluene		210					0.001 J	0.006 J		350			13
Chlorobenzene								0.005 J					
Ethylbenzene		3.2								26			5
Total Xylenes		210								173	0.78 J		35
<u>Semi-Volatiles (mg/kg)</u>													
4-Methylphenol										13 J			
Isophorone								0.27 J					
2-Nitrophenol								0.12 J					
Benzoic Acid			0.12 J										
Naphthalene		2.2 J								100			
2-Methylnaphthalene		4.6 J								150	4.4		0.42
Dimethylphthalate											0.091 J		
Acenapthylene							9.4 J				0.43 J		
Acenaphthene											2.0 J		
Dibenzofuran											0.46 J		
Diethylphthalate		1.4 J					8.0 J	0.21		29	0.32 J		
Fluorene										11	2.3		
4-Nitroaniline											1.1 J		
4-,6-Dinitro-2-Methylphenol											2.4 J		
N-nitrosodiphenylamine								0.043 J					
Pentachlorophenol					0.18 J	1.4 J							
Phenanthrene	0.39 J	1.2 J	0.096 J		0.036 J	0.064 J	7.6 J		0.38 J	38	4.6		0.22 J
Anthracene	0.086 J									110			
Di-n-butylphthalate	0.046 J	3.2 J	0.12 J		0.37 B	0.35 B	9.7 J	0.098 J		77	0.42 B		0.15 J
Fluoranthene	0.86		0.13 J						0.42 J				0.11 J
Pyrene	0.77	0.79 J	0.31 J				4.6 J		0.40 J				0.10 J
Butylbenzylphthalate		19	0.087 J							120			0.17 J
3,3'-Dichlorobenzidine			0.44										
Benzo(a)anthracene	0.55								0.17 J				
Chrysene	0.62								0.22 J				
Bis(2-ethylhexyl)phthalate	0.43 B	53	1.2 B	0.37 B	0.37 B	0.35 B		0.47 B	0.48 B	720	1.3 B	0.39 B	5.7
Benzo(b)fluoranthene	0.63												
Benzo(k)fluoranthene	0.54												
Benzo(a)pyrene	0.63												
Indeno(1,2,3-cd)pyrene	0.47												
Dibenz(a,h)anthracene	0.17 J												
Benzo(g,h,i)perylene	0.58												

CITY OF ROCHESTER, ROCHESTER FIRE ACADEMY, RI/FS

SUMMARY OF ANALYTES DETECTED IN SURFICAL AND SUBSURFACE SOILS OF TRAINING GROUNDS

SAMPLE NUMBER	SS-5	SS-6	SS-7	SS-8	SS-10	SS-11	SS-12	TP-6	TP-8	B-2	B-4	MW-13S*	MW-14S*
SAMPLE DEPTH (1)	0-.3'	0-.3'	0-.3'	0-.3'	0-1'	0-1'	0-1'	0-2'	0-3'	0-2'	0-2'	0-2'	0-4'
PARAMETER (2) (3) (4)													
Pesticide/PCBs (mg/kg)													
Aroclor-1254										10			21
Aroclor-1260			31	0.30	0.11	0.024	1.7	2.4			0.14		
Inorganic Elements (mg/kg)													
Aluminum	8050	3640	5350	2270	10400	10600	4310	4610	11900	3760	4990	6470	7840
Antimony		12.5 J					12.8 J						12.3 J
Arsenic	4.1	3.9	3.5	3.8	6.2	4.7	4.0	6.7	8.3	3.6	3.9	3.6	8.8
Barium	55.3	63.5	75.5	12.1 J	49.5	45 J	18.3 J	38.5 J	56.9	55.9 J	64.6 J	19.5 J	47.6 J
Beryllium	0.28 J				0.39 J	0.40 J	0.24 J		0.35 B		0.22 J	0.24 J	0.32 J
Cadmium	0.74 J	2.5 J	5.0 J	0.73 J	0.28 J	0.42 J	1.3	11.9 J		0.62 J	0.22 J		0.26 J
Calcium	39600	106000	112000	156000	78700	65300	153000	93800	5250	149000	105000	48100	89700
Chromium	11.5	42.6	62.1	6.3	14.1	14.1	7.7	12.2	14.8	27.1	17.6	8.1	12.2
Cobalt	5.5 J	3.2 J	31.3		6.2 J	6.90 J	3.30 J	4.8 J	9.1 J	3.9 J	4.4 J	6.7 J	5.2 J
Copper	22.8	55.6	29.8	13.8	11.8	8.0	6.6	66.6	14.9	17.4	188	14.3	32.1
Iron	12600 J	7610 J	9970 J	5990 J	17700	14400	8100 J	10900 J	20900 J	7750 J	11300 J	13200 J	16200 J
Lead	73.5	384	555	46	19.5	8.4	19.9	136	16.2	202	107	8.4	42.6
Magnesium	13700	51500	31200	80200	39800	25400	63500	49900	4660	61800	43200	16300	40400
Manganese	353 J	204 J	228 J	229 J	380	300 J	239 J	264 J	336 J	245 J	250 J	166 J	326 J
Mercury	0.2							0.23	0.21				
Nickel	7.5 B	7.1 B	11.5		14.3	10.4	5.8 B	14.4	18.9	4.2 B	42	10.1	12.1
Potassium	1290	1700	1740	1300	2020	2270	1690	2030	1560	1580	2150	988 J	1820
Selenium		0.47						0.78 J					
Silver													
Sodium	108 J	122 J	169 J	167 J	221 J	167 J	152 J	146 J	81.2 J	156 J	212 J	92.4 J	148 J
Thallium						0.53 J		0.78 J					
Vanadium	18.4	8.0 J	15.4	7.1 B	20.7	20	10.2 J	9.5 J	24	8.1 J	7.1 J		14.7
Zinc	114 J	118 J	165 J	33.1 J	47.8 J	33.3 J	36.7 J	97.5 J	58.5 J	53 J	224 J	36.5 J	53.5 J

NOTES:

(1) Depth below ground surface

(2) Only those analytes found above analytical detection limits at a minimum of one location are presented.

(3) Laboratory Qualifers: B - Estimated detection limit due to blank contamination,

J - Estimated value due to limitations identified during the quality control review.

(4) All results based on mg/kg dry weight of soil

* Soil samples collected before monitoring well installation.

CITY OF ROCHESTER, ROCHESTER FIRE ACADEMY, RI/FS
SUMMARY OF ANALYTES DETECTED IN SURFICAL AND SUBSURFACE SOILS
OF POLICE OBSTACLE COURSE AND FIRING RANGE AREA AND OFFSITE LOCATION*

SAMPLE NUMBER	SS-16	SS-18	SS-13	BKGD
SAMPLE DEPTH (1)	0-1'	0-1'	0-1'	0-1.2'
PARAMETER (2) (3) (4)				
Volatiles (mg/kg)				
Methylene Chloride	0.026 B	0.010 B	0.015 B	
Acetone	0.092 B	0.060 B	0.013 B	
2-Butanone	0.006 J			
Tetrachloroethene	0.001 J			
Toluene	0.006 J			
Semi-Volatiles (mg/kg)				
Naphthalene			0.85 J	
2-Methylnaphthalene			1.0 J	
Dibenzofuran			0.52 J	
Phenanthrene			2.6 J	
Anthracene			0.77 J	
Di-n-butylphthalate		0.38 B		
Fluoranthene	0.22 J		3.9	
Pyrene	0.29 J		3.4 J	
Benzo(a)anthracene			2.2 J	
Chrysene			4.1	
Bis(2-ethylhexyl)phthalate		0.38 B		
Benzo(b)fluoranthene			4.3	
Benzo(k)fluoranthene			3.9	
Benzo(a)pyrene			2.5 J	

* SS-13 collected in Genesee Valley Canal Area and BKGD sample collected off-site near entrance gate to Training Grounds (see Figure 7-1).

CITY OF ROCHESTER, ROCHESTER FIRE ACADEMY, RI/FS
SUMMARY OF ANALYTES DETECTED IN SURFICAL AND SUBSURFACE SOILS
OF POLICE OBSTACLE COURSE AND FIRING RANGE AREA AND OFFSITE LOCATION

SAMPLE NUMBER	SS-16	SS-18	SS-13	BKGD
SAMPLE DEPTH (1)	0-1'	0-1'	0-1'	0-1.2'
PARAMETER (2) (3) (4)				
Pesticide/PCBs (mg/kg)				
Aroclor-1254				
Aroclor-1260	0.56			
Inorganic Elements (mg/kg)				
Aluminum	3610	12800	2880	18500
Antimony			15.8 B	
Arsenic	2.6	4.7	11.9	2.8
Barium	18.1 J	69.9 J	48.4	102 J
Beryllium		0.33 J	0.30 J	0.58 J
Cadmium	0.30 J		0.25	
Calcium	161000	49100	18300	40400
Chromium	6.4	16	8.5	24.6
Cobalt	3.2 J	11.4	7.3	10.4 J
Copper	6.9	10.9	66	13.1
Iron	7470 J	21600 J	32100 J	25500 J
Lead	17.1		72.4	
Magnesium	26100	12300	9350	11000
Manganese	222 J	530 J	344 J	451 J
Mercury			0.12 J	
Nickel	7.6 J	21.6	11.4	21.7
Potassium	1270	2460	557 J	3800
Selenium				
Silver				
Sodium	134 J	176 J	79.2 J	229 J
Thallium			0.54 J	
Vanadium	12.4	30.8	10.1 J	37.8
Zinc	23.2 J	43.2 J	45.2 J	54.7 J

NOTES:

(1) Depth below ground surface

(2) Only those analytes found above analytical detection limits at a minimum of one location are presented.

(3) Laborartory Qualifers: B- Estimated detection limit due to blank contamination,
J- Estmated value due to limitions identified during the quality control review.

(4) All results based on mg/kg dry weight of soil

CITY OF ROCHESTER, ROCHESTER FIRE ACADEMY, RI/FS
SUMMARY OF ANALYTES DETECTED IN SURFICAL AND SUBSURFACE SOILS
OF SOUTH DISPOSAL AREA

SAMPLE NUMBER	SS-19	TP-9	TP-10A	TP-10	TP-11A	TP-11	B-6	B-7
SAMPLE DEPTH (1)	0-1'	0-6'	0-2'	0-2'	0-1'	0-1'	0-2'	0-2'
PARAMETER (2) (3) (4)								
Volatiles (mg/kg)								
Vinyl Chloride		0.061			3.0 B	0.23 J	0.27	
Chloroethane							0.11	
Methylene Chloride	0.024 B	0.006 B	2.3 B	0.83 B		1.4 B	0.76 B	0.009 B
Acetone	0.014 B	0.057 B				5.2	17	0.013 B
1,1-Dichloroethene		0.020					0.017 J	
1,1-Dichloroethane		0.16	7.5	1.3	26	4.2	1.3	
1,2-Dichloroethene (total)		0.091	44	12	250	14	0.33	
Chloroform		0.005 J	0.51 J				0.031	
1,2-Dichlorethane		0.043			1.6 J	0.53 J	0.19 J	
2-Butanone		0.018				4.9	7.9	
1,1,1-Trichloroethane		0.055		3.1	14	8.0	0.22	
Trichloroethene	0.015	0.006 J	110	12	58	7.1	0.019 J	
1,1,2-Trichloroethane		0.014						
Benzene		0.001 J					0.009 J	
4-Methyl-2-pentanone				2.8		2.6	3.5	
Tetrachloroethene	0.002 J	0.072	140	1.5	0.92 J		0.05	
1,1,2,2-Tetrachloroethane			1.5 J		1.3 J	3.5		
Toluene		0.023	1.4 J	5.3	4.3		0.41	
Ethylbenzene		0.006 J			0.82 J	0.28 J	0.16	
Total Xylenes		0.040		2.4	8.7 J	1.5 J	1.31	
Semi-Volatiles (mg/kg)								
Phenol						3.0	3.3	
4-Methylphenol								
Isophorone								
2-Nitrophenol								
Benzoic Acid						0.69 J	0.83 J	
Naphthalene								
2-Methylnaphthalene								
Dimethylphthalate								
Acenapthylene								
Acenaphthene								
Dibenzofuran								
Diethylphthalate	0.43		9.7 J	17	51	23	4.9	
Fluorene								
4-Nitroaniline								
4-.6-Dinitro-2-Methylphenol								
N-nitrosodiphenylamine								
Pentachlorophenol								
Phenanthrene						0.37 J		
Anthracene								
Di-n-butylphthalate	0.22 J		3.7 J	1.0 J		2.1 J	0.56	0.42
Fluoranthene						0.28 J		
Pyrene								
Butylbenzylphthalate								
3,3'-Dichlorobenzidine								
Benzo(a)anthracene								
Chrysene								
Bis(2-ethylhexyl)phthalate	0.54 B		53	4.9 B	37	9.1 B	0.99 B	0.42 B
di-n-octyphthalate							0.15 J	
Benzo(b)fluoranthene								
Benzo(k)fluoranthene								
Benzo(a)pyrene								
Indeno(1,2,3-cd)pyrene								
Dibenz(a,h)anthracene								
Benzo(g,h,i)perylene								

CITY OF ROCHESTER, ROCHESTER FIRE ACADEMY, RI/FS
SUMMARY OF ANALYTES DETECTED IN SURFICAL AND SUBSURFACE SOILS
OF SOUTH DISPOSAL AREA

SAMPLE NUMBER	SS-19	TP-9	TP-10A	TP-10	TP-11A	TP-11	B-6	B-7
SAMPLE DEPTH (1)	0-1'	0-6'	0-2'	0-2'	0-1'	0-1'	0-2'	0-2'
PARAMETER (2) (3) (4)								
Pesticide/PCBs (mg/kg)								
Aroclor-1254	3.3				190	61	108	
Aroclor-1260			330	29				
Inorganic Elements (mg/kg)								
Aluminum	6710	11900		20400		16400	16900	14300
Antimony				55.3 J		23 J		
Arsenic	16.3	4.4		46.5		52.5	7.5	5.3
Barium	52.5	77.2		2170		2000	229	92.8
Beryllium	0.24 J	0.33 J					0.49 J	0.47 J
Cadmium	1.3 J			111 J		151 J	33.9 J	
Calcium	42400	68500		11200		30400	6780	53800
Chromium	10.7	17.2		664		417	52.9	19.9
Cobalt	7.20 J	10.4 J		71.3		17	13.4	11.2
Copper	26.3	13		7330		13300	4240	13.8
Iron	15400	20200 J		203000 J		65300 J	28500	25200
Lead	721 J			4460		4880	382 J	
Magnesium	10800	15100		23500		26800	6720	12200
Manganese	393	561 J		2910 J		1020 J	1010	498
Mercury				3.20		1.4	0.27	0.23
Nickel	15.7	16.3		494		672	683	31.3
Potassium	1080	2970		634 J		949 J	2650	2410
Selenium				6.3		7.1	0.70 J	
Silver						50.5		
Sodium	156 J	237 J		903 J		612 J	332 J	184 J
Thallium		0.53 J		1.2 J				
Vanadium	19.7	29.9		56.8		14.4 J	35.9	31.4
Zinc	62.8 J	39.5 J		6760 J		4720 J	1430 J	49.4 J

NOTES:

(1) Depth below ground surface

(2) Only those analytes found above analytical detection limits at a minimum of one location are presented.

(3) Laboratory Qualifers: B - Estimated detection limit due to blank contamination,
J - Estimated value due to limitations identified during the quality control review.

(4) All results based on mg/kg dry weight of soil

CITY OF ROCHESTER, ROCHESTER FIRE ACADEMY RI/FS
SUMMARY OF ANALYTES DETECTED IN SURFICAL AND SUBSURFACE SOILS OF THE GENESEE VALLEY PARK AREA

SAMPLE NUMBER	SS-9	SS-14	SS-15	SS-17	SS-20	TP-7	B-3	B-5	B-8	MW-15S*
SAMPLE DEPTH (1)	0-.4'	0-1'	0-1'	0-1'	0-.3'	5'	0-1.5'	0-2.3'	0-4'	0-4'
PARAMETER (2) (3) (4)										
Volatiles (mg/kg)										
Methylene Chloride	0.010 B	0.015 B	0.006 B	0.009 B	0.018 B	0.006 B	0.006 B	0.012 B	0.006 B	0.005 B
Acetone	0.015 B	0.016 B	0.012 B	0.16	0.076 B	0.013 B	0.11 B	0.036 B	0.086 B	0.082 B
1,1-Dichloroethene					0.003 J					
1,1-Dichloroethane					0.003 J					
1,2-Dichloroethene (total)					0.19			0.002 J		
Chloroform							0.002 J			
2-Butanone							0.011 J			0.013
1,1,1-Trichloroethane					0.17					
Trichloroethene	0.002 J				0.52			0.002 J		
Benzene										
4-Methyl-2-pentanone				0.003 J	0.43					
Tetrachloroethene								0.002 J		
Toluene								0.002 J		0.001 J
Semi-Volatiles (mg/kg)										
4-Methylphenol										
Isophorone									0.20 J	
2-Nitrophenol									0.07 J	
Benzoic Acid										
Naphthalene										
2-Methylnaphthalene		0.027 J							0.059	
Dimethylphthalate										
Acenapthylene									0.038	
Acenaphthene									0.025 J	
Dibenzofuran									0.012 J	
Diethylphthalate				0.13 J	0.29 J			0.10 J		
Fluorene										
4-Nitroaniline										
4-.6-Dinitro-2-Methylphenol										
N-nitrosodiphenylamine										
Pentachlorophenol		0.80 J								
Phenanthrene		0.16 J							0.059 J	
Anthracene									0.38	
Di-n-butylphthalate		0.39 B			0.17 J		0.41 B		0.38 B	0.35 B
Fluoranthene		0.24 J			0.089 J					
Pyrene		0.23 J							0.051 J	
Butylbenzylphthalate									0.059 J	
3,3'-Dichlorobenzidine										
Benzo(a)anthracene		0.14 J								
Chrysene		0.15 J								
Bis(2-ethylhexyl)phthalate	0.47 B	0.39 B	0.46 B	0.49 B	0.50 B	0.42 B	0.41 B	0.40 B	2.0 B	0.35 B
Benzo(b)fluoranthene										
Benzo(k)fluoranthene										
Benzo(a)pyrene										
Indeno(1,2,3-cd)pyrene										
Dibenz(a,h)anthracene										
Benzo(g,h,i)perylene										
1,4 Dichlorobenzene		0.046 J								
3-Nitroaniline									1.9	
4-Chlorophenyl-phenylether									0.38	
Di-n-Octyl phthalate									0.038 J	

CITY OF ROCHESTER, ROCHESTER FIRE ACADEMY RI/FS
SUMMARY OF ANALYTES DETECTED IN SURFICAL AND SUBSURFACE SOILS OF THE GENESEE VALLEY PARK AREA

SAMPLE NUMBER	SS-9	SS-14	SS-15	SS-17	SS-20	TP-7	B-3	B-5	B-8	MW-15S*
SAMPLE DEPTH (1)	0-.4'	0-1'	0-1'	0-1'	0-.3'	5'	0-1.5'	0-2.3'	0-4'	0-4'
PARAMETER (2) (3) (4)										
Pesticide/PCBs (mg/kg)										
Aroclor-1254				1.3	5.3				1.4	
Aroclor-1260	2.5	0.329					0.74	0.059		0.52
Inorganic Elements (mg/kg)										
Aluminum	7070	6930	7760	6960	9150	9090	11100	13500	9250	5510
Antimony										
Arsenic	4.3	6.0	8.8	6.1	6.5	7.1	5.0	5.3	3.5	4.8
Barium	53.6 J	63.5 J	48.9	40.5 J	51.3	49	50.9 J	79.4	48.3	28.1 J
Beryllium	0.32 J	0.25 J		0.25 J	0.36 J	0.32 J	0.35 J	0.44 J	0.29 J	0.24 J
Cadmium	9.1 J	15.5	0.31 J	12.6 J				0.66 J		
Calcium	73100	29900	3290	40900	1980	2390	938 J	40400	5680	88600
Chromium	7.8	9.2	10.3	10.7	12.1	12.3	13.7	18.5	11.4	8.2
Cobalt	3.5 J	6.4 J	8.10 J	6.5 J	8.20 J	9.1 J	8.0 J	10.3	5.0	3.3
Copper	26.3	30.7	16	30.8	11.3	13.9	13.2	18	9.7	10.3
Iron	16000 J	16200 J	17300	14100	18500	20000 J	18100 J	22900	14400 J	11200 J
Lead	50.5	49,5	19 J	34.5 J		21.9	9.8		9.7	25.5
Magnesium	36300	15800	3030	23200	3120	3380	2830	10600	4320	38500
Manganese	299 J	181 J	363	333	363	370	208 J	456	181 J	250 J
Mercury			0.13 J	0.14	0.10 J			0.11	0.25 J	
Nickel	8.8 J	12.4	17.4	16.4	21.8	19.3	15.9	23.90	11.4	8.5 J
Potassium	1400	993 J	1270	919 J	1080	1150 J	810 J	2060	881 J	1870
Selenium		0.51 J	0.57 J	0.93 J	0.52 J			0.57 J		
Silver		0.74 J								
Sodium	252 J	105 J	41.7 J	85.6 J	74 J	75.7 J	73.2 J	160 J	83.1 J	139 J
Thallium		0.52 J								
Vanadium	14	15.1	14.6	16.2	17.6	18.9	18.2	28.7	16.0	10.9
Zinc	60.5 J	99 J	70.3 J	76.9 J	54 J	55.6	47.3 J	57.8 J	41.5 J	36.2 J

NOTES:

(1) Depth below ground surface

(2) Only those analytes found above analytical detection limits at a minimum of one location are presented.

(3) Laboratory Qualifers: B - Estimated dectection limit due to blank contamination,
J - Estimated value due to limitations identified during the quality control review.

(4) All results based on mg/kg dry weight of soil

* Soil sample collected before monitoring well installation.

MALCOLM PIRNIE

APPENDIX G

SOIL SAMPLE DESCRIPTIONS

TABLE 4-14

CITY OF ROCHESTER FIRE ACADEMY - SUPPLEMENTAL RI

SUMMARY OF SAMPLE COMPOSITING

Composite Sample No.	Number of Grab Samples	Composite Sample No.	Number of Grab Samples	Composite Sample No.	Number of Grap Samples	Composite Sample No.	Number of Grab Samples
Depth[1] 0 - 6 in.		Depth[1] 6 - 12 in.		Depth[1] 12 - in.		Depth[1] - 18 - 24 in.	
1 A 06	3	1 A 612	3	1 A 1218	3	1 A 1824	3
1 B 06	3	1 BC 612	6	1 BC 1218	6	1 BC 1824	6
1 C 06	3	1 DE 612	6	1 DE 1218	6	1 DE 1824	6
1 D 06	3						
1 E 06	3						
2 A 06	3	2 AB 612	6	2 AB 1218	6	2 AB 1824	6
2 B 06	3	2 C 612	2	2 C 1218	2	1 C 1824	2
2 C 06	2						
3 A 06	2	3 A 612	2	3 A 1218	2	3 A 1824	2
3 B 06	3	3 B 612	3	3 B 1218	3	3 B 1824	3

(1) Depth below base of crushed stone.

MALCOLM PIRNIE

MALCOLM PIRNIE, INC.

BY RHO DATE 3-26-98 SHEET NO. 1 OF 8

CHKD. BY .... DATE .... JOB NO. 0965-07-1

SUBJECT SOIL SAMPLING OBSERVATIONS

CITY OF ROCHESTER

ROCHESTER FIRE ACADEMY - SUPPLEMENTAL RI

DESCRIPTION OF SOIL SAMPLES

(15)

NORTH DISPOSAL AREA

SAMPLE LOCATION	SAMPLE DEPTH BELOW GRADE	SAMPLE DEPTH BELOW FILL	SAMPLE DESCRIPTIONS
ND-1	0-6"	-	Loose brown sandy silt
ND-2	0-6"	-	"
ND-3	0-6"	-	"
ND-4	0-6"	-	"
ND-5	0-6"	-	"
ND-6	0-6"	-	"
NDB-1	0-2.25'	-	Fill with Cobbles, Gravel and Sand
	2.25-3.25'	—	Clayey Silt with burned and rust stained fill material
			Auger to 4.0 ft.
	@ 4.0 ft.		Clayey Silt - Native Soil
NDB106		0-6"	firm yellow/brown Clayey Silt
NDB1612		6-12"	A/A
NDB11218		12-18"	A/A with sand
NDB11824		18-24"	A/A wet
NDB-2	0-4 ft		Augered to base of Fill and began collecting samples.
NDB206		0-6"	Dense yellowbrown/gray Clayey Silt
NDB2612		6-12"	A/A
NDB21218		12-18"	A/A
NDB21824		18-24"	A/A
NDB-3	0-4 ft		Fill composed of brown sand and bricks with peat on auger plug @ 4 ft.
	@ 4 ft	0-3"	Loose black, medium sand with C&D debris.
NDB306		3-9"	Loose yellow brown medium sand and silt

City of Rochester
Rochester Fire Academy - Supplemental RI
Descriptions of Composite Soil Samples

(18)

TRAINING GROUNDS AREA

COMPOSITE SAMPLE NO.	GRAB SAMPLE LOCATION	SAMPLE DEPTH	Total Org. Vapors in Headspace	SAMPLE DESCRIPTION	NOTES
1A06	1A1	0-6	0	Brown Silt w/ Vegetation	Grassy: no stone
	1A2	0-6	36	Black Stained Silt + Gravel - Strong Odor	0-4" Crushed Stone
	1A3	0-6	1.0	Dense Gray Silt + Gravel	0-5" Crushed Stone
1A612	1A1	6-12	0.2	Brown Sandy Silt + Gravel	
	1A2	6-12	40	A/A	
	1A3	6-12	1.8	A/A	
1A12-18	1A1	12-18	0.2	A/A	
	1A2	12-18	8	Gray Sandy Silt w/ little clay and Gravel	
	1A3	12-18	4.2	A/A	
1A1824	1A1	18-24	0	A/A	
	1A2	18-24	10.4	A/A	
	1A3	18-24	0.2	Brown + Gray clayey silt	
1B06	1B1	0-6	1.3	Dk. Brown Sandy Silt with mothball odor	
	1B2	0-6	0.8	Wet Silt and Gravel	Location flooded
	1B3	0-6	0.1	Loose Brown Sandy Silt	
1C06	1C1	0-6	0.6	Gravel and Silt	
	1C2	0-6	0.5	Gravelly Silt	
	1C3	0-6	0.1	Brown Organic Rich Silt	

MALCOLM PIRNIE

MALCOLM PIRNIE, INC.

BY .... DATE .... SHEET NO. 3 OF 8

CHKD. BY .... DATE .... JOB NO. ....

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(24)

TRAINING GROUNDS AREA

COMPOSITE SAMPLE NO.	GRAB SAMPLE LOCATION	SAMPLE DEPTH	TOTAL ORG VAPORS In Headspace	SAMPLE DESCRIPTION	NOTES
1BC612	1B1	6-12	0	Dk Brown Sandy Silt with mothball odor	
	1B2	6-12	1.8	Wet silt and gravel	location flooded
	1B3	6-12	0	Firm Brown Silt	
	1C1	6-12	3.8	Gray Clayey Silt with Petroleum Odor	
	1C2	6-12	0	Gray Clayey Silt	
	1C3	6-12	2.6	Brown Gravelly Silt with "cobalt blue" brick fragments	
1BC1218	1B1	12-18	0.8	Firm Gray Sandy Silt	
	1B2	12-18	0.6	Firm Brown Clay Silt	
	1B3	12-18	0	A/A	
	1C1	12-18	0.8	Gray fine Sand	
	1C2	12-18	0.2	Gray Sandy Silt	
	1C3	12-18	100	Gray clayey silt with odor	
1BC1824	1B1	18-24	0	A/A	
	1B2	18-24	0.2	A/A	
	1B3	18-24	0	Dk. Brown Silty Gravel	
	1C1	18-24	0.8	Gray fine Sand	
	1C2	18-24	0.4	Gray Silty fine Sand	
	1C3	18-24	390	Gray Clayey Silt with Odor	
1D06	1D1	0-6	0	Brown Sandy Gravel	
	1D2	0-6	1.0	Dense Gravelly Silt	
	1D3	0-6	0.8	Brown Organic Rich Silt	
1E06	1E1	0-6	0	Brown Silt with Gravel	
	1E2	0-6	0	Black Gravelly Organic Rich Silt	
	1E3	0-6	0.2	Loose Brown Silt w/ organic material	

MALCOLM PIRNIE

MALCOLM PIRNIE, INC.

BY .... DATE .... SHEET NO. 4 OF 8

CHKD. BY .... DATE .... JOB NO. ....

SUBJECT ....

TRAINING GROUNDS AREA

COMPOSITE SAMPLE NO.	GRAB SAMPLE LOCATION	SAMPLE DEPTH	TOTAL ORG VAPORS in Headspace	SAMPLE DESCRIPTION	NOTES
1 DE 612	1D1	6-12	0.8	Brown Gravelly Silt w/ Petroleum Odors and Staining	
	1D2	6-12	1.9	Dense Gravelly Silt	
	1D3	6-12	30	Gray/Brown Clayey Silt with Solvent Odor, some Black stains	
	1E1	6-12	0.6	Brown Silt and Gravel	
	1E2	6-12	0.6	Brown Silt with gravel	
	1E3	6-12	0.4	Silt with Coarse Gravel	
1 DE 1218	1D1	12-18	1.0	A/A with Petroleum stain and odor	
	1D2	12-18	1.0	Loose Gravelly Silt	
	1D3	12-18	300	Gray Clayey Silt with Solvent odor and black stains	
	1E1	12-18	0	Gray A/A	
	1E2	12-18	0.2	Firm, Brown Clayey Silt	
	1E3	12-18	0.2	A/A	
1 DE 1824	1D1	18-24	0.6	A/A with Petroleum Stain and odor	
	1D2	18-24	4.4	Firm brown clayey Silt	
	1D3	18-24	320	A/A w/ solvent odor	
	1E1	18-24	2.4	Brown/Gray, firm Silt	
	1E2	18-24	0	A/A	
	1E3	18-24	0.4	A/A	
2A06	2A1	0-6	0	Brown Silt and Gravel	Grassy Area
	2A2	0-6	0.2	Brown/Gray Silty Gravel	2" Crushed stone
	2A3	0-6	1.0	Silty Gravel	3" Crushed Stone
2B06	2B1	0-6	0	Gravel and Silt	Grassy Area
	2B2	0-6	0.2	Gray Silty Gravel	3" Crushed Stone
	2B3	0-6	0.2	Gray Silty Gravel	4" Crushed Stone

MALCOLM PIRNIE

(26)

TRAINING GROUNDS AREA

COMPOSITE SAMPLE NO.	GRAB SAMPLE LOCATION	SAMPLE DEPTH	TOTAL ORG. VAPORS IN HEADSPACE	SAMPLE DESCRIPTION	NOTES
2 AB 612	2A1	6 - 12	0	Brown Clayey Silt	Grassy Area
	2A2	6 - 12	0.2	Gravelly Silt	
	2A3	6 - 12	5.4	Silty Gravel with Black stains	
	2B1	6 - 12	0.2	Silt and fine gravel	
	2B2	6 - 12	0.3	Silty Gravel	
	2B3	6 - 12	0.2	Silty Gravel	
2 AB 1218	2A1	12 - 18	0	A/A	
	2A2	12 - 18	0.4	Gravelly Silt	
	2A3	12 - 18	56	A/A with Black Stains	
	2B1	12 - 18	0.2	Silt with little Gravel	
	2B2	12 - 18	0	Brown Sand and Silt	
	2B3	12 - 18	0.2	Gray/Brown Silty fine Sand	
2 AB 1824	2A1	18 - 24	0	Gray fine Sand	
	2A2	18 - 24	0.4	Brown Sandy Silt	
	2A3	18 - 24	4.0	Gray fine Sand with Black stains	
	2B1	18 - 24	0	Gray Clayey Silt	
	2B2	18 - 24	0	Brown Clayey Silt, tr. sand	
	2B3	18 - 24	0	Gray Silt w/ tr. gravel	
2 C 06	2C1	0 - 6	0.1	Dk. Brown silt w/ vegetative materials	Grassy Area.
	2C2	0 - 6	0.1	Silt and Gravel	2" Crushed Stone
2 C 612	2C1	6 - 12	0	Gravelly Silt	
	2C2	6 - 12	0	Gravelly clayey Silt	
2 C 1218	2C1	12 - 18	0.2	A/A	
	2C2	12 - 18	0.1	Gray Brown Clayey Silt	
2 C 1824	2C1	18 - 24	0.1	Brown Clayey Silt	
	2C2	18 - 24	0.1	A/A	

MALCOLM PIRNIE

MALCOLM PIRNIE, INC.

BY .... DATE .... SHEET NO. 6 OF 8

CHKD. BY .... DATE .... JOB NO. ....

SUBJECT ....

(20)

~~TH~~ TRAINING GROUNDS AREA

COMPOSITE SAMPLE NO.	GRAB SAMPLE LOCATION	SAMPLE DEPTH	TOTAL ORG. VAPORS IN HEADSPACE	SAMPLE DESCRIPTION	NOTES
3 A 0 6	3 A 1	0 - 6	0.2	Silty Gravel	2" crushed stone
	3 A 2	0 - 6	0.9	Silty Sand + Gravel	3" crushed stone
3 A 6 12	3 A 1	6 - 12	0.9	A/A	
	3 A 2	6 - 12	0.4	A/A	
3 A 12 18	3 A 1	12 - 18	0.2	Brown, silty fine sand	
	3 A 2	12 - 18	0.4	Clayey Silt and Gravel with Black stains	
3 A 18 24	3 A 1	18 - 24	0	A/A	
	3 A 2	18 - 24	0.2	A/A	
3 B					
3 B 0 6	3 B 1	0 - 6	1.0	Silty Gravel	2" Crushed Stone
	3 B 2	0 - 6	0	Silty Gravel with little asphalt	2" Crushed stone
	3 B 3	0 - 6	0.4	Silty Gravel	4" Crushed Stone
3 B 6 12	3 B 1	6 - 12	0.4	A/A	
	3 B 2	6 - 12	0	Silty Gravel	
	3 B 3	6 - 12	1.0	Dense Silt and Gravel	
3 B 12 18	3 B 1	12 - 18	0	Brown Clayey Silt	
	3 B 2	12 - 18	8	A/A	
	3 B 3	12 - 18	0.9	Silt with Black stains	
3 B 18 24	3 B 1	18 - 24	0	A/A	
	3 B 2	18 - 24	32	Clayey Silt	
	3 B 3	18 - 24	0	Clayey Silt	

CITY OF ROCHESTER

ROCHESTER FIRE ACADEMY – SUPPLEMENTAL RI

DESCRIPTION OF SOIL SAMPLES

SOUTH DISPOSAL AREA

(1a)

SAMPLE LOCATION	SAMPE DEPTH BELOW GRADE	SAMPLE DEPTH BELOW FILL	SAMPLE DESCRIPTION
SD-1	0-6"		Firm brown silty clay
SD-2	0-6"		Reworked Soil - Clayey Silt and, tr. gravel
SD-3	0-6"		Loose Dk. Brown Sandy Silt w/ roots
SD-4	0-6"		A/A
SD-5	0-6"		Reworked soil w/ some Incineration residue
SD-6	0-6"		Reworked clayey silt w/ occ. burnt wood fragments
SD-7	0-6"		A/A
SD-8	0-6"		Dk Brown Silty Sand, tr. clay - Abundant roots
SD-9	0-6"		A/A
SD-10	0-6"		Reworked Dk. Brown Gravelly Silt.
SDB-1	0-6"		Black Fill material
SDB-106		0-6"	Brown Clayey silt
SDB1612		6-12"	A/A
SDB11218		12-18"	A/A
SDB11824		18-24"	A/A
SDB-2	0-4"		Black Fill Material
SDB206		0-6"	Brown Clayey Silt
SDB2612		6-12"	A/A
SDB21218		12-18"	A/A
SDB21824		18-24"	A/A
SD-PROD	0"		Black tarry material with solvent odor.

MALCOLM PIRNIE

MALCOLM PIRNIE, INC.

BY .... DATE .... SHEET NO. 8 OF 8

CHKD. BY .... DATE .... JOB NO. ....

SUBJECT ....

CITY OF ROCHESTER

ROCHESTER FIRE ACADEMY - SUPPLEMENTAL RI

DESCRIPTION OF SOIL SAMPLES

19 + 1 = 20

GENESEE PARK AREA

SAMPLE NO.	SAMPLE DEPTH	SAMPLE DESCRIPTION
GP-1	0-6"	Loose brown Silt with
GP-2	↓	Loose brown Silt with
GP-3	↓	Loose brown, medium sand, some fine-Coarse gravel
GP-4	↓	Dark brown organic rich silt
GP-5	↓	Dk brown to black Silty Sand, some gravel (Fill for bike path)
GP-6	↓	A/A
GP-7	↓	Sandy Loam
GP-8	↓	Sandy Loam w/ vegetative matter (roots etc)
GP-9	↓	Silty Gravelly sand, vegetative matter - Fill

POLICE FIRING RANGE AREA

PF-1	0-6"	Silty Gravel
PF-2	↓	Brown Sandy Silt, tr Gravel with grass
PF-3	↓	A/A with occ. cinders
PF-4	↓	Brown Silt with some gravel.

NYSDEC CONFIRMATORY SAMPLES

DEC-1	0-6"	Loose, brown sandy silt
DEC-2	↓	Fill: Loose sandy silt over silt and some gravel.
DEC-3	↓	Gray Silty Gravel - removed 3" of gravel cover
DEC-4	↓	Brown Silty sand
DEC-5	↓	Fill beneath bike path: Silt w/ little fine gravel
DEC-6	↓	Fill beneath bike path: black Silt w/ little fine gravel.

+ 1 DOH

MALCOLM PIRNIE

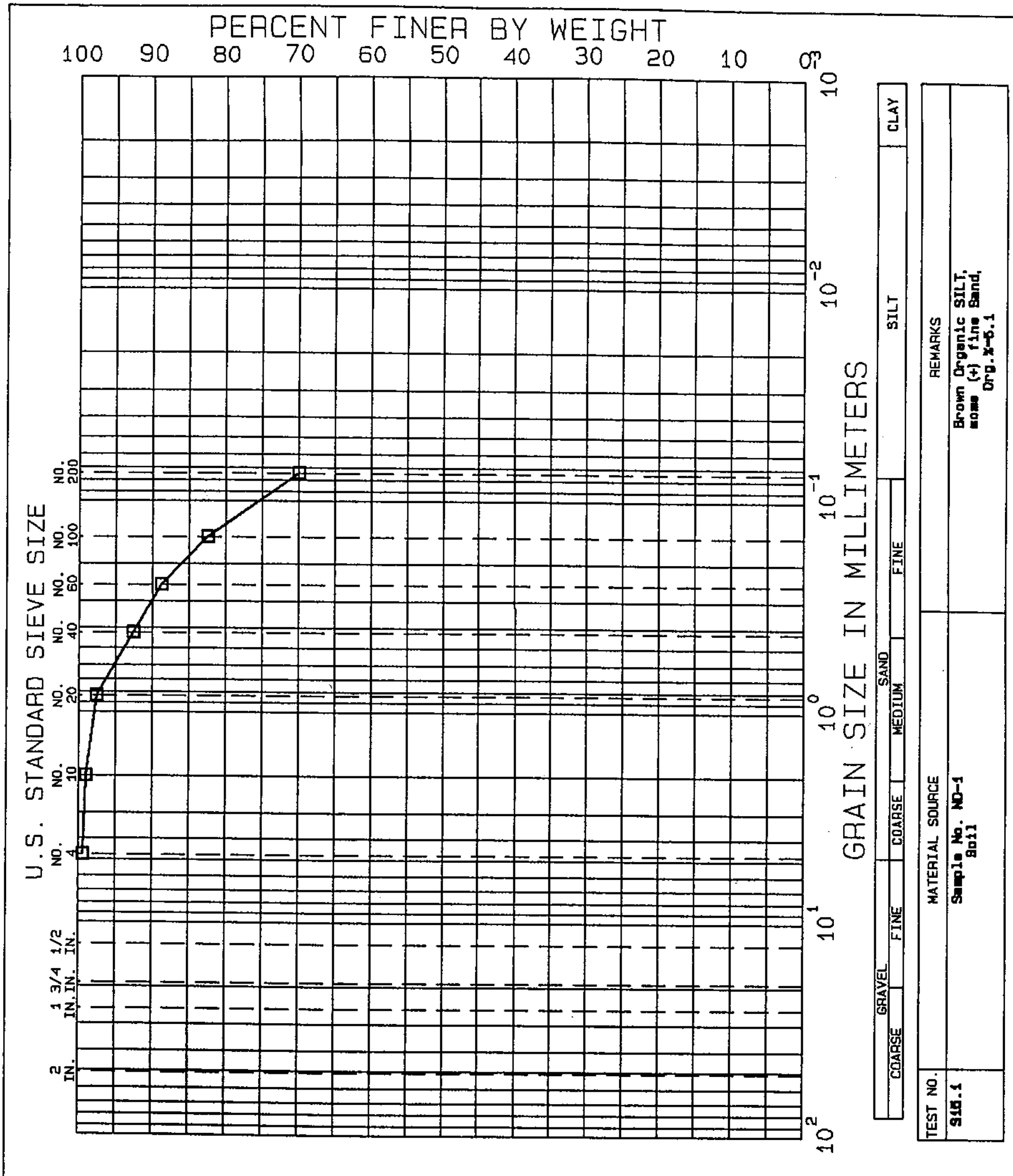
APPENDIX H

PHYSICAL TESTING RESULTS

APPENDIX F4

PHYSICAL TESTING RESULTS

Location	Type	% Gravel	% Sand	% Fines	D_{50}	% OC	Description
North Disposal Area:							
ND-1	Fill	20	20	60	0.1	3.5	Moderately loose, red-to-dard brown clayey silt; little fine-to-coarse subangular gravel; tr cobbles; refractory brick, black peat (moist).
ND-2	Fill	65	23	12	6.4	8.7	Loose, dark brown to black, silty fine sand; tr. fine-to-coarse subrounded gravel; abundant brick fragments; some plant matter.
ND-1	Soil	0	30	70	0.1	5.1	Mod. loose, brown-grey silt; tr. fine sand, with abundant roots (moist).
ND-2	Soil	1	23	76	0.1	11.0	Mod. loose, dark grey silt, trace fine sand, with roots (moist).
Training Grounds Area:							
TG-1	Fill	62	23	15	7.0	2.5	Loose light brown sandy silt, some coarse subangular gravel, trace organic matter (moist).
TG-2	Fill	78	15	7	10.0	0.6	Dense, grey sandy silt and gravel (moist).
TG-3	Fill	61	26	12	7.0	5.2	Dense grey sandy silt and coarse subangular gravel (moist).
South Disposal Area:							
SD-1	Fill	22	66	12	1.0	20.5	Loose, mixture of black sand sized material, and white powdery residue.
SD-2	Fill	17	58	25	0.3	25.0	Moderately loose, black incineration residue, sandy with abundant gravel, C&D debris, glass, refractory bricks (moist).
SD-1	Soil	0	3	97	2.1	2.1	Red clayey silt with burnt wood fragments (reworked).
SD-2	Soil	2	5	93	0.1	2.7	Brown clayey silt with trace clay (undisturbed native soil).
Genesee Valley Park Area:							
GP-1	Soil	0	35	65	0.1	3.8	Brown organic silt and fine sand.
GP-2	Soil	2	38	60	0.1	2.5	Brown organic silt and fine sand, trace gravel.



ROCHESTER FIRE ACADEMY
ROCHESTER, N.Y.
GRADATION TESTS

BORING NO.
SAMPLE ND-1
DEPTH
TECH. BF
REVIEWER DAS

TEST SERIES
NO. 15
DATE Dec. 91

FILE L12783

GZA GEOENVIRONMENTAL, INC.
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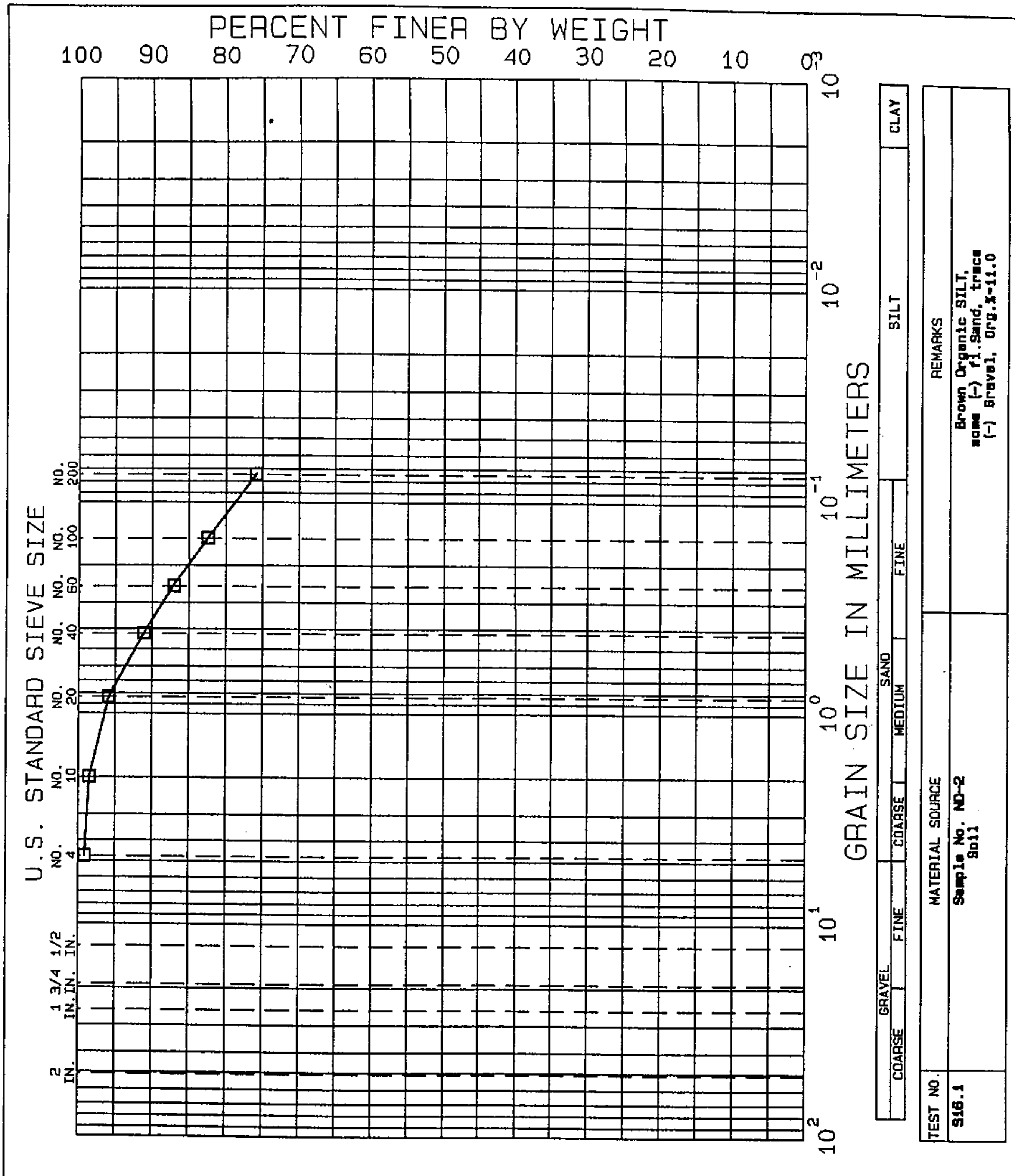
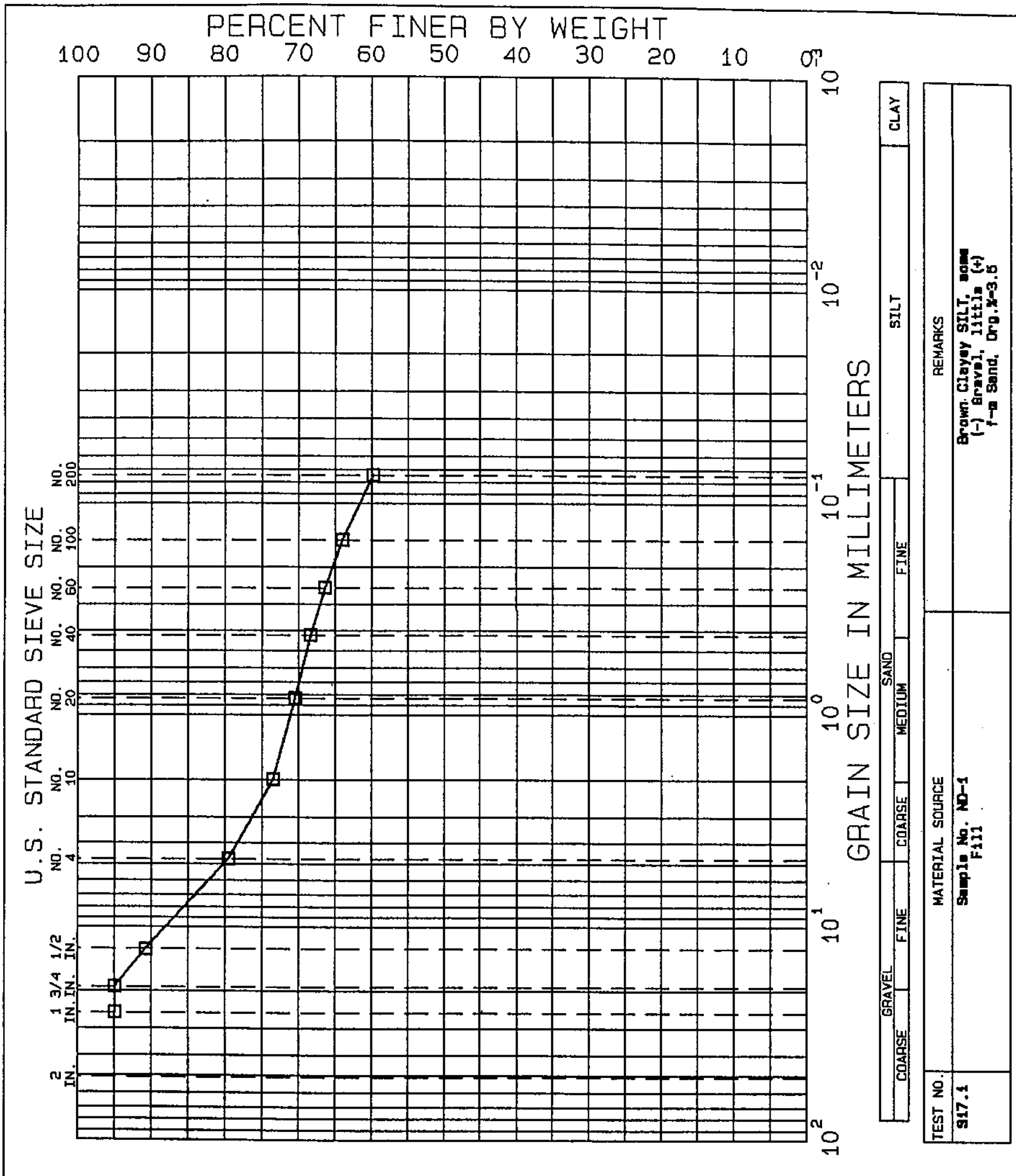


ROCHESTER FIRE ACADEMY
ROCHESTER, N.Y.

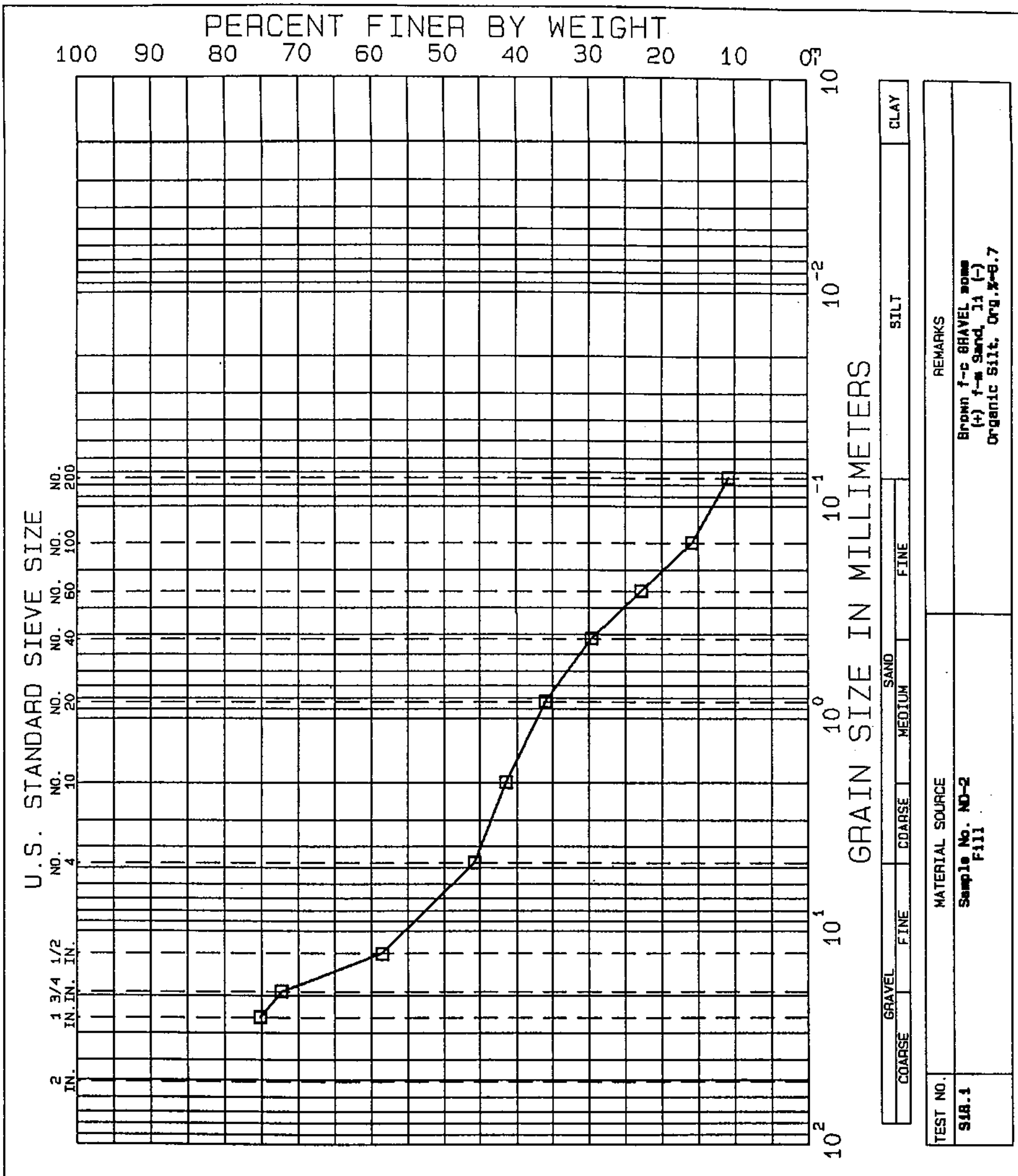
GRADATION TESTS

BORING NO.		TEST SERIES NO.	16
SAMPLE	ND-2	DATE	Dec. 91
DEPTH			
TECH.	BF	FILE	L12783
REVIEWER	DAS		



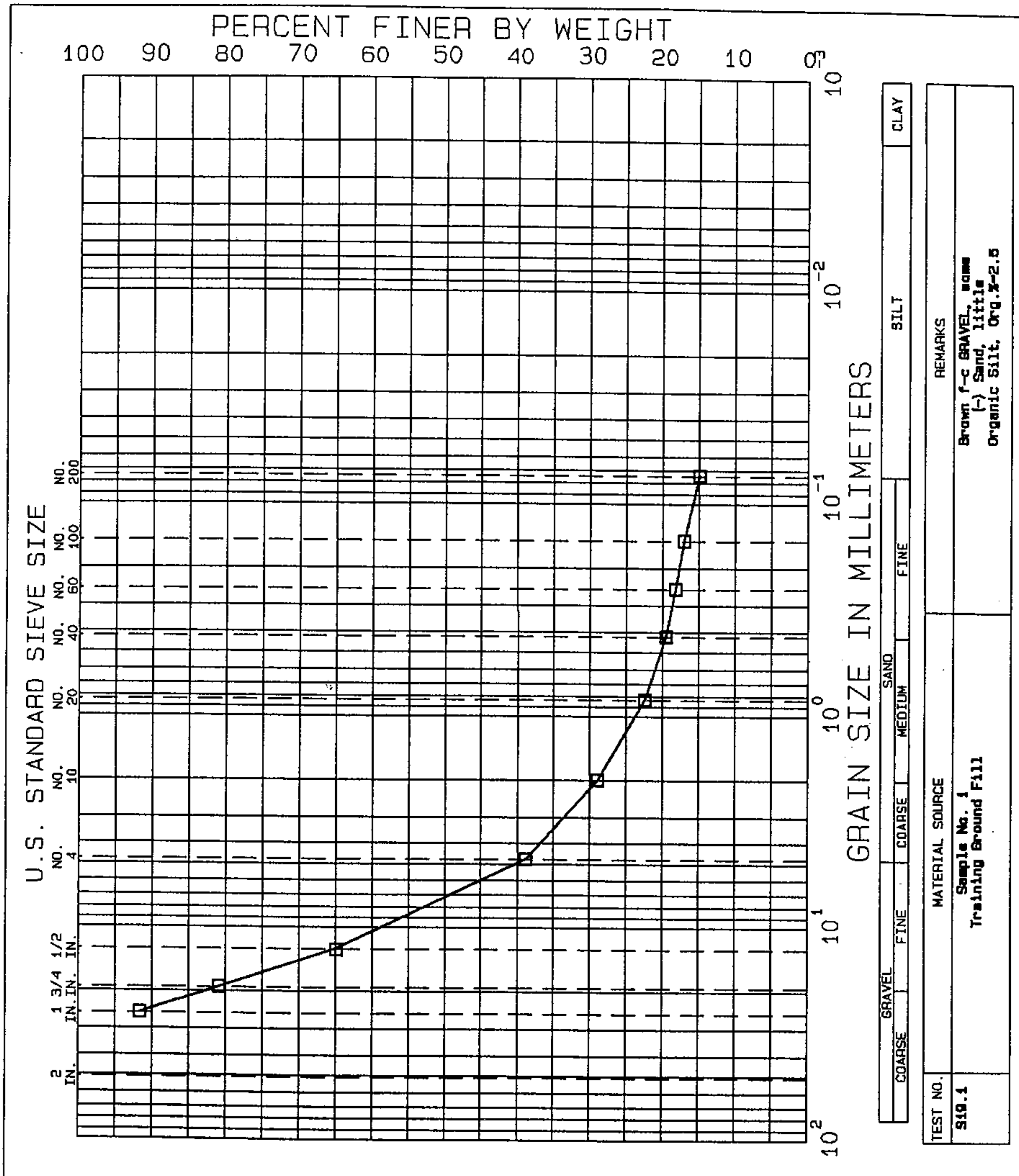
ROCHESTER FIRE ACADEMY
ROCHESTER, N.Y.
GRADATION TESTS

BORING NO.	TEST SERIES
SAMPLE ND-1	NO. 17
DEPTH	DATE Dec. 91
TECH. BF	
REVIEWER DAS	FILE L12783



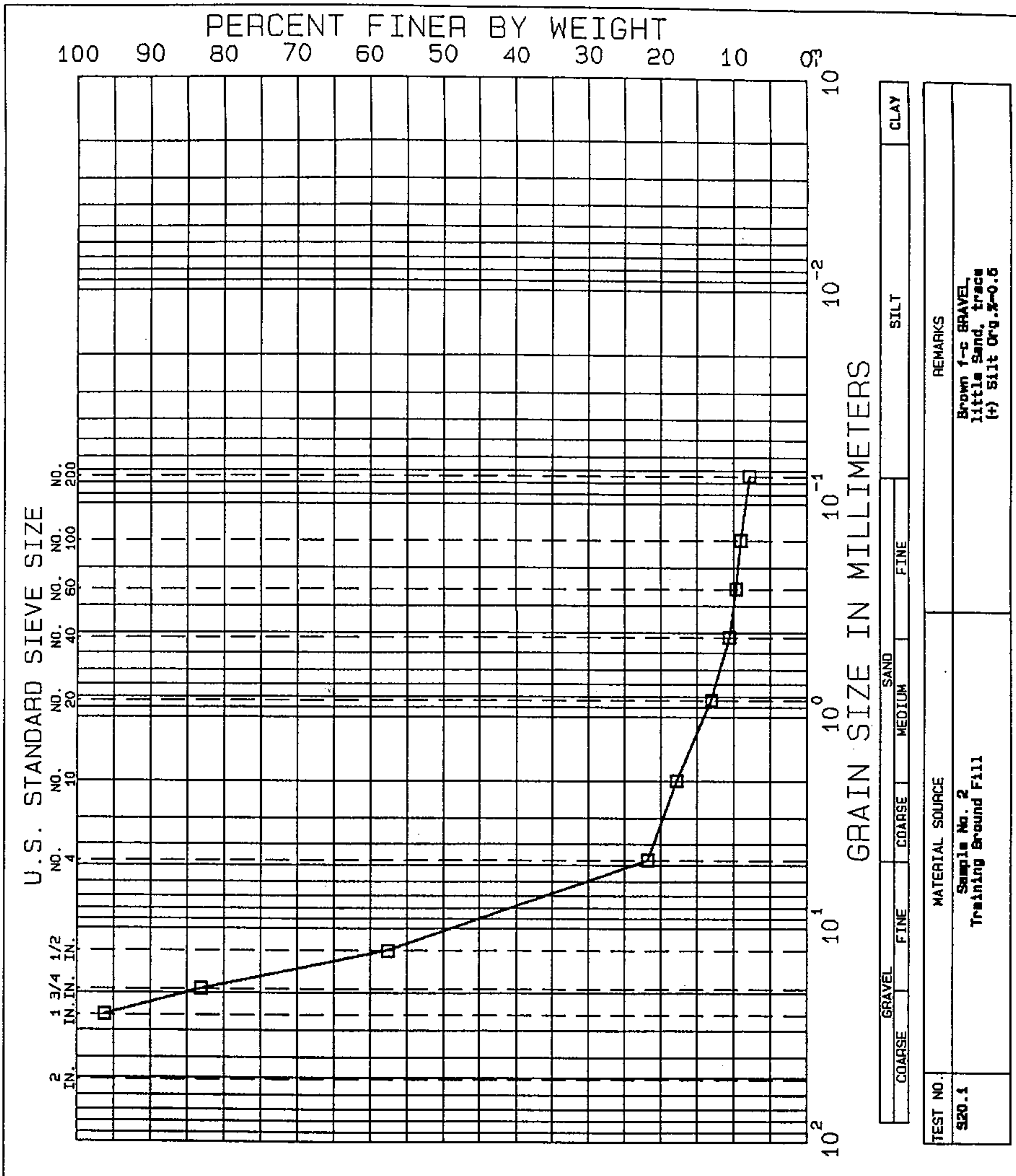
ROCHESTER FIRE ACADEMY
ROCHESTER, N.Y.
GRADATION TESTS

BORING NO.		TEST SERIES	
SAMPLE	ND-2	NO.	18
DEPTH		DATE	Dec. 91
TECH.	BF		
REVIEWER	DAS	FILE	L12783



ROCHESTER FIRE ACADEMY
ROCHESTER, N.Y.
GRADATION TESTS

BORING NO.	TEST SERIES
SAMPLE 1	NO. 19
DEPTH	DATE Dec. 91
TECH. BF	
REVIEWER DAB	FILE L12783

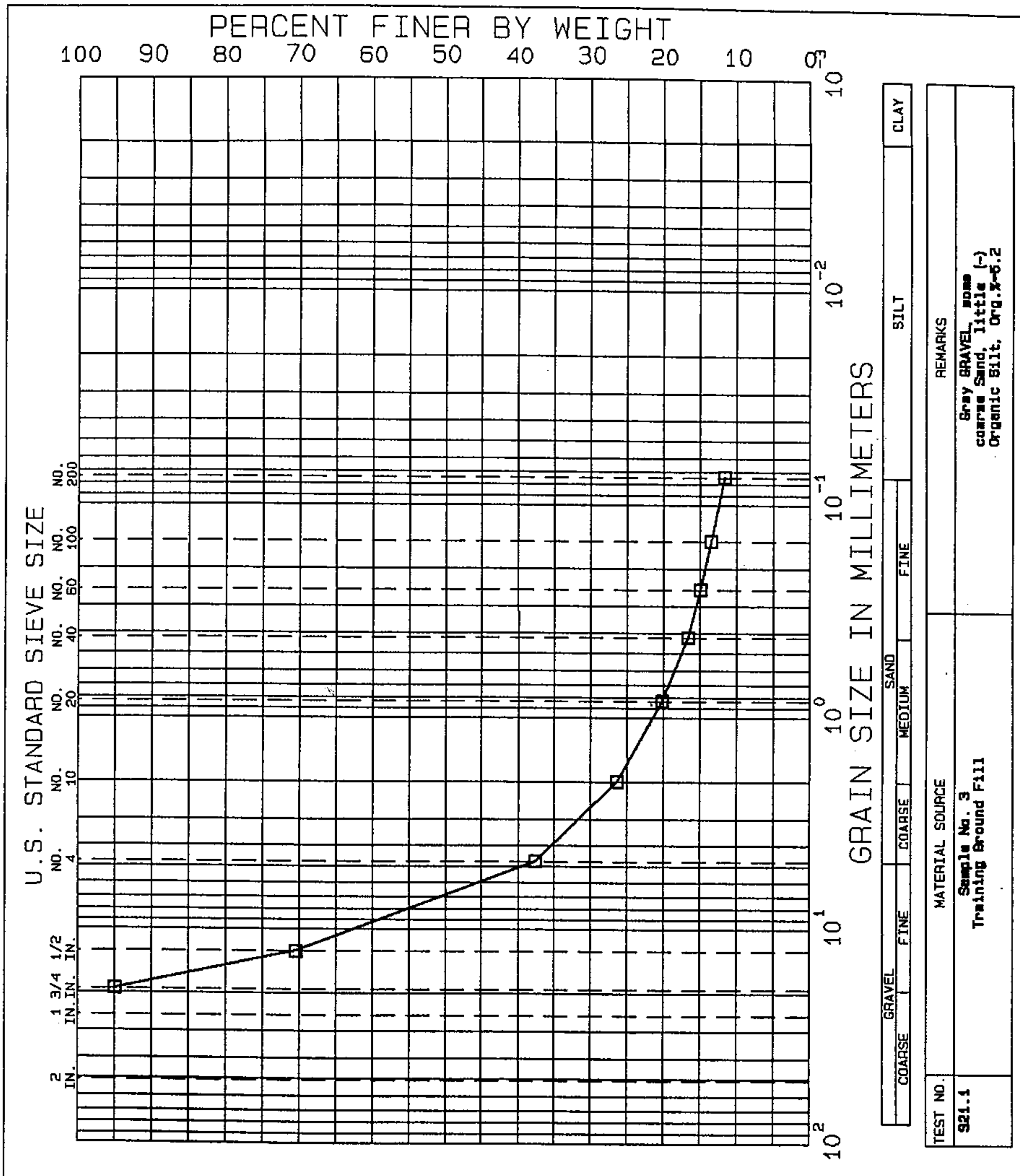


ROCHESTER FIRE ACADEMY
ROCHESTER, N.Y.
GRADATION TESTS

BORING NO.
SAMPLE 2
DEPTH
TECH. SF
REVIEWER DAS

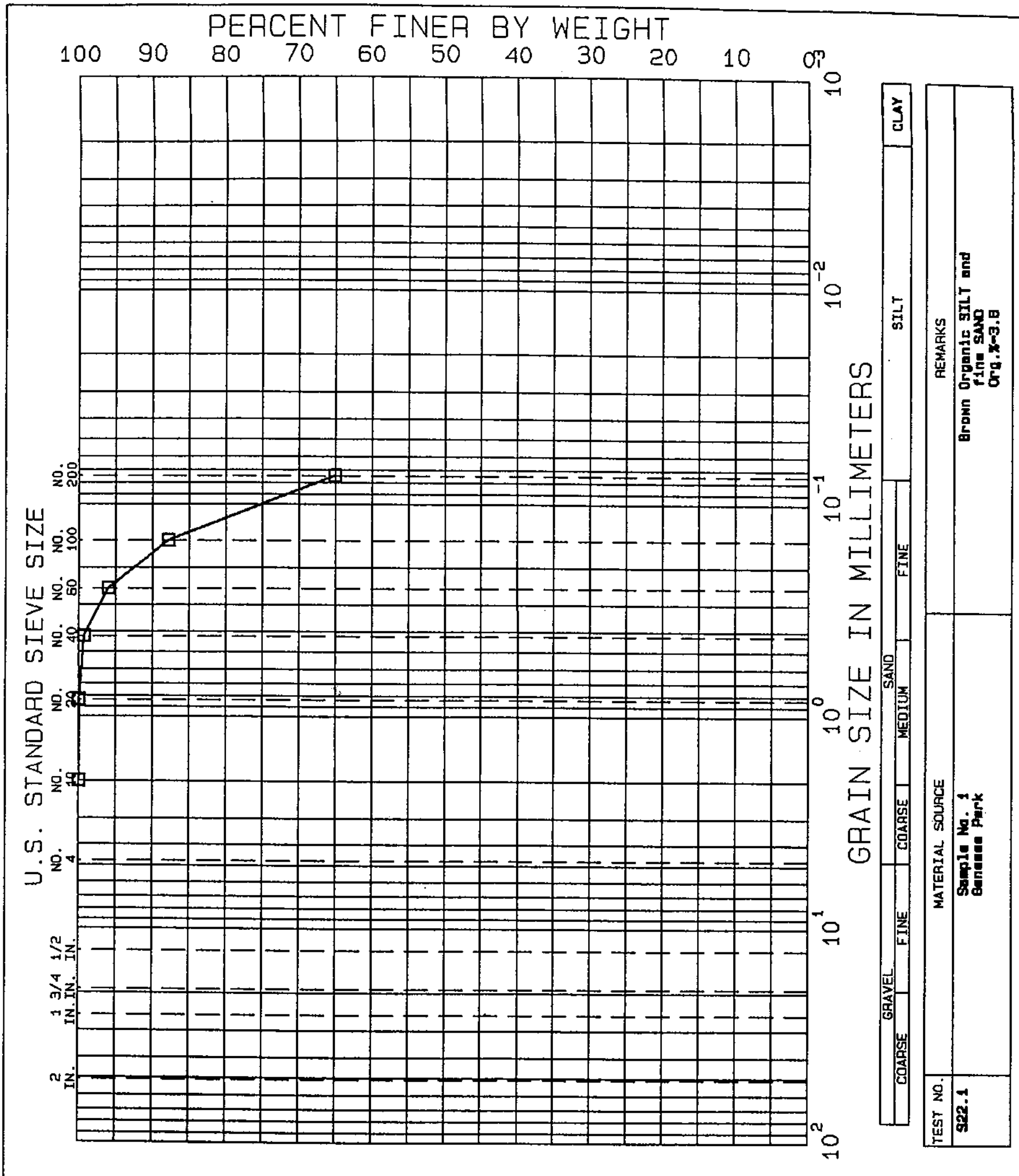
TEST SERIES
NO. 20
DATE Dec. 91

FILE L12783



ROCHESTER FIRE ACADEMY
ROCHESTER, N.Y.
GRADATION TESTS

BORING NO. SAMPLE **3** DEPTH TECH. **BF** REVIEWER **DAS**	TEST SERIES NO. **21** DATE **Dec. 91** FILE **L12783**



ROCHESTER FIRE ACADEMY

ROCHESTER, N.Y.

GRADATION TESTS

BORING NO.		TEST SERIES NO.	22
SAMPLE	1	DATE	Dec. 91
DEPTH			
TECH.	BF	FILE	L12783
REVIEWER	DAB		

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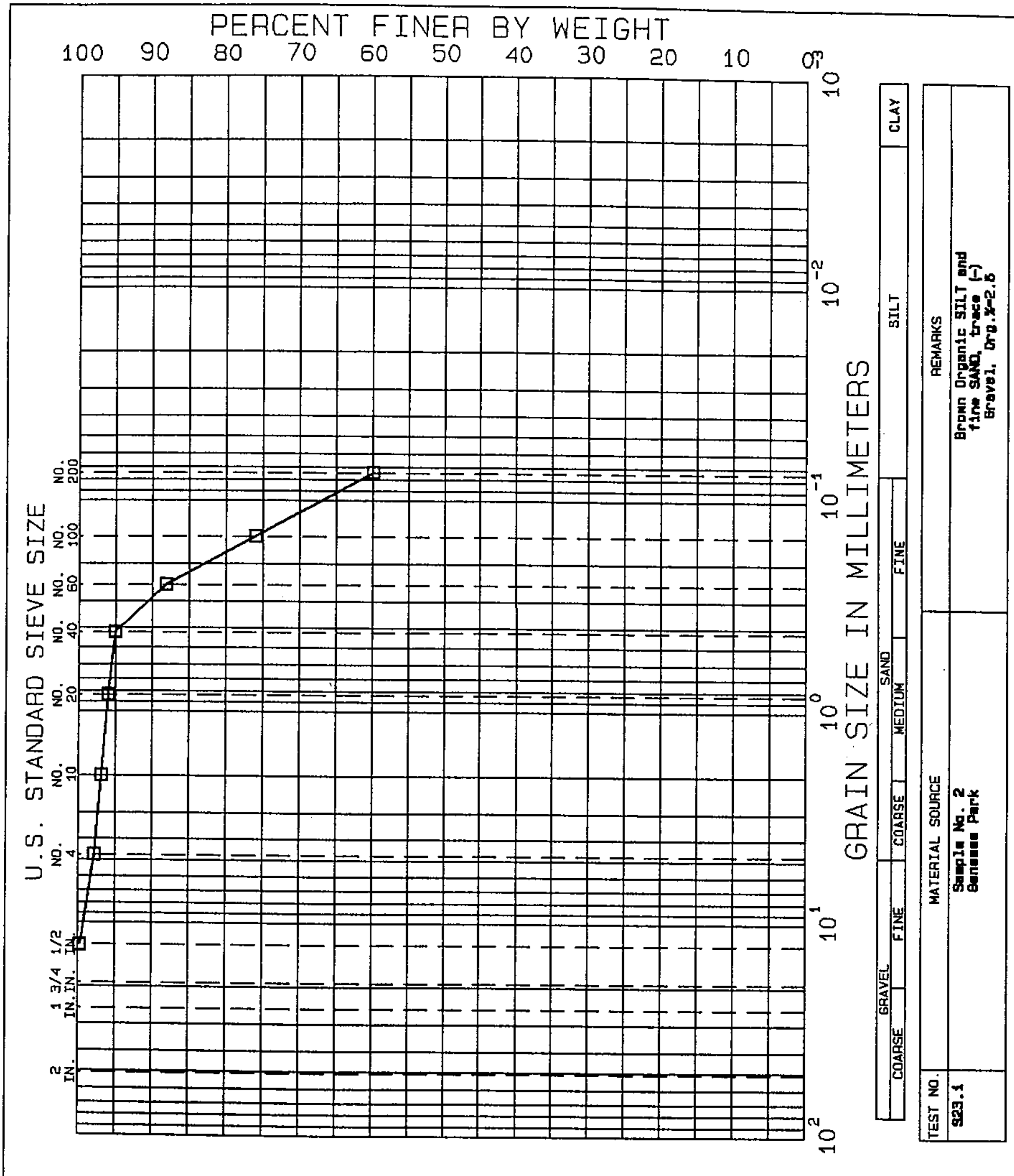


ROCHESTER FIRE ACADEMY

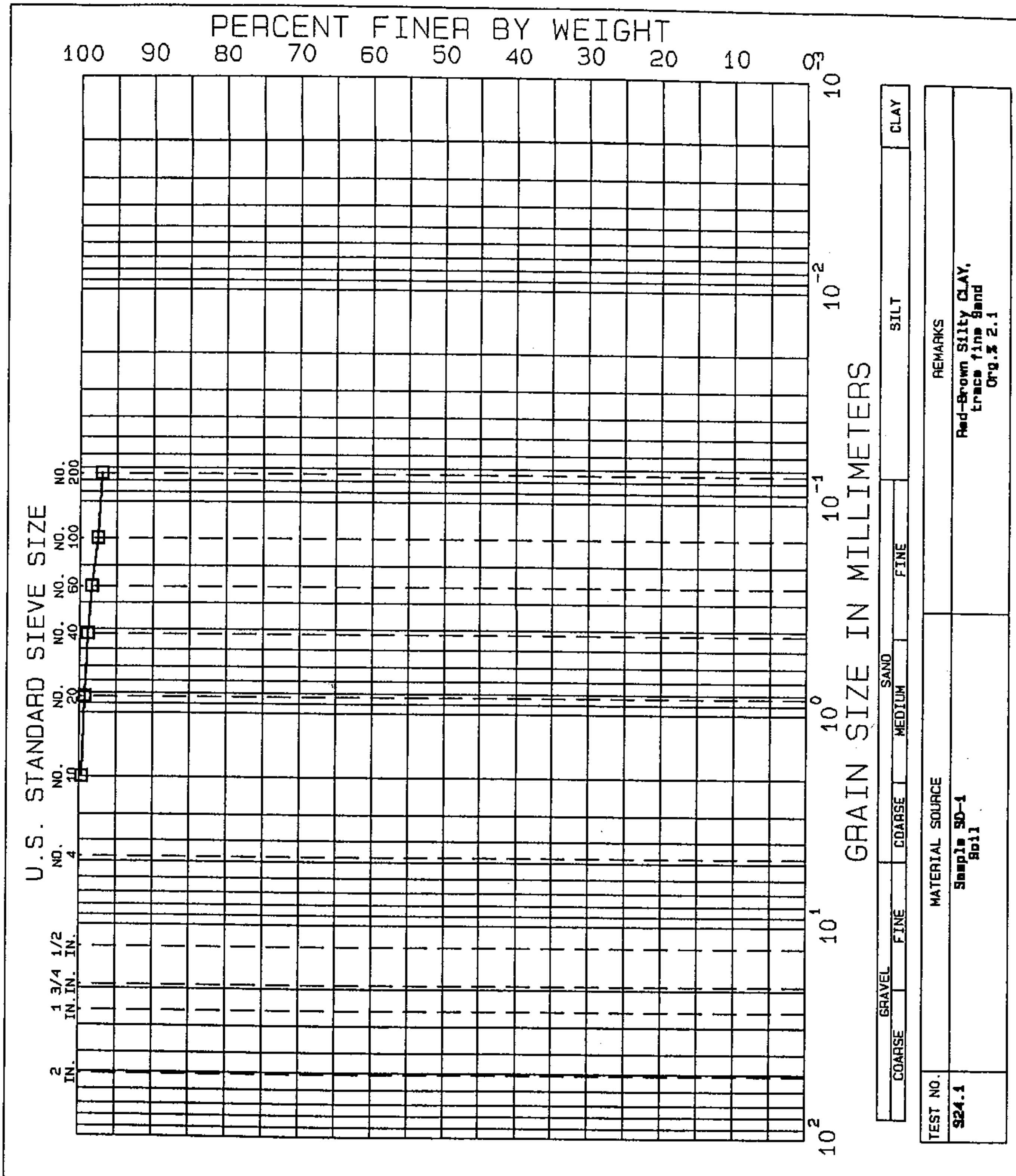
ROCHESTER, N.Y.

GRADATION TESTS

BORING NO.
SAMPLE 2
DEPTH
TECH. BF
REVIEWER DAS

TEST SERIES
NO. 23
DATE Dec. 91

FILE L12783



ROCHESTER FIRE ACADEMY
ROCHESTER, N.Y.
GRADATION TESTS

BORING NO.
SAMPLE SD-1
DEPTH
TECH. BF
REVIEWER DAS

TEST SERIES
NO. 24
DATE Dec. 91

FILE L12783

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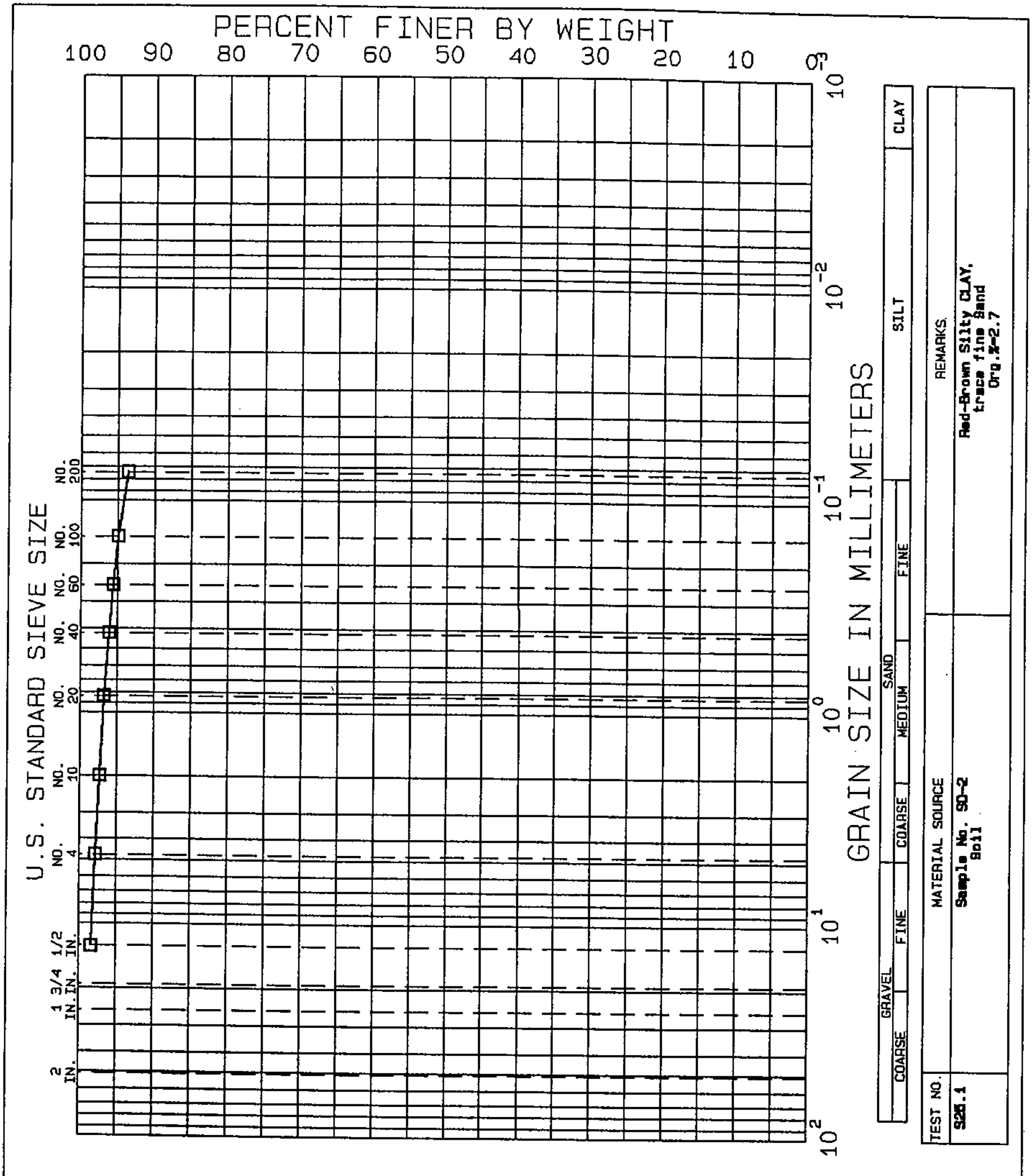
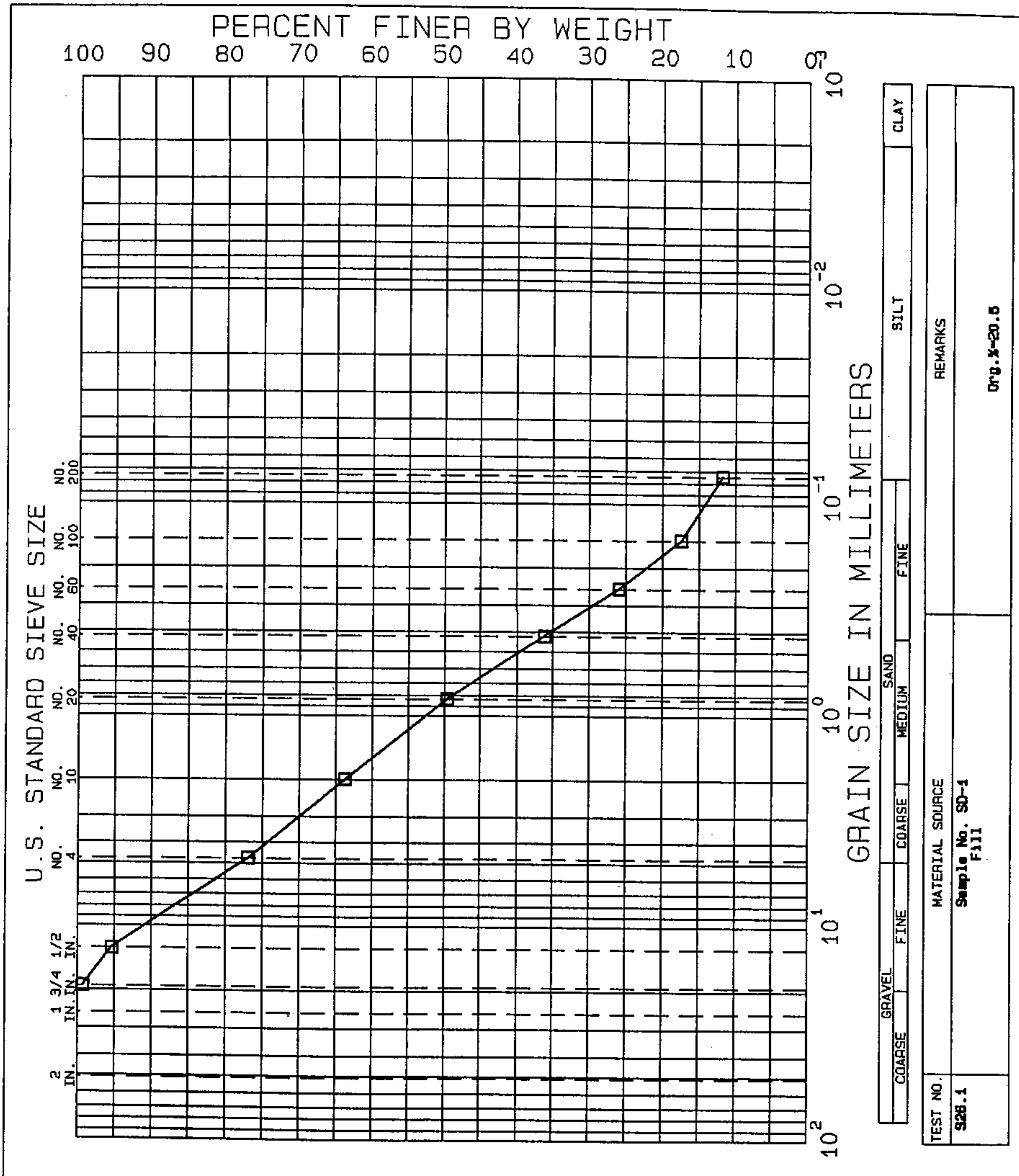


ROCHESTER FIRE ACADEMY
ROCHESTER, N.Y.
GRADATION TESTS

BORING NO.
SAMPLE SD-2
DEPTH
TECH. BF
REVIEWER DAS

TEST SERIES NO. 25
DATE Dec. 91
FILE L12783

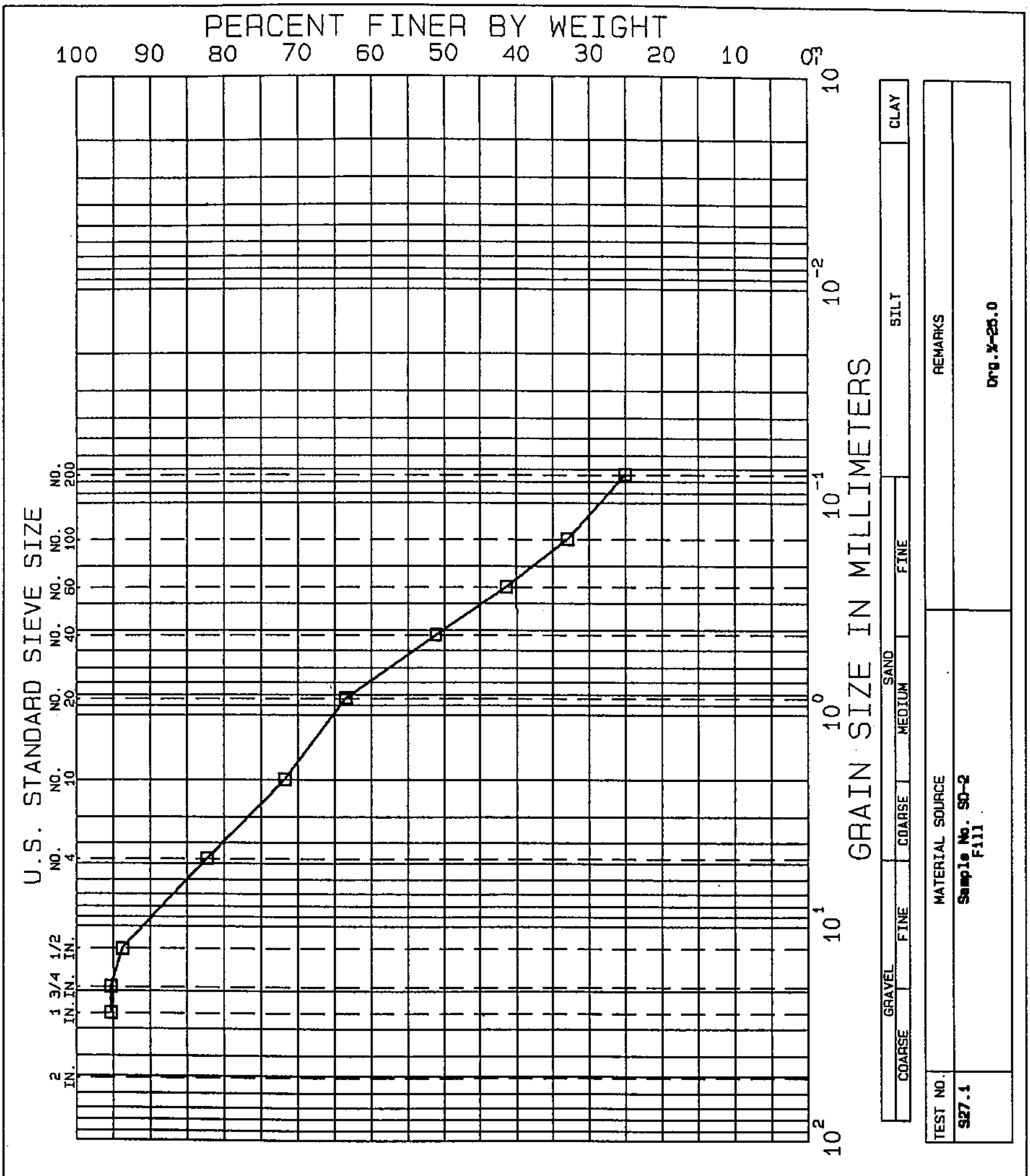


ROCHESTER FIRE ACADEMY
ROCHESTER, N.Y.
GRADATION TESTS

BORING NO.
SAMPLE **SD-1**
DEPTH
TECH. **BF**
REVIEWER **DAS**

TEST SERIES
NO. **26**
DATE **Dec. 91**

FILE **L12783**



ROCHESTER FIRE ACADEMY
ROCHESTER, N.Y.
GRADATION TESTS

BORING NO.		TEST SERIES NO.	**27**
SAMPLE	**SD-2**	DATE	**Dec. 91**
DEPTH			
TECH.	**BF**		
REVIEWER	**DAS**	FILE	**L12783**

MALCOLM PIRNIE

APPENDIX I

CONTAMINANT LOADING CALCULATIONS

MALCOLM PIRNIE

BY RHO DATE 3-12-91 SHEET NO. 1 OF 4

CHKD. BY .... DATE .... JOB NO. 0965-04-1

SUBJECT GROUND WATER LOADING TO THE GENESEE RIVER VIA OVERBURDEN

REVISED 4-13-92

SITE IS DIVIDED INTO 3 AREAS. GROUND WATER LOADING IS CALCULATED SEPARATELY FOR EACH AREA.

ASSUMPTIONS:

1. PRIMARY CONTRIBUTION OF CONTAMINANTS TO RIVER IS THROUGH THE OVERBURDEN WATER BEARING ZONE.

2. MAY 1990 WATER LEVELS REPRESENT AN AVERAGE OR STEADY STATE CONDITION

3. USE GROUND WATER DISCHARGE IN CUBIC FT/DAY AVERAGED ANNUALLY AS PRESENTED IN SECTION 6.1.2.

4. USE CONTAMINANT CONCENTRATIONS AVERAGED FROM OVERBURDEN WELLS ALONG THE RIVER IN EACH AREA

AVERAGE CONCENTRATIONS

NORTH DISPOSAL AREA: AVERAGE RESULTS FROM MW-11S

PARAMETER	NUMBER OF ANALYSES	AVERAGE (mg/L)
TOTAL VOCs	3	0
TOTAL [illegible]OCs	3	0.013
TOTAL PCBs	3	0
TOTAL Fe + Mn	2	12.2
TOTAL TRACE METALS (Sb, As, Be, Cd, Cr, Cu, Pb, Hg, Ni, Se, Ag, Tl, Zn, V)	1	0.167

REVISED 4-13-92

AVERAGE CONCENTRATIONS

TRAINING GROUNDS AREA: AVERAGE RESULTS FROM MW-8S, MW-12S AND MW-15S

PARAMETER	NO. OF ANALYSES	AVERAGE (mg/L)
TOTAL VOCs	9	0.026
TOTAL SEMI-VOCs	1	0.005
TOTAL PCBs		0
TOTAL Fe and Mn	6	10.4
Total Trace Metals	3	0.081

SOUTH DISPOSAL AREA: AVERAGE RESULTS FROM MW-7S

PARAMETER	NO. OF ANALYSES	AVERAGE (mg/L)
TOTAL VOCs	3	28.7
TOTAL [illegible]I-VOCs	3	0.114
TOTAL [illegible]	2	0.004
TOTAL Fe and Mn	2	17.8
TOTAL TRACE METALS	1	0.254

REVISED 4-13-92

LOADING CALCULATIONS

NORTH DISPOSAL AREA

PARAMETER	CONCENTR. mg/L	× DISCHARGE ft³/day	× CONVERSION L/ft³	× kg/mg	× day/yr	= LOADING kg/yr
TVOCs	0	× 207	× 28.3	× 10^{-6}	× 365	= 0
Semi-VOCs	0.013 ×	(2.138)				= 0.028
TOTAL PCBs	0					= 0
Total FeMn	17.2					= 36.8
TOTAL TRACE METALS	0.167					= 0.36
UPGRADIENT TOTAL FeMn	5.4	× 18	× 28.3	× 10^{-6}	× 365	= 1.0

TRAINING GROUNDS AREA

TVOCs	0.026	× 1,033	× 28.3	× 10^{-6}	× 365	= 0.28
Semi-VOCs	0.005 ×	(10.670)				0.05
PCBs	0	×				0
Fe Mn	10.4	×				111
Total Trace Metals	0.081	×				0.86
UPGRADIENT Fe Mn	1.1	× 161	× 28.3	× 10^{-6}	× 365	= 1.8

REVISED 4-13-92

SOUTH DISPOSAL AREA

PARAMETER	CONCEN.		DISCHARGE		CONVERSION							LOADING
	mg/L	x	ft³/Day	x	L/ft³	x	Kg/mg	x	Day/yr	=		Kg/yr
TVOCs	28.7	x	126	x	28.3	x	10^{-6}	x	365	=		37
SEMI-VOCs	0.114	x	(		1.302		)			=		0.15
PCBs	0.004											0.005
Fe Mn	17.8											23
TRACE METALS	0.254											0.33
UPGRADIENT FE Mn	3.1	x	50	x	28.3	x	10^{-6}	x	365	=		1.6

MALCOLM PIRNIE

BY RHO DATE 3-12-91 SHEET NO. 1 OF 3
CHKD. BY ...... DATE ......
JOB NO. 0965-04-1
SUBJECT GROUND WATER LOADING VIA UPPER BEDRK

revised 4/15/92 RMF

BEDROCK AQUIFER - AVERAGE CONCENTRATIONS

NORTH DISPOSAL AREA - MW-11I and MW-16I

PARAMETER	NO. OF ANALYSES	AVERAGE (mg/L)
TOTAL VOCs	5	.028
Total Semi-VOCs	5	.001
TOTAL PCBs	5	0
TOTAL Fe, Mn	4	4.7
Total Trace Metals	2	0.14

TRAINING GROUNDS AREA - MW-8I, MW-12I

PARAMETER	NO. OF ANALYSES	AVERAGE (mg/L)
TOTAL VOCs	6	* 0.225
TOTAL Semi-VOCs	6	0.004
Total PCBs	6	0
TOTAL Fe, Mn	6	3.4
TOTAL Trace Metals	2	.14

SOUTH DISPOSAL AREA - MW-7I

PARAMETER	NO. OF ANALYSES	AVERAGE (mg/L)
TOTAL VOCs	3	7.0
TOTAL-Semi-VOCs	3	0.012
TOTAL PCBs	3	0.001
TOTAL Fe, Mn	2	0.35
TOTAL Trace Metals	1	0

* Value excludes First Round of Sampling for MW-12I

BEDROCK AQUIFER : GROUNDWATER DISCHARGE

$Q = K i A$

K = Mean hydraulic conductivity of bedrock wells in the Area - from Table 5-10
i = Hydraulic Gradient from Table 5-10
A = Saturated Thickness x Width of Area
Use 10 feet as the thickness of the monitored intervals - Contaminant concentrations are substantially lower in the 10-20 foot interval of rock

Parameter	NORTH DISPOSAL AREA	TRAINING GROUNDS AREA	SOUTH DISPOSAL AREA
K cm/sec	1.9×10^{-2}	1.9×10^{-2}	2.8×10^{-2}
i ft/ft	0.004	0.006	0.003
A ft^2	2000	7400	2000
Q ft^3/day	431	2392	476

	AREA WIDTH (ft)
NORTH DISPOSAL AREA	200
TRAINING GROUNDS AREA	740
SOUTH DISPOSAL AREA	200

Revised 4/15/92 RHF

LOADING CALCULATIONS : BEDROCK AQUIFER

PARAMETER	CONCENTR.	×	DISCHARGE	×	CONVERSION	=	LOADING
	mg/L	×	ft^3/day	×	L/ft^3 × Kg/mg × day/yr	=	Kg/yr
NORTH DISPOSAL AREA							
TVOCs	0.028	×	431	×	28.3 × 10^{-6} × 365	=	0.12
Semi-VOCs	0.001	×	(4.452)			=	0.004
TOTAL PCBs	0					=	0
TOTAL Fe Mn	4.7					=	21
TOTAL TRACE METALS	0.14					=	0.62
TRAINING GROUNDS AREA							
TVOCs	0.225	×	2392	×	28.3 × 10^{-6} × 365	=	5.6
Semi VOCs	0.004	×	(24.708)			=	0.10
Total PCBs	0					=	0
Total Fe Mn	3.4					=	84
TOTAL TRACE M[illegible]	0.14					=	3.5
SOUTH DIS[illegible] AREA							
TVOCs	7.0	×	476	×	28.3 × 10^{-6} × 365	=	34
Semi-VOCs	0.012	×	(4.917)			=	0.06
TOTAL PCBs	0.001					=	0.005
TOTAL Fe Mn	0.35					=	1.72
TOTAL TRACE METALS	0					=	0

MALCOLM PIRNIE

APPENDIX J

TOXICITY PROFILES FOR CHEMICALS-OF-CONCERN

ECOLOGICAL RISK ASSESSMENT

TOXICITY PROFILES FOR CHEMICALS OF POTENTIAL CONCERN

ECOLOGICAL RISK ASSESSMENT

ALUMINUM

Aluminum is often taken up and concentrated in root tissue. According to the Draft Toxicological Profile for Aluminum (ATSDR, 1991), it is unclear to what extent aluminum is taken up into root food crops and leafy vegetables, however, it is not bioconcentrated in plants. In addition, aluminum is not expected to biomagnify in terrestrial food chains.

The potential for accumulation of aluminum has been studied in several aquatic species. Bioconcentration of aluminum in fish is a function of the water quality. Brook trout have been shown to accumulate slightly more aluminum as pH levels increase. In smallmouth bass, aluminum accumulation was higher in gill tissues than other tissues. Aluminum concentrations were also highest in the gill tissues and lowest in the muscles of rainbow trout. No information was found on the biomagnification of aluminum in aquatic food chains.

Most studies of the health effects of aluminum to animals involved oral and inhalation exposure. Few studies are available regarding respiratory effects in animals. Two studies that involved exposure of rats, guinea pigs and hamsters to aluminum chlorohydrate, reported reactions similar to that of dust exposure, sometimes accompanied by pneumonia.

According to the Draft Toxicological Profile for Aluminum (ATSDR, 1991), the effects of aluminum on the development of laboratory animals are controversial. Some studies show decreases in pup growth and neurological development, while others do not. In mice, aluminum chloride has not been shown to produce adverse effects in pups, when administered during gestation. However, aluminum lactate in food during gestation produced weight decreases and lowered birth weights in pups, but it was difficult to determine whether these effects were permanent. Studies on pups that were exposed to aluminum after they were born also have mixed results. Aluminum is fatal to laboratory animals (rats, mice) only at very high doses.

BIS (2-ETHYLHEXYL) PHTHALATE

Bis (2-ethylhexyl) phthalate is readily adsorbed onto particulates, but it tends to be lipophilic, so bioaccumulation is considered an important fate process for this compound. Accumulation has been shown to occur at a rate of 350 to 3900 times the concentration in water after seven days (USEPA, 1979). Aquatic organisms are more apt to concentrate phthalates than warm blooded animals since cold blooded animals metabolize phthalates more slowly than warm blooded ones. It is biodegraded under most conditions, and can be metabolized by multicellular organisms. However, bis (2-ethylhexyl) phthalate is considered to be one of the least biodegradable phthalate esters (Mathur 1974, cited in Versar, Inc., 1979).

Acute median effect values range from 1,000 to 11,100 μg/L for the freshwater cladoceran Daphnia magna. The LC50 values for the midge, scud, and bluegill all exceeded the highest concentrations tested, which were 18,000, 32,000 and 770,000 μg/L, respectively. As these values are greater than the water solubility of the chemical, it is unlikely that bis (2-ethylhexyl) phthalate will be acutely toxic to organisms in natural waters. In a chronic toxicity test with Daphnia magna, significant reproductive impairment was found at the lowest concentration tested, 3 μg/L. A chronic toxicity value of 8.4 μg/L was reported for the rainbow trout. Reported bioconcentration factors in fish and invertebrates range from 14 to 2,680 (Clement Associates, 1985).

CADMIUM

Cadmium is strongly accumulated by all organisms, both through food and water. Cadmium accumulates in fresh water and marine organisms at concentrations hundreds to thousands of times higher than it does in the water itself. Bioconcentration of cadmium by aquatic organisms is a well-known phenomenon. Bioconcentration factors are about 1,000 for fresh water and marine plants and about 3,000 for fresh water and marine fish. The cadmium content of fish in general ranges from 1 to 50 μg/g and that of shellfish (e.g., mussels, scallops, and oysters) typically is between 100 to 1,000 μg/g.

Fresh water acute values for cadmium are available for species in 44 genera and range from 1.0 μg/L for rainbow trout to 28,000 μg/L for a mayfly. The antagonistic effect of hardness on acute toxicity has been demonstrated with five aquatic species. Chronic tests have been conducted on cadmium with 12 freshwater fish species and 4 invertebrate species with chronic values ranging from 0.15 $\mu g/L$ for Daphnia magna to 156 $\mu g/L$ for the Atlantic salmon (USEPA, 1986).

Freshwater aquatic plants are affected by cadmium at concentrations ranging from 2 to 7,400 $\mu g/L$. These values are in the same range as the acute toxicity values for fish and invertebrate species, and are considerably above the chronic values. Bioconcentration factors (BCFs) for cadmium in fresh water range from 164 to 4,190 for invertebrates and from 3 to 2,213 for fishes (USEPA, 1986).

In mammals, cadmium is toxic to all tissues. Symptoms of chronic cadmium toxicity include growth retardation, impaired kidney function, poor reproductive capacity, hypertension, tumor formation, hepatic dysfunction, poor lactation, and lowered hematocrit levels. Teratogenic effects are noticed in offspring when pregnant animals are exposed to chronic toxic doses of cadmium. Carcinogenicity of cadmium in animals has been well established by parenteral administration, although cadmium is not carcinogenic by the oral route (Luckey et al., 1977).

COBALT

Cobalt is an essential element and can be accumulated by plants and animals, though generally not to excessive concentrations. This compound has been found to be essential for both blue-green algae and microorganisms in nitrogen fixation. It is not clear, however, whether cobalt is essential for higher plants, although there has been some evidence of a favorable effect on plant growth. It has also been recognized as a component of a precursor of vitamin B_{12} for ruminant animals (Kabata-Pendias, 1984).

Little information regarding toxic effects of exposure to cobalt or cobalt compounds is available. Acute cobalt toxicity is seen in chickens at 50 ppm in the diet (approximately 3 mg/kg of body weight) per day and in sheep at 6 mg/kg of body weight per day. In sheep, daily doses of 3 mg/kg of body weight, which is about 1,000 times the normal daily intake of cobalt, do not produce harmful effects, even after several weeks. The oral LD50 value for cobalt is 1,500 mg/kg in the rat. The oral LD50 values for a variety of inorganic cobalt compounds range from about 150 mg/kg for cobalt fluoride to 503 mg/kg for cobalt acetate (Clement Associates, 1985).

COPPER

The bioconcentration factor (BCF) of copper in fish obtained in field studies is 10-100 indicating a low potential for bioconcentration. The BCF is higher in molluscs, like oysters, where it may reach 30,000. However, abundant evidence has shown that there is no biomagnification in the food chain. Studies have been performed on bottom-feeding fish such as suckers and bullheads, as well as on herbivorous, omnivorous and carnivorous animals.

Health effects in animals from long-term exposure (greater than two weeks) to copper in food include liver and kidney damage in rats, liver damage in pigs, and increased blood pressure in rats. In water, long-term exposure has caused liver damage in rats and decreased survival in mice.

Although information concerning the environmental fate of copper in water and soil is available, the fate of copper is highly site-specific and species-specific.

IRON

Iron is an essential element required by both plants and animals. The ferrous, or bivalent (Fe^{++}), and the ferric, or trivalent (Fe^{+++}) irons are the primary forms of concern in the aquatic environment, although other forms may be in organic and inorganic wastewater streams. Prime pollution sources are industrial wastes, mine drainage waters, and iron-bearing groundwaters. In the presence of dissolved oxygen, iron in water is precipitated as a hydroxide, $Fe(OH)_3$ or occasionally as ferric oxide (Fe_2O_3). Both of these precipitates form as gels or flocs that may be detrimental, when suspended in water, to fishes and other aquatic life. They can settle to form flocculent materials that cover stream bottoms thereby destroying bottom-dwelling invertebrates, plants or incubating fish eggs.

A 96-hour LC_{50} value of 0.32 mg/L (320 μg/L) was obtained for mayflies, stoneflies, and caddisflies (USEPA, 1976). Iron was found to be toxic to carp at concentrations of 0.9 mg/L (900 μg/L) when the pH of the water was 5.5, and both pike and trout died at iron concentrations of 1 to 2 mg/L (1,000 to 2,000 μg/L) (USEPA, 1976). The USEPA (1986) has established a criterion of 1,000 μg/L for fresh water, based upon laboratory tests. Data obtained under laboratory conditions suggest a greater toxicity for iron than that obtained in natural ecosystems, due to variations in alkalinity, pH, hardness, temperature and the presence of ligands which change the valence state and solubility, and therefore the toxicity of the metal.

LEAD

Lead does not seem to be biomagnified in food chains, yet it may accumulate in plants, such as fungi, earthworms, millipedes, terrestrial birds and mammals, freshwater invertebrates and fish. In aquatic environments, lead concentrations are usually highest in benthic organisms and algae, and lowest in upper-trophic-level predators like carnivorous fish. High BCF's were determined in studies using oysters, freshwater algae and marine algae.

Acute (less than two weeks) effects of lead from significant oral exposure are developmental in the mouse and rat, and lethal in the dog and guinea pig. Intermediate effects (two weeks - 1 year) are developmental in the mouse and rat, blood pressure and neuro-behavior effects in the rat, and reproduction effects in the rat. Chronic (year +) exposure to lead in rats causes cancer.

The acute and chronic toxicity of lead to several species of freshwater animals has been shown to decrease as the hardness of water increases. Freshwater algae are affected by concentrations of lead above 500 ug/L.

PCBs

Measurements of acute toxicity of PCBs to freshwater organisms have resulted in acute LC50s (lethal concentrations to 50 percent mortality of test organisms) ranging from 10 to 400 μg/L (parts per billion) for three invertebrate species and from 2 to 7.7 μg/L for four fish species (USEPA, 1980). Fish fry were more sensitive than adults.

Exposure to Aroclor 1242 at 30 μg/L resulted in no significant effects to the amphipod Hyalela azteca, whereas exposures to 100 μg/L resulted in complete mortality (Borgmann et al, 1990, cited in TAMS et al, 1991). Daphnia magna, a common aquatic organism used in establishing toxicity benchmarks, is very sensitive to PCB exposure. Lethal exposures for this species range from 1.2 μg/L for Aroclor 1248 to 2.5 μg/L for Aroclor 1254 (Eisler, 1986, cited in TAMS et al., 1991). Eisler (1986) also reports that chironomids (midges) are sensitive to Aroclor 1254 at concentrations of 0.5 to 1.2 μg/L.

Six chronic tests with three species of freshwater invertebrates gave effective concentration to 50 percent (EC50) values of 0.8 to 4.9 μg/L. Chronic tests with freshwater fish gave EC50 values of 0.2 to 9.0 μg/L for fathead minnows and 1.0 μg/L for brook trout. Little data exists on aquatic plants, but effects on certain species of phytoplankton have been reported at concentrations as low as 0.1 μg/L (USEPA, 1980).

Because of their low water solubility and tendency to accumulate in fatty tissue (lipophilicity), PCBs have a strong tendency to bioaccumulate in aquatic organisms. Reported bioconcentration factors range from 2,700 to 108,000 for freshwater invertebrates (i.e., the PCB levels are from 2,700 to 108,000 times higher in the invertebrates than in the river water) and from 3000 to 274,000 for freshwater fish. Eisler (1986, cited in TAMS et al., 1991) reports a BCF value of 47,000 for Daphnia magna. Recent studies by Jones et al. (1989 cited in TAMS et al, 1991) indicated that caged fathead minnows studied in the Upper Hudson River selectively accumulated tetra- and penta-chlorinated biphenyls, suggesting a congener-specific bioaccumulation preference.

The EPA Ambient Water Quality Criteria for PCBs for the protection of aquatic life are 0.014 μg/L, as a 24-hour average, for freshwater organisms. Available data suggest that acute toxicity would occur only at concentrations above 2 μg/L for freshwater organisms.

Although very few studies address the issues of PCB toxicity associated with tissue residues, a PCB concentration of 0.4 mg/kg (ppm) in whole-body fish tissues has been observed to cause reproductive impairment in rainbow trout (Eisler, 1986 cited in TAMS et al, 1991). Trout are particularly sensitive to PCBs and other species may be more tolerant to PCB exposures (TAMS et al., 1991).

In a study conducted by the U.S. Army Corps of Engineers (1988), adult fathead minnows (Pimephales promelas) were exposed to sediments containing 0.82, 14.0 and 27.0 μg/g (ppm) (low, medium and high, respectively) dry weight PCB (expressed as Aroclor 1254 equivalents). This study concluded that PCB-contaminated sediments had a significant deleterious effect of the species' fecundity and frequency of reproduction. Reproduction was significantly impaired in fish exposed to the medium and high PCB-contaminated sediment treatments compared to fish in the controls and low PCB-contaminated sediment. Mean PCB tissue concentrations in the fish ranged from 13.7 to 47.2 μg/g (ppm) wet weight, expressed as Aroclor 1254 equivalents (USACOE, 1988).

TOLUENE

No information was found indicating that toluene would bioaccumulate. Moreover, Metcalf and Sanborn (1975, cited in Versar, Inc., 1979) maintain that, in general, compounds with solubilities of 50 mg/L or more have little potential for aquatic bioaccumulation. Some species of soil bacteria have been demonstrated to be capable of using toluene as a sole carbon source (Versar, Inc., 1979). In mammals, toluene is detoxified by oxidation to benzoic acid, which then reacts with glycine to form hippuric acid which is rapidly excreted in the urine.

The available data for toluene indicate that acute toxicity to freshwater aquatic life occurs at concentrations as low as 17,500 μg/L and would occur at lower concentrations among species that are more sensitive than those tested. No data are available concerning the chronic toxicity of toluene to sensitive freshwater aquatic life (USEPA, 1986).

ZINC

Microcosm studies generally indicate that zinc is not biomagnified. Although biota seem to be a minor sink compared to sediments, this compound is actively bioaccumulated in aquatic systems. Zinc has been found to accumulate in freshwater animal tissues from 51 to 1,130 times the concentration present in the water. A 1981 study reported zinc BCF values of 1000 for both aquatic plants and fish. Steady-state bioconcentration factors for twelve saltwater species range from 3.692 to 23,820.

Acute toxicity values are available for 43 species of freshwater animals and data for eight species indicate that acute toxicity decreases as hardness increases. Additional data indicate that toxicity increases as temperature increases. Chronic values for two invertebrates ranges from 46.73 μg/L for Daphnia magna to >5,243 μg/L for the caddisfly, Clistoronia magnificia. Chronic values for seven fish species ranged from 36.41 μg/L for the flagfish, Jordanella floridae, to 854.7 μg/L for the brook trout, Salvelinus fontinalis (USEPA, 1986).

The sensitivity range of freshwater plants to zinc is greater than that for animals. Growth of the alga, Selenastrum capricornutum, was inhibited by 30 μg/L. On the other hand, with several other species of green algae, 4-day EC50s exceeded 200,000 μg/L. Zinc was found to bioaccumulate in freshwater animal tissues from 51 to 1,130 times the concentration present in the water (USEPA, 1986).