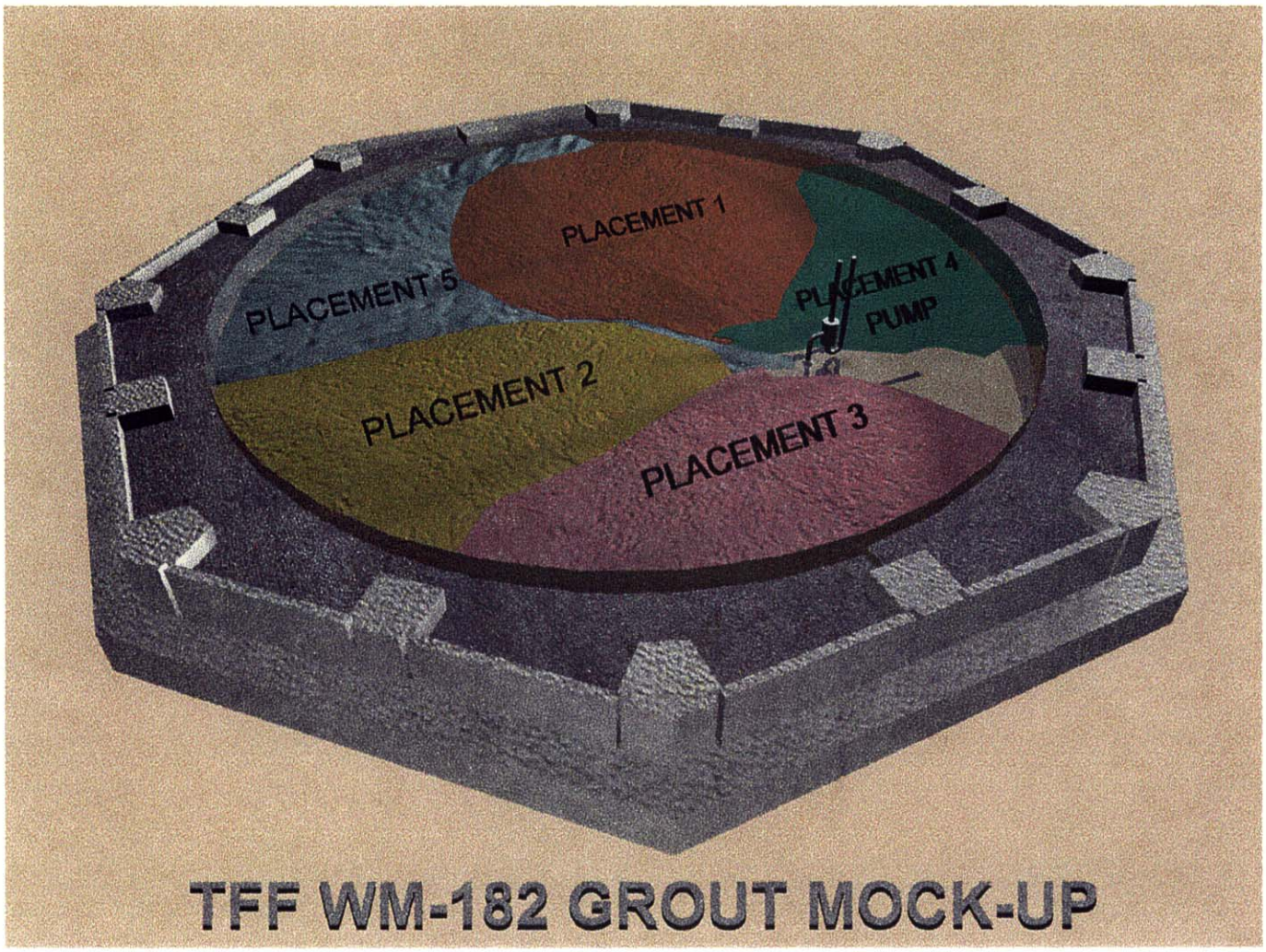
IDAHO NUCLEAR TECHNOLOGY AND ENGINEERING CENTER

TANK FARM FACILITY (TFF) CLOSURE



IDAHO NATIONAL ENGINEERING AND ENVIRONMENTAL LABORATORY

Prepared for the
U.S. Department of Energy
DOE Idaho Operations Office

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INEEL/EXT-99-01067

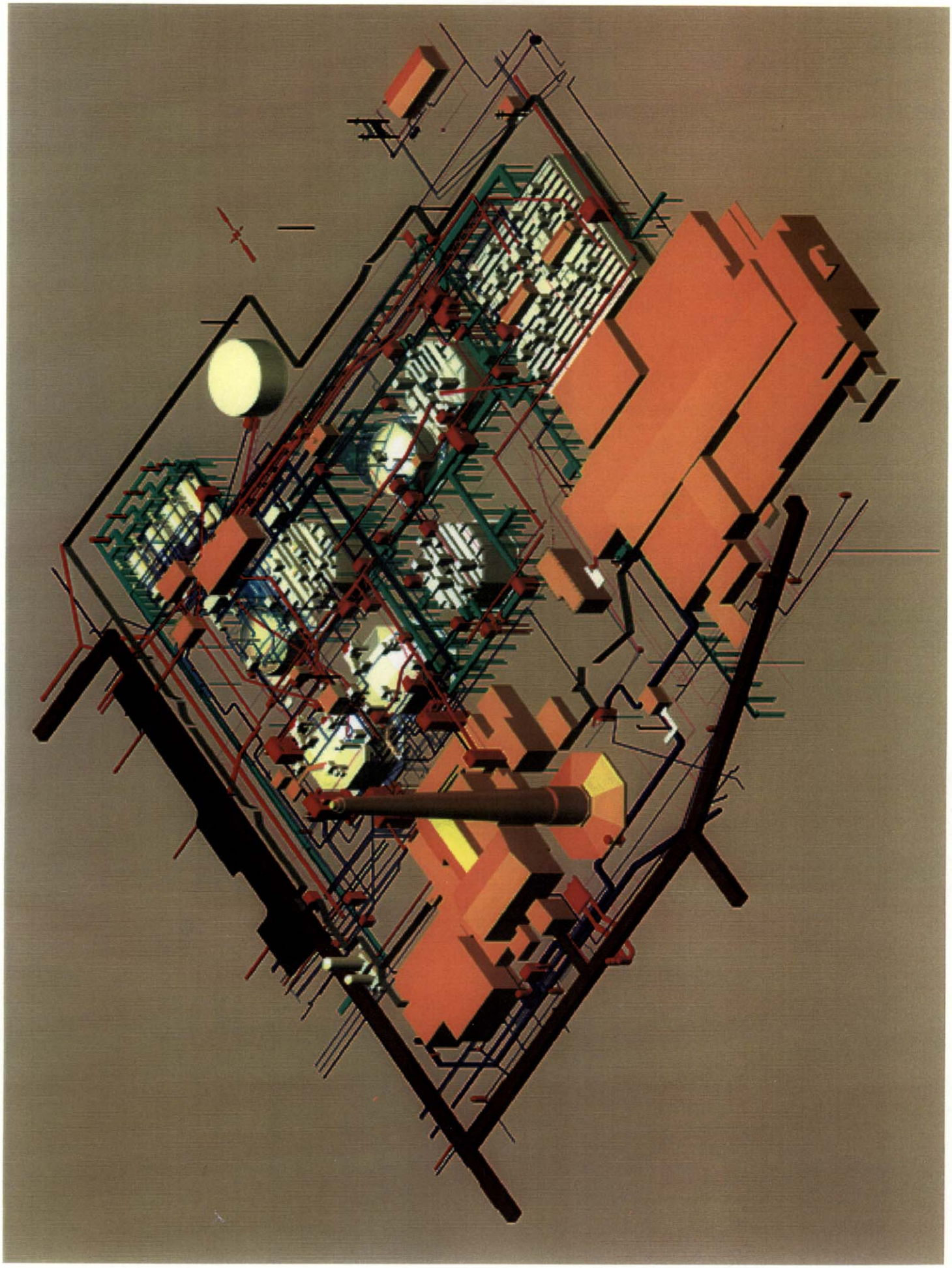
PROJECT SUMMARY

The Idaho Nuclear Technology and Engineering Center (INTEC) Tank Farm Facility (TFF) tank system has been used historically for storage of high level waste (HLW) from spent nuclear fuel (SNF) reprocessing and other radioactive wastes derived from INTEC mission operations. The TFF tank system consists of 11 nominal 300,000-gallon below ground stainless steel tanks contained within concrete vaults of various construction; 4 inactive 30,000-gallon below grade stainless steel tanks; and valve boxes, encasements, and various process and instrumentation piping associated with the tanks. The TFF will be closed in phases over the next fifteen years.

Closure of the TFF will be initiated upon approval of the Closure Plan by the State of Idaho Division of Environmental Quality (IDEQ) and the U.S. Department of Energy (DOE). The TFF will be closed to Hazardous Waste Management Act (HWMA)/Resource Conservation and Recovery Act (RCRA) closure standards and DOE Order 435.1 Radioactive Waste Management requirements. Closure will be integrated with Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) management of contaminated soils surrounding TFF components.

Tanks will be closed in phases with each phase consisting of a group of 2 or more tanks. The first phase of TFF closure will include tanks WM-182 and WM-183 and will be used as a proof-of-process demonstration of the waste removal, decontamination, and sampling techniques. Additionally, the first-phase demonstration of TFF closure will allow for determination of the achievable reduction in non-HWMA/RCRA contaminant concentrations (for evaluation of residual CERCLA risk and performance assessment). Waste liquids removed or generated during tank closure activities for a given phase will be transferred to TFF tanks continuing to operate. These fluids will be reduced in volume with existing INTEC treatment systems pending final treatment and disposition with methods being identified by the High Level Waste Environmental Impact Statement.

Closure to performance-based standards by removal or decontamination of all hazardous wastes will be attempted for each tank and associated equipment. Sampling and analysis will be performed to demonstrate decontamination effectiveness and allow for assessment to performance-based closure standards. If closure to performance-based standards is not achievable, then the contingent closure under HWMA/RCRA landfill standards will be implemented. The entire TFF will be closed and turned over to Environmental Restoration for completion of cap installation and groundwater monitoring.



TFF CLOSURE SEQUENCE

The INTEC Tank Farm Facility (TFF) Closure sequence consists of multiple steps to be accomplished through the existing tank riser access points. Currently, the tank risers contain steam and process waste lines associated with the steam jets, corrosion coupons, and liquid-level indicators. As necessary, this equipment will be removed from the risers to allow adequate space for closure equipment and activities. The basic tank closure sequence is as follows:

- Empty the tank to the residual heel using the existing jets. Liquid and solids removed will be transferred to portions of the TFF tank system still in operation.
- Video and sample the heel.
- Flush tank with 5,000 gallons of water. After each flush using the existing steam jets the tank is emptied, leaving a diluted heel. This is repeated four times.
- Wash the tank interior with demineralized water utilizing a tank cleaning wash head. Approximately 4,000 gallons of water will be used for washing. Washing is expected to agitate and mix the heel.
- Video and sample the heel. Evaluate decontamination effectiveness.
- Displace the residual heel with multiple placements of grout.
- Grout piping, vault, and remaining tank volume.

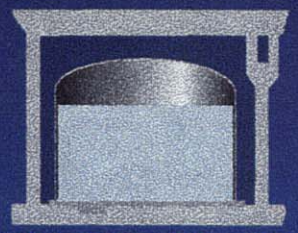
MOCK-UP TESTING

A full-scale mock-up of WM-182 was constructed to test heel management and closure techniques utilizing a sequence of grout placements. The mock-up included the tank bottom, vault, cooling coils, pump location, and riser locations. A simulated heel was placed in the tank consisting of 1 in. of crushed cinders and 3 in. of water. The cinders placed into the tank were red to provide visual distinction of solids movement in grout. From prior tank inspection and sampling efforts, it is anticipated that the actual solids will be more flocculent and less that ½ in. deep.

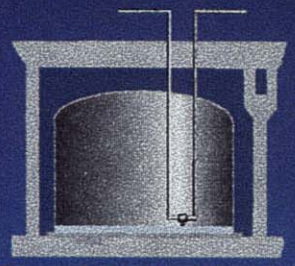
Grout mix designs were initially developed in small-scale tests and subsequently applied to the full-scale mock-up. The basic mix design for tank and vault grout consisted of Type I & II cement, fly ash, sand, and water. High and medium range water reducing admixtures are included in the design to enhance the workability, or flowability, of the grout and minimize water content. Excessive water content increases shrinkage cracking, bleed water, and permeability of the cured grout

In developing heel management techniques, the primary concerns were the characteristics of grout flow over cooling coils and associated supports, the displacement and mixing of solids with the grout, and the ability to eliminate free liquids.

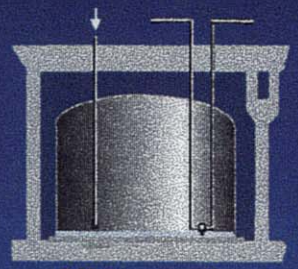
Tank Closure Sequence



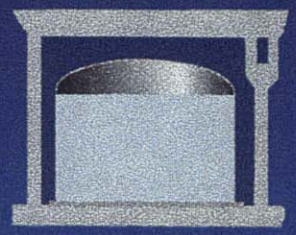
Storage of liquid waste



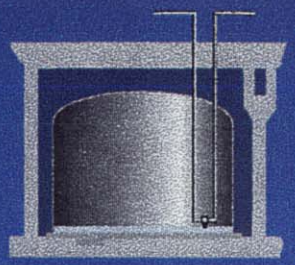
Empty to heel with existing jets



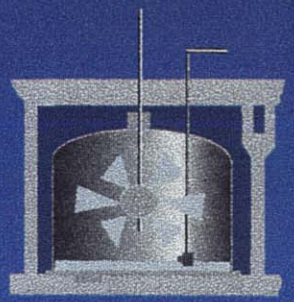
Video and sample heel



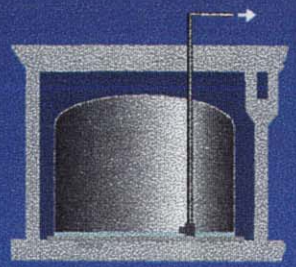
Flush tank and piping



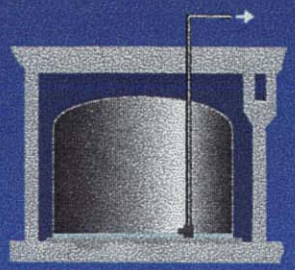
Empty to heel with existing jets



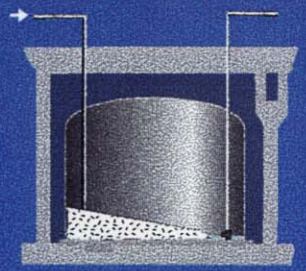
Wash tank and pump



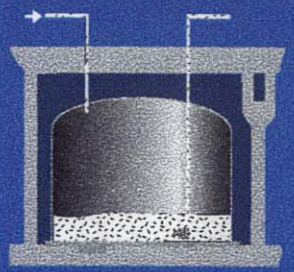
Video and sample heel



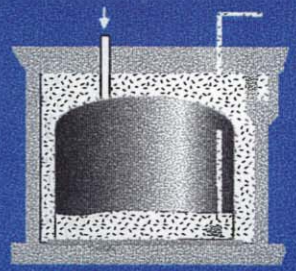
Tank evaluation



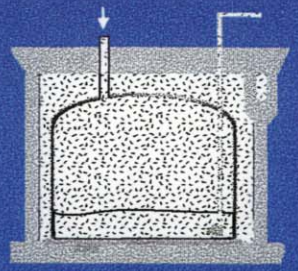
Displace heel with grout



Grout piping



Fill tank vault with grout



Fill tank and vault with grout

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DECONTAMINATION EFFECTIVENESS

Appendix A contains tables of liquid composition for the first two tanks, WM-182 and WM-183, for the closure sequence. After four flushes and an interior wash, the mass/curies of hazardous constituents in the heel will be significantly reduced. By displacing the heel with a series of grout placements the final heel is reduced to less than 10% of the residual heel volume (0.15% of the original tank volume). The final heel indicated for each tank (400 gallons) conservatively assumes that the existing jet suction legs are not lowered. However, it is anticipated that the jets will be lowered during the closure process to maximize heel removal.

GROUT

A brief summary of grout mix designs and properties of tank, vault and pipe grout is given in Appendix B. There were three placements for the vault and then an additional five for the tank. Grout slump measurements were taken on each truck and concrete test cylinders were collected for each placement. Strength data obtained from test cylinders is summarized in Appendix B on the respective graphs.

GROUT PLACEMENT SEQUENCE

To maximize heel displacement to the discharge pump, grout was placed in a sequence of five positions utilizing two riser locations. The conceptual design for the grout placement arm allows grout to be placed anywhere within a 10 ft. radius of the riser centerline. The first figure in Appendix C, shows the reach of the grout placement arm within the tank.

Appendix C shows, in successive steps, all five placements. Each placement in Appendix C begins with a computer model of the placement followed by photos of the actual mock-up.

- The first placement consisted of approximately 40 cubic yards of grout with an average approximate slump of 9 in. The grout effectively encapsulated all coils and supports leaving no voids. The leading edge of the grout flow displaced liquids and pushed solids. The displaced heel was pumped into a settling pond located next to the mock-up.

- The slump of the second placement had a higher value, approximately 10 ¼ in. The initial perception of higher slump grout was that it displaced the solids more effectively, but this was not supported by later core samples. The second placement was continued until the leading edge of the grout was within a foot of the suction pump; to maximize the heel displacement. This resulted in the second placement overlapping the first placement thereby trapping a small pool of heel away from the pump. The pool was later displaced to the pump with placement five

- Placement three utilized the same riser as the second placement, except the grout discharge arm was placed along the wall towards the suction pump. This placement had a slump of approximately 10 ¼ in. similar to that of placement two. The objective of this placement and subsequent placement four, was to displace the heel in the area between the pump and the tank wall. The heel solids mixed with the grout as the heel was displaced to the suction pump. As the leading edge moved to within one foot of the suction pump placement three was terminated.

- Placement four utilized the same riser as placement one. The grout discharge arm was positioned along the wall towards the suction pump. The lower slump of placement one created a trough along the wall. This "wall trough" directed the grout along the wall for more effective displacement of heel and solids towards the pump.

- The purpose of placement five was to displace the residual heel trapped by placements one and two. The grout discharge arm utilized the same riser as placement one and was placed along the wall towards the trapped pool. Again, the trough along the wall, created from the lower slump of placement one, effectively channeled placement five into the area of concern. The heel trapped in the pool was displaced over the dam created by placements one and two, but some of the solids were trapped in the area.

SUMMARY AND PRIMARY LESSONS LEARNED

The Mock-Up was instrumental in understanding the characteristics of grout flow over cooling coils and associated supports, the displacement and mixing of solids with the grout, and the ability to eliminate free liquids. Although the sequence applied to the mock-up successfully displaced the majority of the heel, the application of several key lessons learned will substantially improve closure performance.

Placements one and two in the pour sequence should be discharged 4 ft. from the inner tank wall with a slump of approximately 9 in. The object is to establish "wall troughs" along the tank wall in both directions. Utilization of these wall troughs results in more effective control of residual heel displacement to the suction pump.

In performance of the mock-up, the second placement overlapped the first placement creating a dam and trapping a pool of heel away from the pump. The fifth placement effectively displaced the pool to the pump, but solids were trapped in the low point. The second placement should be terminated at a point where an uninterrupted channel of approximately 24 in. exists between placement one and two. This channel will allow the fifth placement to more effectively displace liquids and solids to the pump suction point.

The above changes constitute an improved grout placement sequence which is illustrated in Appendix E with computer generated views.

During the performance of the Mock-up, higher slump grout had the appearance of moving solids more effectively; this apparently due to the thinner more dynamic leading edge of the grout. However, the results from core samples and subsequent demolition of the mock-up did not indicate that solids movement and mixing is directly related to slump. Additional testing with a less conservative solids surrogate may provide more conclusive information.

Appendix D contains photos that show the cured grout pad with the tank wall removed and photos of cooling coils and supports exposed during demolition.

Appendix A

Tank WM-182: Impact of Closure Activities on Liquid Composition

Closure Step:	"Full Tank"	Current Condition	Drain Tank	1st Flush	2nd Flush	3rd Flush	4th Flush	Spray Ball Wash	Final Drain (after grout addition)
Starting Tank Volume, gal	300,000	10,300	10,300	3,500	3,500	3,500	3,500	3,500	3,500
Ending Tank Volume, gal:	300,000	10,300	3,500	3,500	3,500	3,500	3,500	3,500	400
Volume of water added, gal	N/A	N/A	-	5,000	5,000	5,000	5,000	4,065	-
Volume of water removed, gal	N/A	N/A	6,800	5,000	5,000	5,000	5,000	4,065	3,100
Selected Chemical Species:	Mass in Tank Liquid at End of Step, lbs								
Al^{+3}	41,007	1,367	464	191	79	32	13	4	0.5
Cr^{+6}	804	27	9	4	2	1	0.3	0.1	0.0
NO_3^-	629,298	20,977	7,128	2,462	1,014	417	172	54	6
Selected Radionuclides:	Activity in Tank Liquid at End of Step, Ci								
Cs-137	146,196	4,873	1,656	682	281	116	48	15	2
Sr-90	118,126	3,938	1,338	551	227	93	38	12	1
Pu-241	399	13	5	2	1	0.3	0.1	0.0	0.0

Notes:

1. Data on Current Condition are from the High Level Waste Program and were current as of 2/28/99
2. "Full Tank" composition is estimated from Current Condition Data
3. Use of spray ball assumes complete mixing of wash water with tank residual water (to be verified)

Flushing and Decontamination, Tank WM-182

Initial volume of liquid:	10,300	gal			
"Heel" volume:	3,500	gal			
Liquid added at each flush:	5,000	gal			
Final volume of liquid	400	gal			
Volume of liquid after jetting:	3,500	gal			
Volume of rinse water:	4,061	gal	Total rinse time	81	minutes

	Initial Conditions		After Drain		After 1st Flush		After 2nd Flush		After 3rd Flush		After 4th Flush		After Decon. Rinse		After Final Pumpout	
Parameter	Initial Concentration, M	Initial Total, g-moles	Concentration, M	Total, g-moles	Concentration, M	Total, g-moles	Concentration, M	Total, g-moles	Concentration, M	Total, g-moles	Concentration, M	Total, g-moles	Concentration, M	Total, g-moles	Concentration, M	Total, g-moles
Sp. Gr.*	1.214															
H+	1.11	43,274	1.110	14,705	0.457	6,055	0.188	2,493	0.077	1,027	0.0319	423	0.0100	132	0.0100	15.1
NO3-	3.94	153,603	3.940	52,195	1.622	21,492	0.668	8,850	0.275	3,644	0.1133	1,500	0.0355	470	0.0355	53.7
Al	0.59	23,001	0.590	7,816	0.243	3,218	0.100	1,325	0.041	546	0.0170	225	0.0053	70	0.0053	8.0
B	0.009	351	0.009	119	0.004	49	0.002	20	0.001	8	0.0003	3	0.0001	1	0.0001	0.1
Cd	0.001	39	0.001	13	0.000	5	0.000	2	0.000	1	0.0000	0	0.0000	0	0.0000	0.0
Ca	0.027	1,053	0.027	358	0.011	147	0.005	61	0.002	25	0.0008	10	0.0002	3	0.0002	0.4
Cl-	0.019	741	0.019	252	0.008	104	0.003	43	0.001	18	0.0005	7	0.0002	2	0.0002	0.3
Cr	0.006	234	0.006	79	0.002	33	0.001	13	0.000	6	0.0002	2	0.0001	1	0.0001	0.1
F	0.024	936	0.024	318	0.010	131	0.004	54	0.002	22	0.0007	9	0.0002	3	0.0002	0.3
Fe	0.025	975	0.025	331	0.010	136	0.004	56	0.002	23	0.0007	10	0.0002	3	0.0002	0.3
Pb	0.001	39	0.001	13	0.000	5	0.000	2	0.000	1	0.0000	0	0.0000	0	0.0000	0.0
Mn	0.003	117	0.003	40	0.001	16	0.001	7	0.000	3	0.0001	1	0.0000	0	0.0000	0.0
Hg	0.001	39	0.001	13	0.000	5	0.000	2	0.000	1	0.0000	0	0.0000	0	0.0000	0.0
Mo	0	-	-	-	-	-	-	-	-	-	-	-	0.0000	-	0.0000	-
Ni	0.002	78	0.002	26	0.001	11	0.000	4	0.000	2	0.0001	1	0.0000	0	0.0000	0.0
PO4-3	0	-	-	-	-	-	-	-	-	-	-	-	0.0000	-	0.0000	-
K	0.11	4,288	0.110	1,457	0.045	600	0.019	247	0.008	102	0.0032	42	0.0010	13	0.0010	1.5
Na	1.16	45,223	1.160	15,367	0.478	6,328	0.197	2,605	0.081	1,073	0.0333	442	0.0105	138	0.0105	15.8
SO4-2	0.035	1,364	0.035	464	0.014	191	0.006	79	0.002	32	0.0010	13	0.0003	4	0.0003	0.5
Zr	0.001	39	0.001	13	0.000	5	0.000	2	0.000	1	0.0000	0	0.0000	0	0.0000	0.0
UDS			-	-	-	-	-	-	-	-	-	-	0.0000	-	0.0000	-
	Ci/liter		-	-	-	-	-	-	-	-	-	-	0.0000	-	0.0000	-
Pu-240	1.39E-05	1	0.000	0	0.000	0	0.000	0	0.000	0	0.0000	0	0.0000	0	0.0000	0.0
Am-241	4.84E-04	19	0.000	6	0.000	3	0.000	1	0.000	0	0.0000	0	0.0000	0	0.0000	0.0
Ce-144	9.26E-07	0	0.000	0	0.000	0	0.000	0	0.000	0	0.0000	0	0.0000	0	0.0000	0.0
Co-60	4.64E-05	2	0.000	1	0.000	0	0.000	0	0.000	0	0.0000	0	0.0000	0	0.0000	0.0
Cs-134	7.28E-04	28	0.001	10	0.000	4	0.000	2	0.000	1	0.0000	0	0.0000	0	0.0000	0.0
Cs-137	1.25E-01	4,873	0.125	1,656	0.051	682	0.021	281	0.009	116	0.0036	48	0.0011	15	0.0011	1.7
Eu-154	7.04E-04	27	0.001	9	0.000	4	0.000	2	0.000	1	0.0000	0	0.0000	0	0.0000	0.0
Eu-155	2.19E-04			-												
H-3	2.04E-04	8	0.000	3	0.000	1	0.000	0	0.000	0	0.0000	0	0.0000	0	0.0000	0.0
I-129	1.20E-05	0	0.000	0	0.000	0	0.000	0	0.000	0	0.0000	0	0.0000	0	0.0000	0.0
Ni-63	1.23E-05	0	0.000	0	0.000	0	0.000	0	0.000	0	0.0000	0	0.0000	0	0.0000	0.0
Np-237	6.05E-07	0	0.000	0	0.000	0	0.000	0	0.000	0	0.0000	0	0.0000	0	0.0000	0.0
Pu-238	5.81E-04	23	0.001	8	0.000	3	0.000	1	0.000	1	0.0000	0	0.0000	0	0.0000	0.0
Pu-239	1.12E-04	4	0.000	1	0.000	1	0.000	0	0.000	0	0.0000	0	0.0000	0	0.0000	0.0
Pu-241	3.41E-04	13	0.000	5	0.000	2	0.000	1	0.000	0	0.0000	0	0.0000	0	0.0000	0.0
Pu-242	2.07E-08	0	0.000	0	0.000	0	0.000	0	0.000	0	0.0000	0	0.0000	0	0.0000	0.0
Ru-106	2.93E-06	0	0.000	0	0.000	0	0.000	0	0.000	0	0.0000	0	0.0000	0	0.0000	0.0
Sb-125		-	-	-	-	-	-	-	-	-	-	-	0.0000	-	0.0000	-
Sr-90	1.01E-01	3,938	0.101	1,338	0.042	551	0.017	227	0.007	93	0.0029	38	0.0009	12	0.0009	1.4
Tc-99		-	-	-	-	-	-	-	-	-	-	-	0.0000	-	0.0000	-
U-234	6.11E-07	0	0.000	0	0.000	0	0.000	0	0.000	0	0.0000	0	0.0000	0	0.0000	0.0
U-235	1.92E-08	0	0.000	0	0.000	0	0.000	0	0.000	0	0.0000	0	0.0000	0	0.0000	0.0
U-236	3.16E-08	0	0.000	0	0.000	0	0.000	0	0.000	0	0.0000	0	0.0000	0	0.0000	0.0
U-238	1.14E-08	0	0.000	0	0.000	0	0.000	0	0.000	0	0.0000	0	0.0000	0	0.0000	0.0

Appendix B

INTRODUCTION AND SUMMARY OF GROUT MIX DESIGN

Two types of grout mixtures are proposed for the closure of the INTEC Tank Farm. One type is a mixture of cement, fly ash, water and water reducing admixtures. For the purposes of this project it is called the pipe grout. It will be used to fill piping, small vessels or other items that require a very fluid grout.

The basic mix design for a cubic yard of the pipe grout is as follows:

Cement	680 lbs	Type I & II Cement
Pozzolan Class F	1,600 lbs	Fly Ash
Water	Up to 800 lbs	(96 gallons)

The pipe grout will readily flow through pipes as small as 1/2 inch in nominal diameter. It has been pumped through holes as small as 1/8 inch in diameter. However, if the pipe grout is pumped for an extended period or pumping stops and then restarted the small diameter holes or pipes tend to plug. The slump of this grout as tested by ASTM C143 is in excess of 11.5 inches. This test procedure is not accurate for grouts that are this fluid.

The other type of grout is a mixture of cement, fly ash, sand, water and water reducing admixtures. For this project this type of grout mixture is called either tank grout or vault grout. The main differences between the tank grout and the vault grout are the required strength and the slump or flowability. The vault grout is required to flow around at least half the circumference of the existing 50 foot diameter tanks. The minimum slump for the vault grout using ASTM C143 is 11 inches. The tank grout slump using ASTM C143 will vary from about 9 inches and 11 inches depending on the requirements of a placement.

The vault grout is required to have a compressive strength of at least 3,000 psi for seismic and structural integrity with the tank empty. It also must flow readily around the circumference of the liquid waste storage tank. The tank grout will be used to minimize the residual heel within the tanks. It also provides the weight necessary to resist buoyant forces from the initial vault grout placement.

The basic mix design for tank and vault grout is as follows:

Cement	320 lbs	Type I & II Cement
Pozzolan Class F	640 lbs	Fly Ash
Fine Aggregate	2,200 lbs	Sand
Water	Up to 433 lbs	(52 gallons)

High and medium range water reducing admixtures are also included in the mixes to enhance the workability of the grout mixtures without increasing the water content. Additional water reduces strength and density, increases shrinkage and shrinkage cracking,

increases bleed water and increases permeability of the cured grout. Therefore the water content of the grout mixtures needs to be minimized.

The materials used in the grout mixtures were used because they are readily available in the intermountain west. Most ready-mix suppliers in the region near the INEEL are also set up to supply concrete or grout mixtures similar to the proposed grout mixtures. Other materials, such as finely ground blast furnace slag, were considered for the grout mixtures. However, they were not used since they are not readily available in the region near the INEEL.

The testing to date indicates that all mixtures are flowable and will achieve 28 day compressive strengths of at least 2,000 psi. Because of the high fly ash content of the mixtures, they continue to gain significant strength over a longer time period than typical construction grouts. 56 day compressive strengths are approximately 1,000 psi stronger than the 28 day compressive strengths.

Data on flowability, bleed water, shrinkage and temperature as well as strength are available for the proposed grout mixtures.

CONCLUSIONS

All of the test batches appeared to perform in a satisfactory manner regarding bleed water amounts and shrinkage.

Flowability was acceptable when concrete slumps were within the ranges previously mentioned.

Compressive strengths exceeded requirements, in some cases by substantial amounts. See the attached graphs.

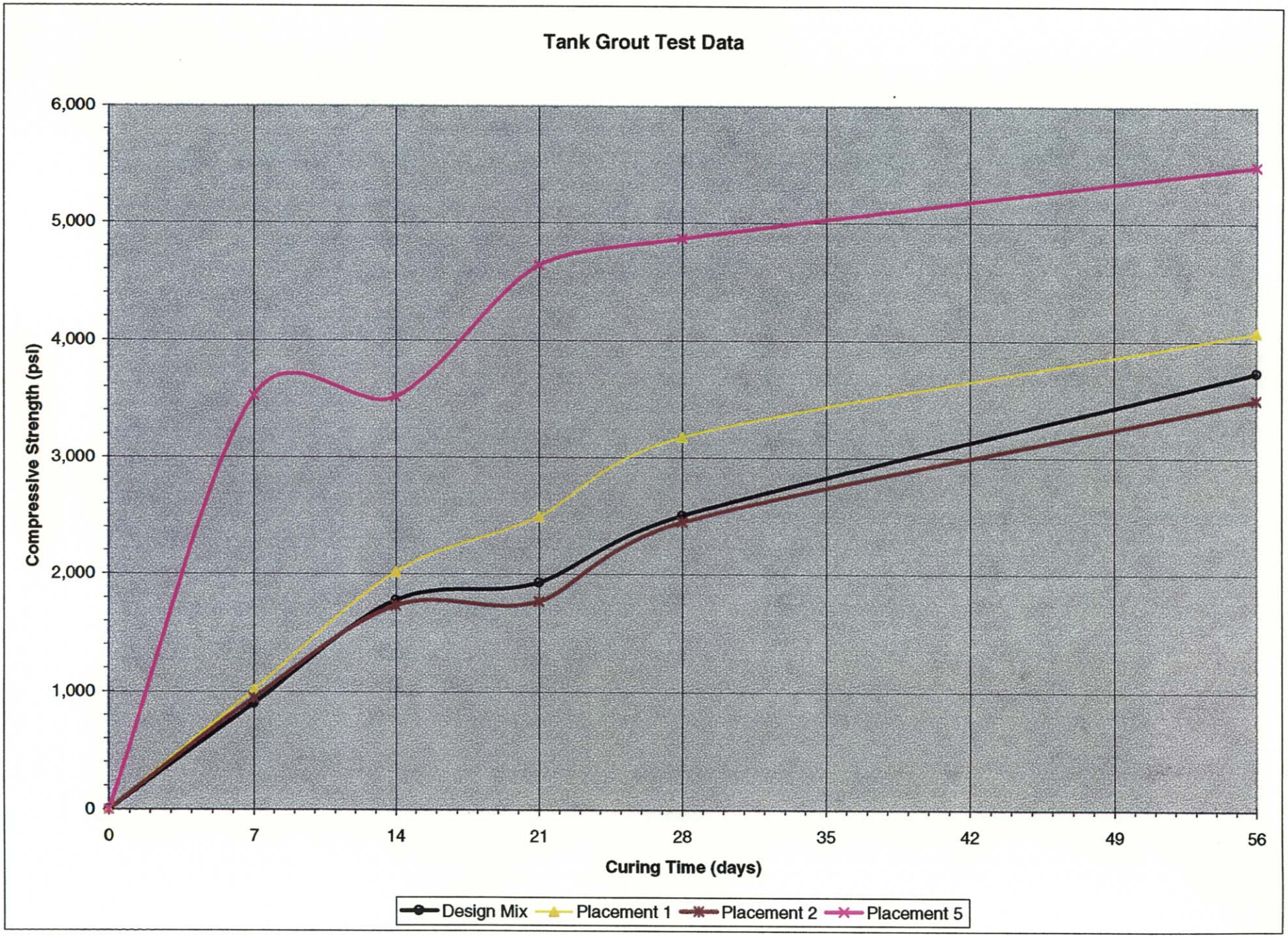
RECOMMENDATIONS

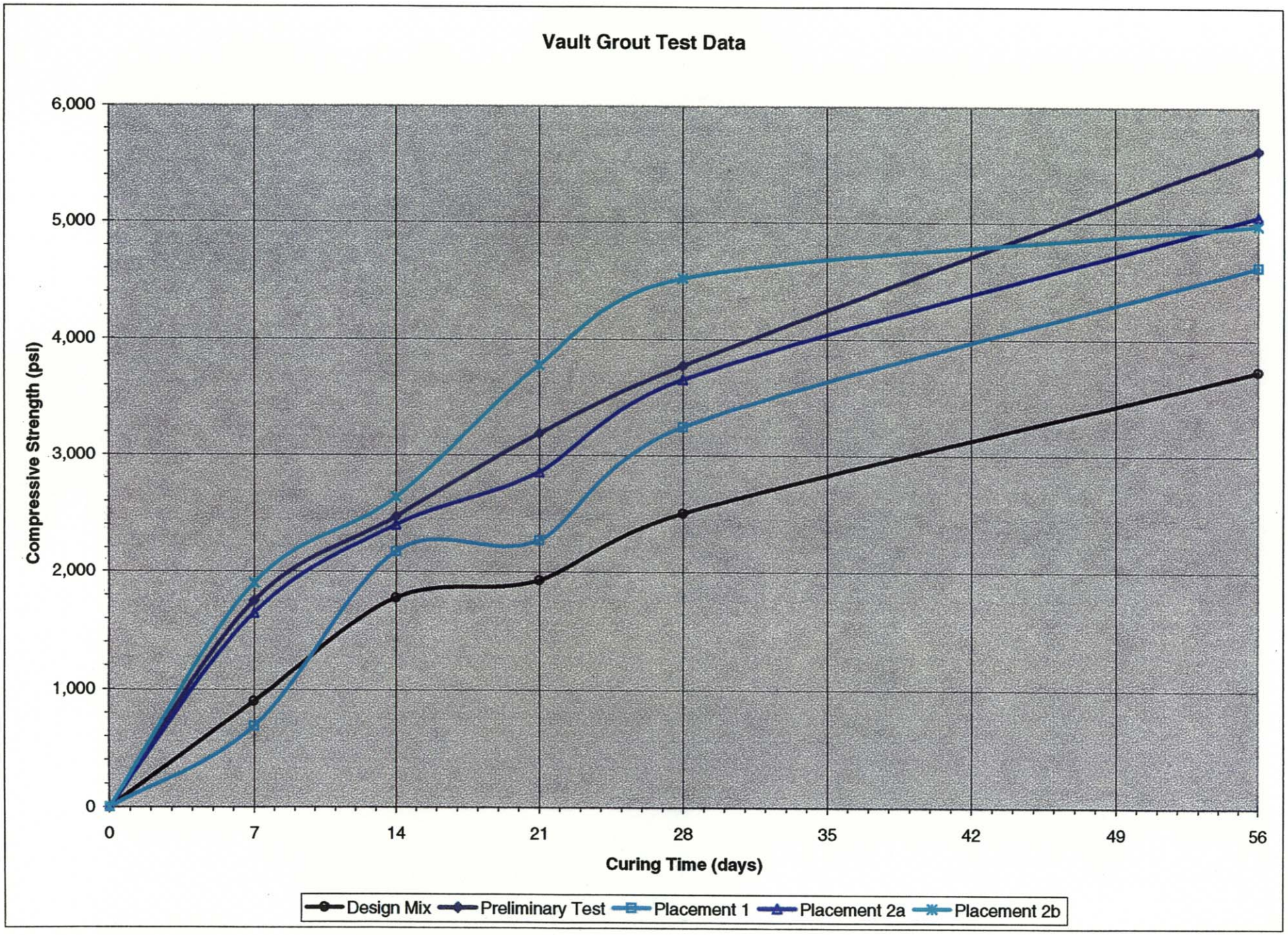
Future studies are recommended for the grout mixtures, particularly the tank grout. These studies may include additional strength tests, flow tests, sensitivity of the grout mixture to different environmental conditions, tests to determine the pumping characteristics for the grout, tests that indicate the long term durability of the cured grout, and other tests related to the proposed grout placement equipment or systems. The strength tests may include grout cylinders cured under conditions more closely matching actual conditions inside the tanks.

A more sensitive test for flowability of the grout mixture is necessary. ASTM C143 does not provide enough sensitivity since the required slumps for the grout are at least 9 inches and for most proposed placements are in excess of 11 inches.

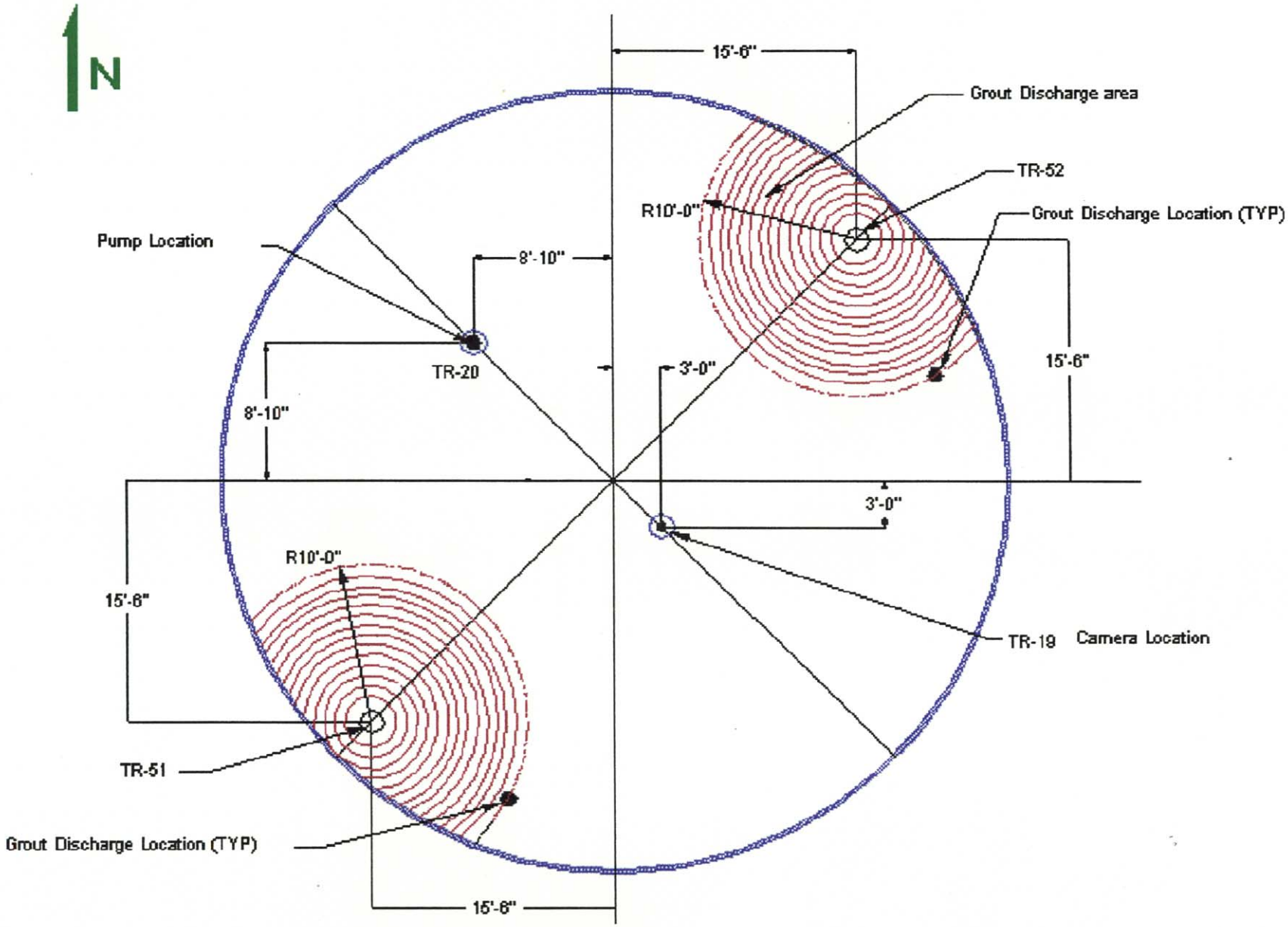
SUMMARY OF DATA

The following graphs summarize the strength data obtained from the recent tests.

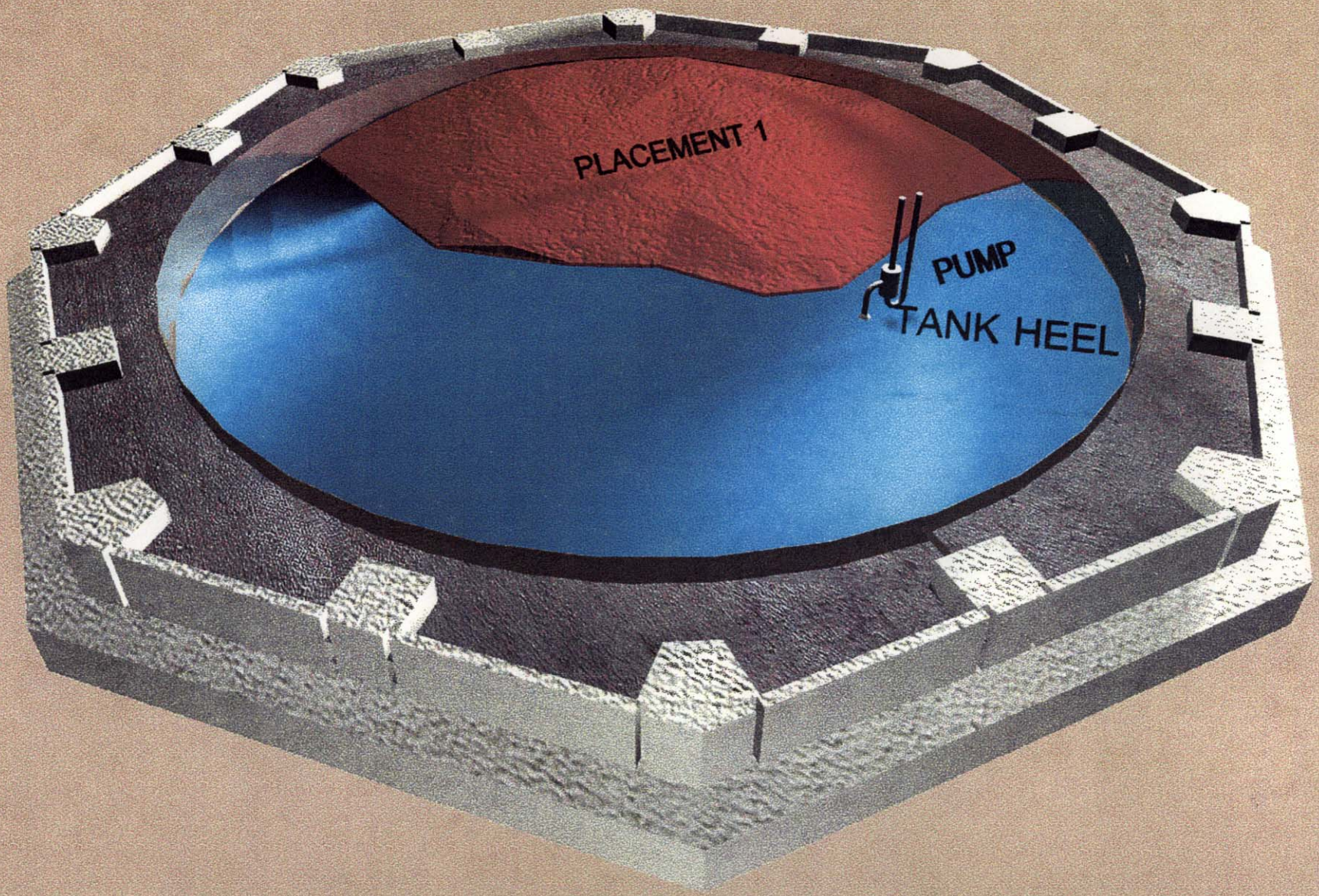

Tank Grout Test Data
Compressive Strength (psi)
6,000
5,000
4,000
3,000
2,000
1,000
0
0
7
14
21
28
35
42
49
56
Curing Time (days)
Design Mix
Placement 1
Placement 2
Placement 5


Vault Grout Test Data
Compressive Strength (psi)
6,000
5,000
4,000
3,000
2,000
1,000
0
0
7
14
21
28
35
42
49
56
Curing Time (days)
Design Mix
Preliminary Test
Placement 1
Placement 2a
Placement 2b

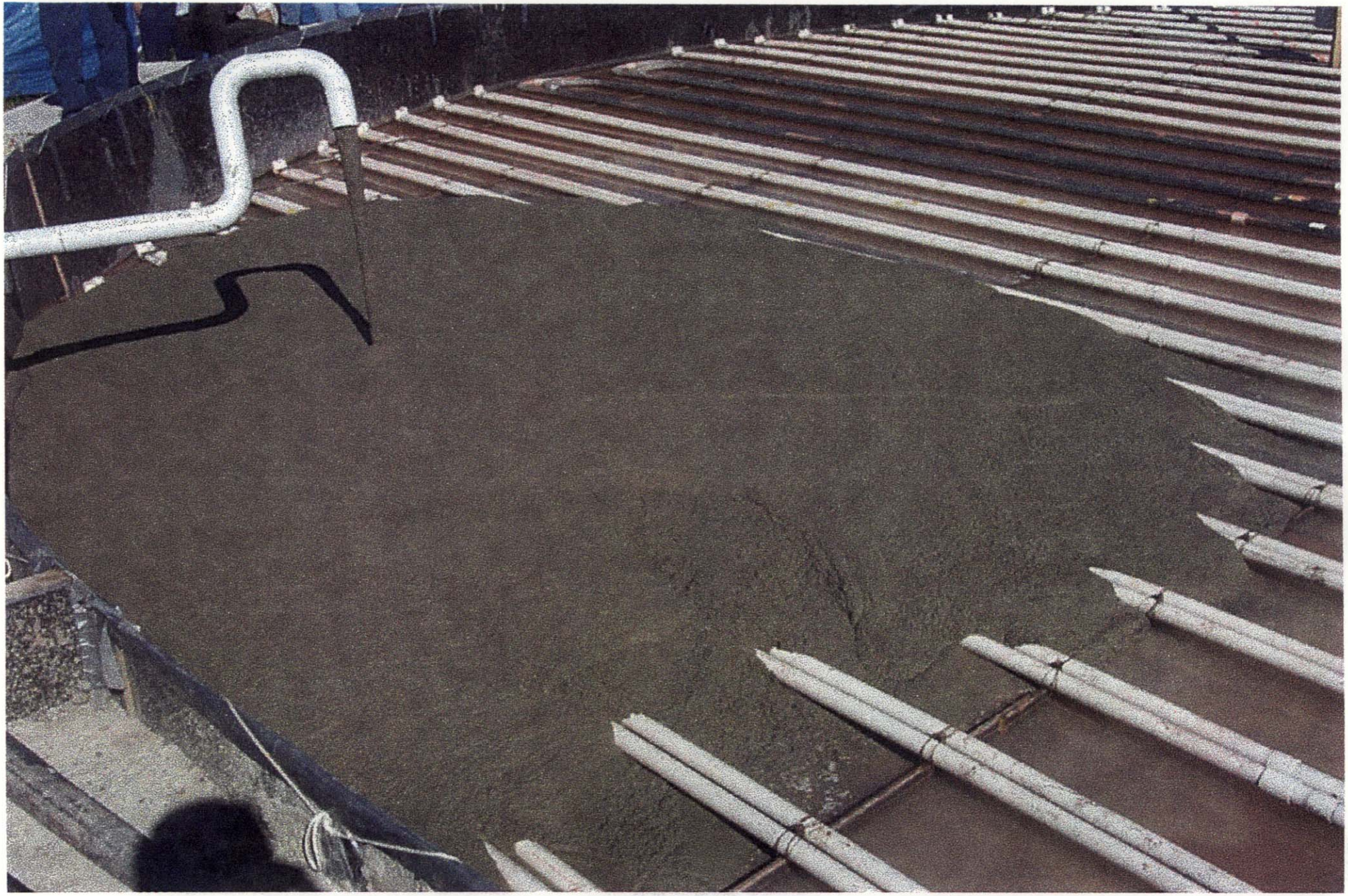
Appendix C

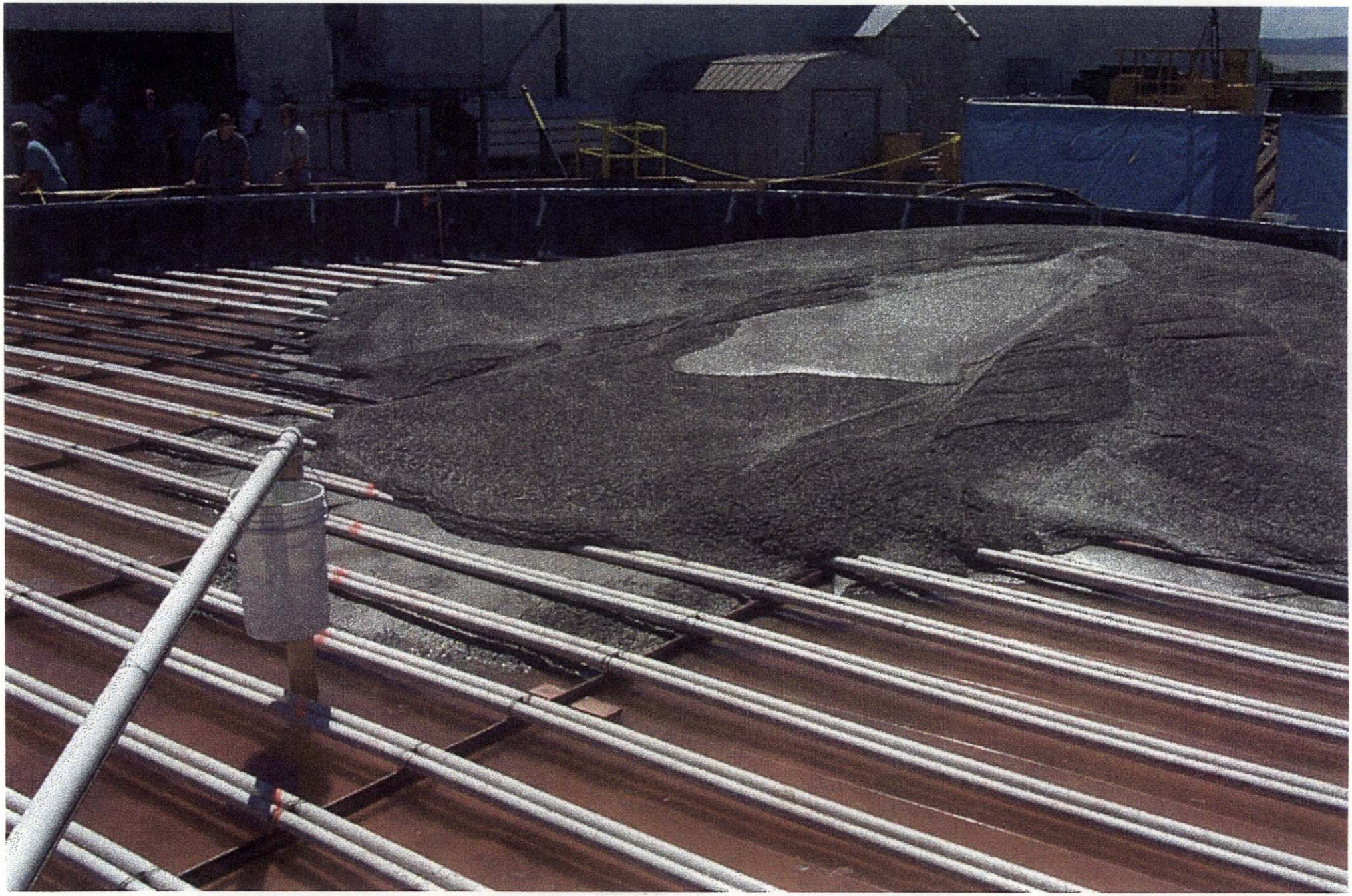

N
15'-6"
Grout Discharge area
TR-52
R10'-0"
Grout Discharge Location (TYP)
Pump Location
8'-10"
TR-20
3'-0"
15'-6"
8'-10"
3'-0"
R10'-0"
15'-6"
TR-19
Camera Location
TR-51
Grout Discharge Location (TYP)
15'-6"

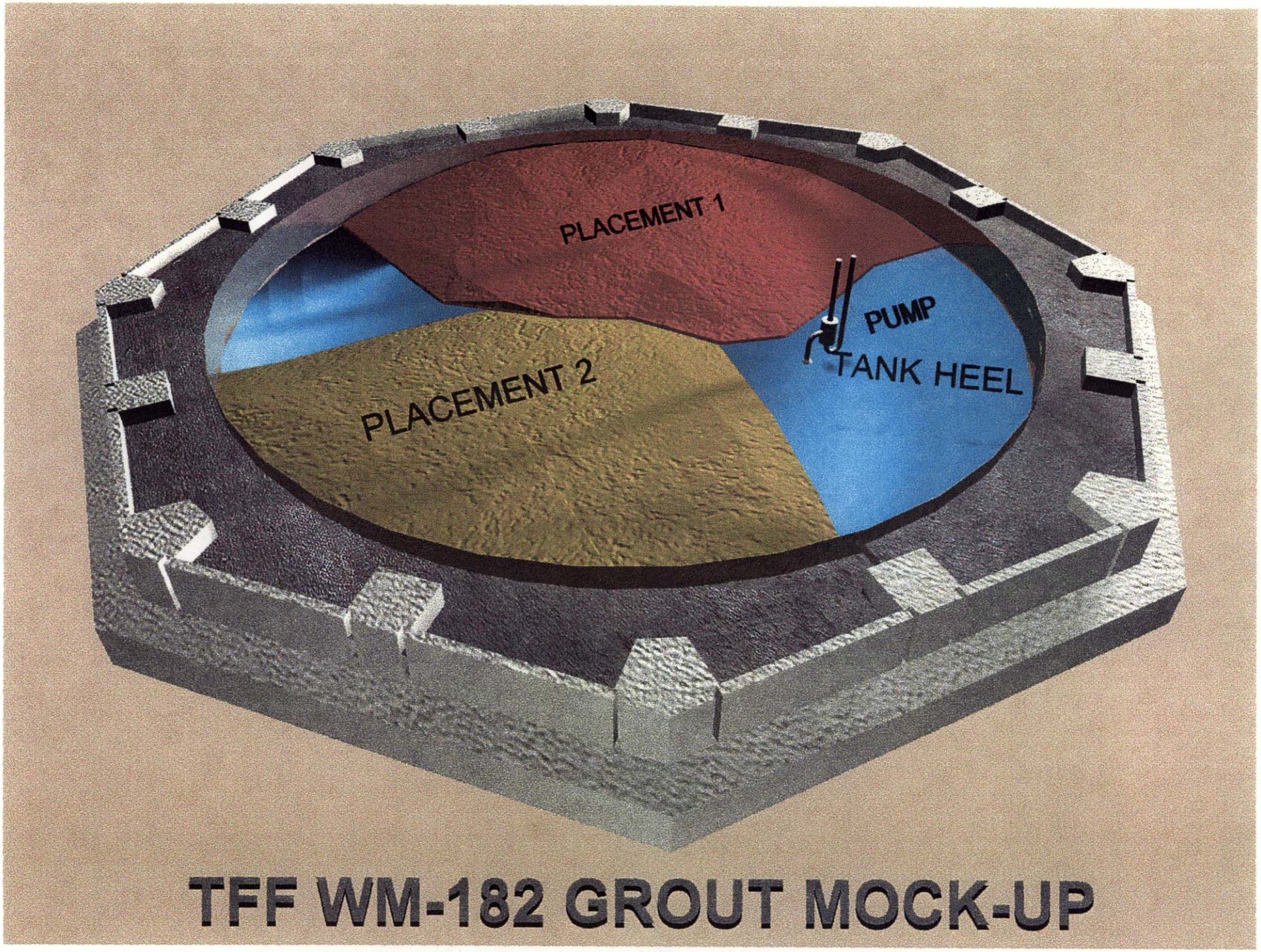
WM-182

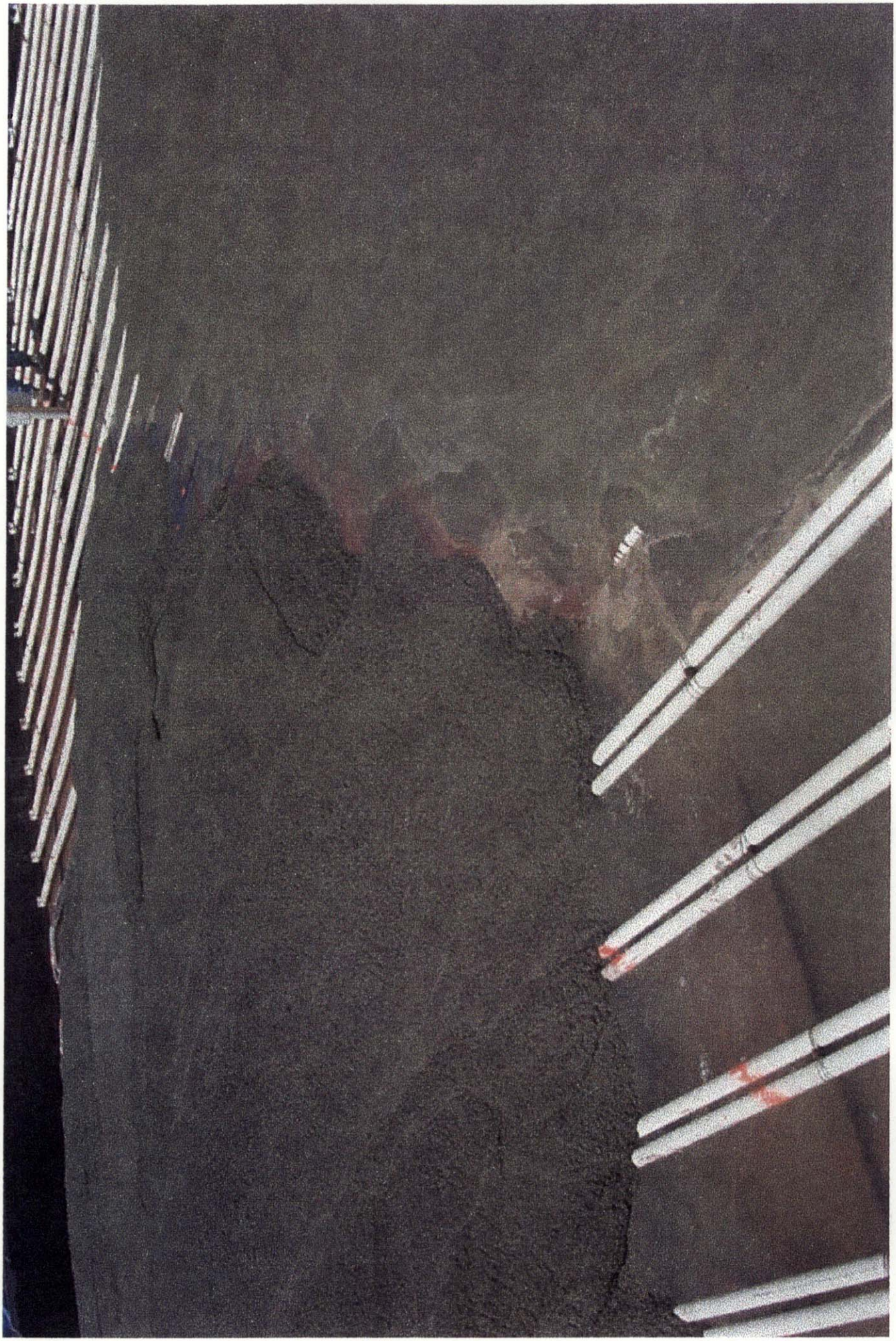


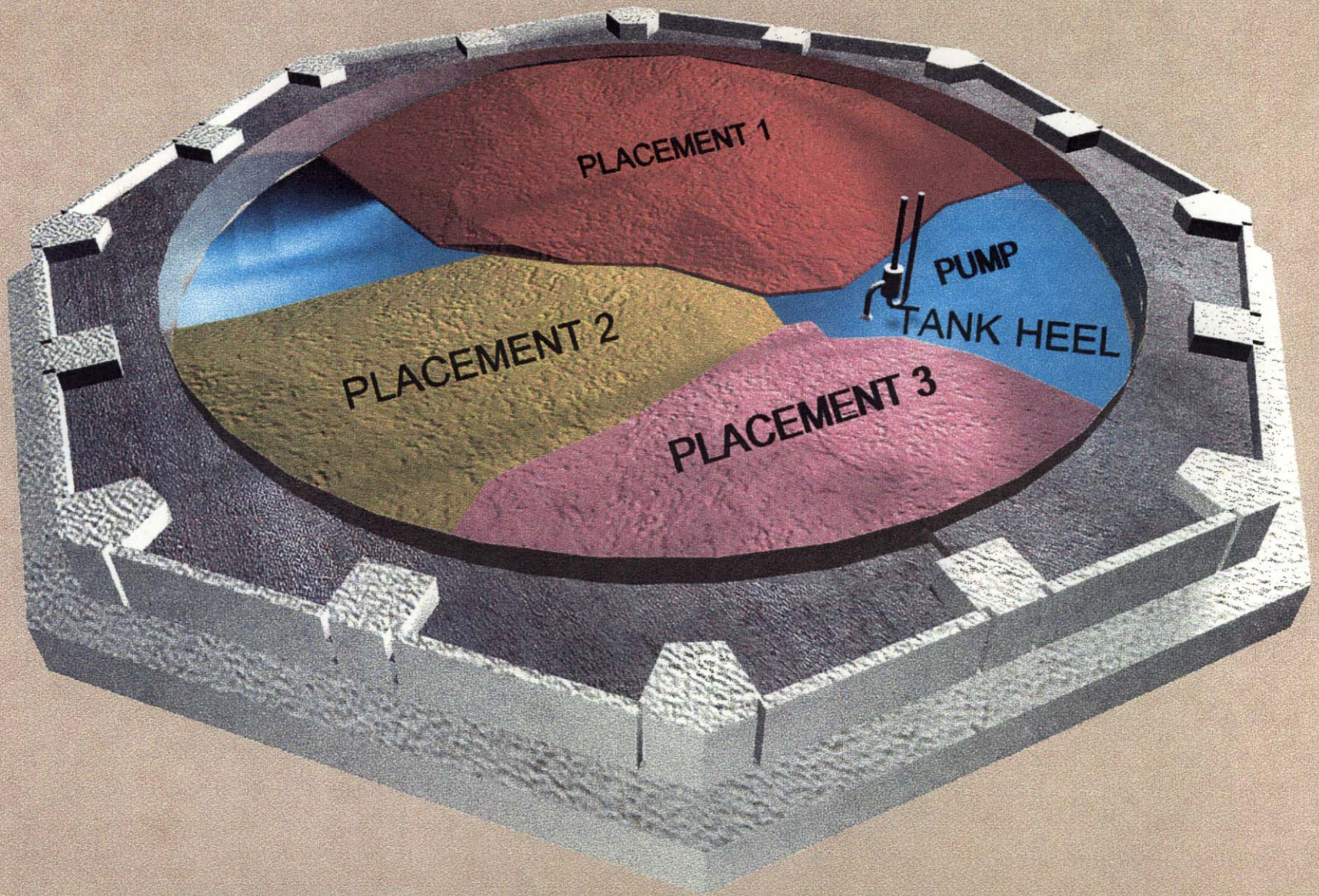
TFF WM-182 GROUT MOCK-UP



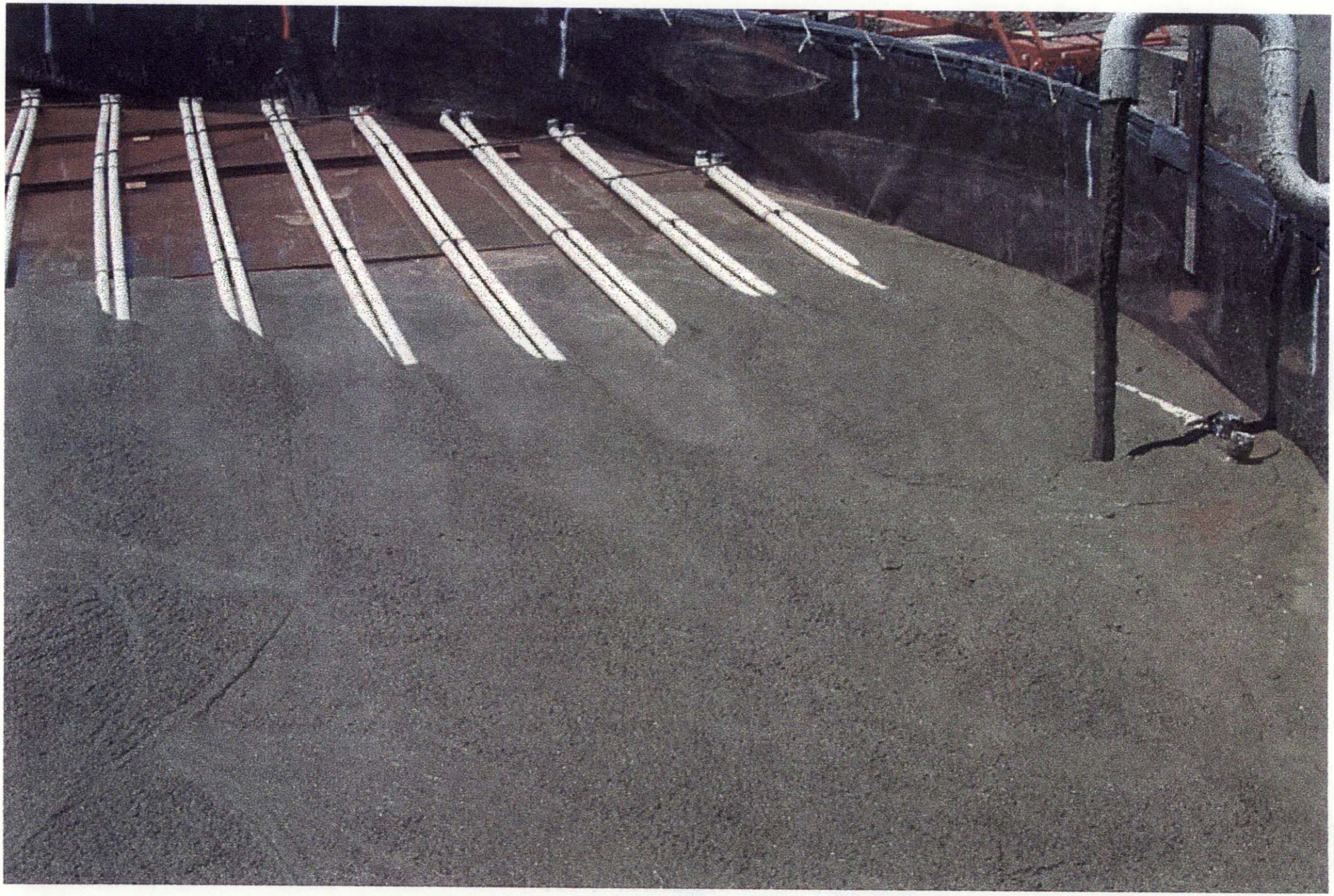


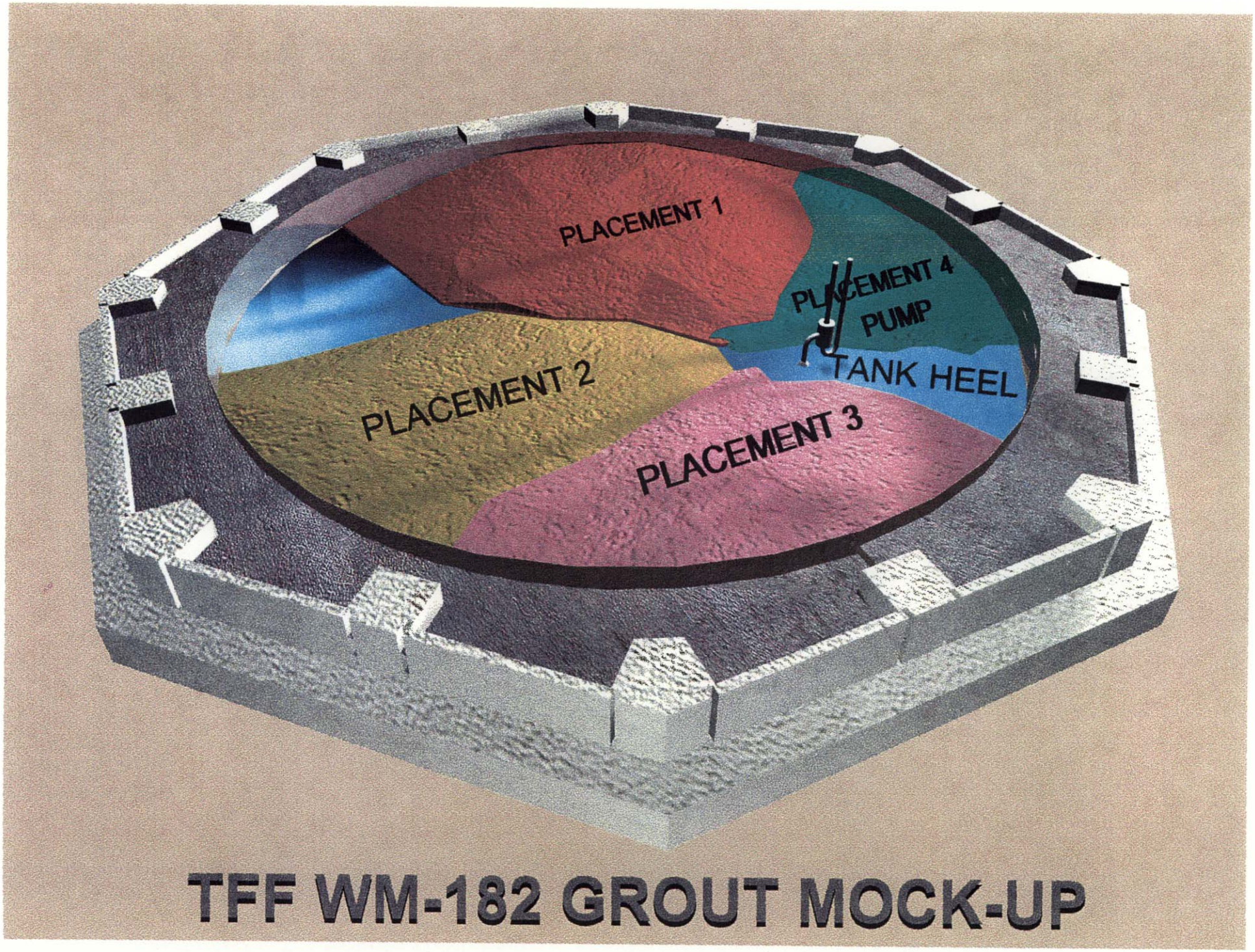

PLACEMENT 1
PUMP
TANK HEEL
PLACEMENT 2
TFF WM-182 GROUT MOCK-UP

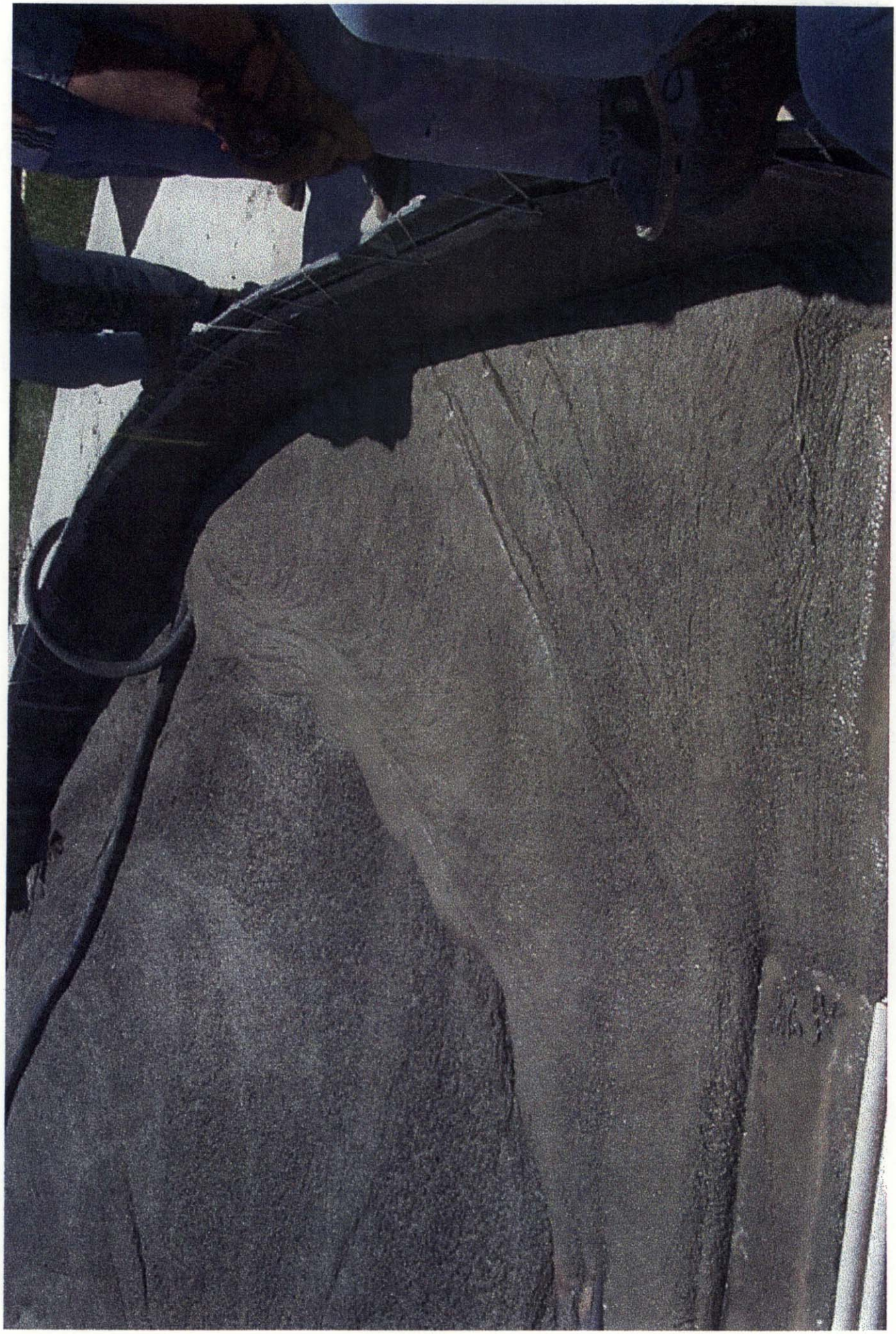


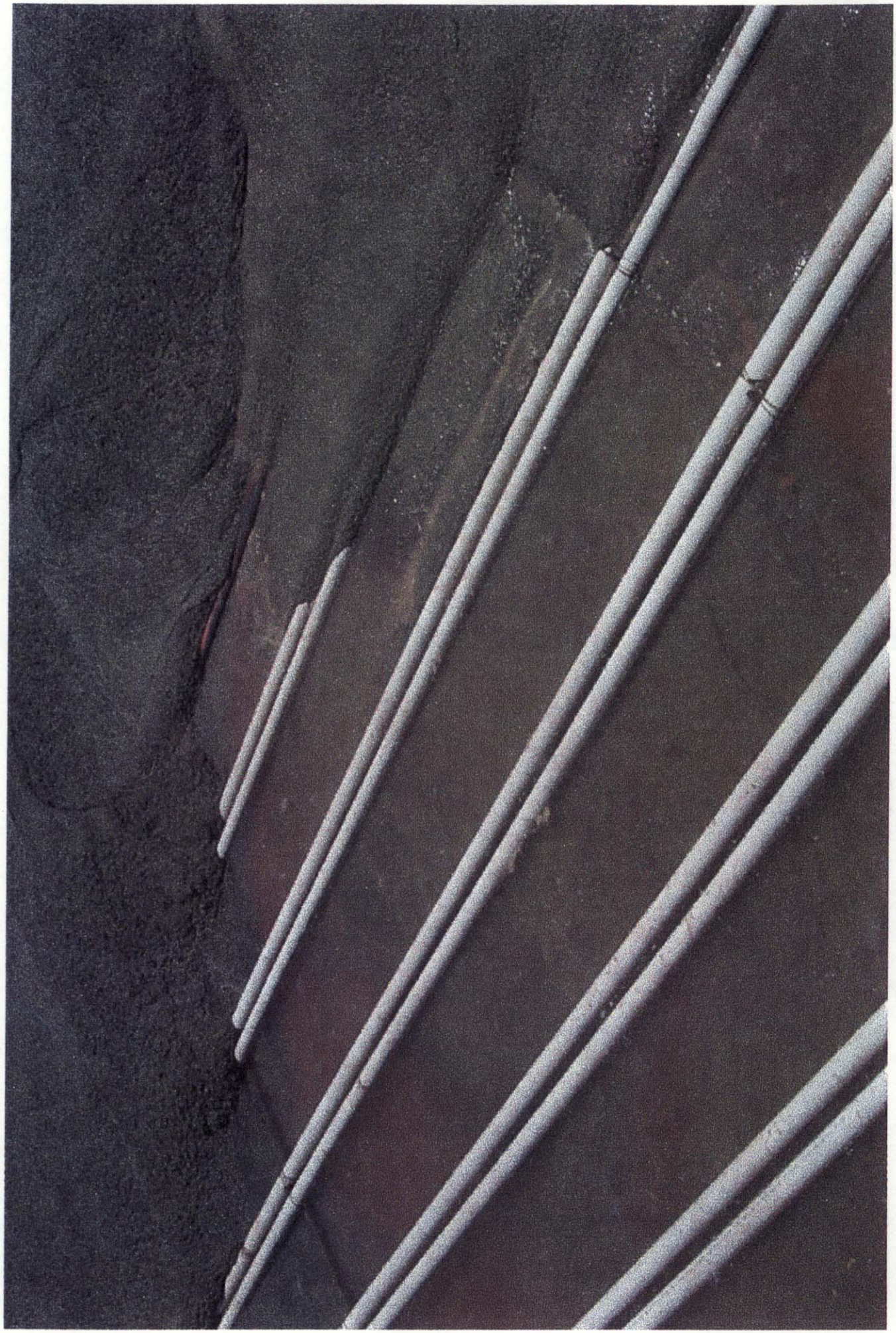


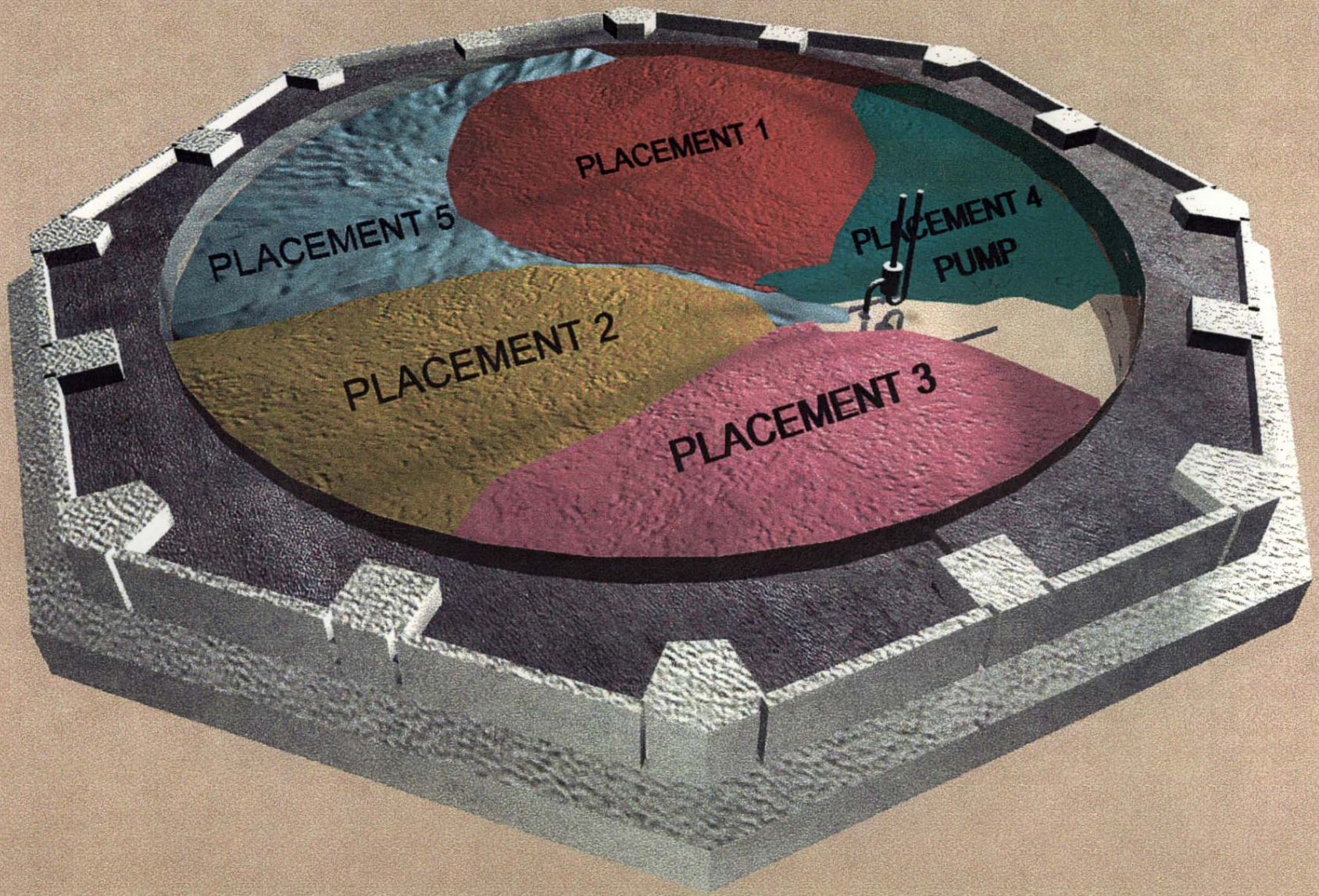
TFF WM-182 GROUT MOCK-UP



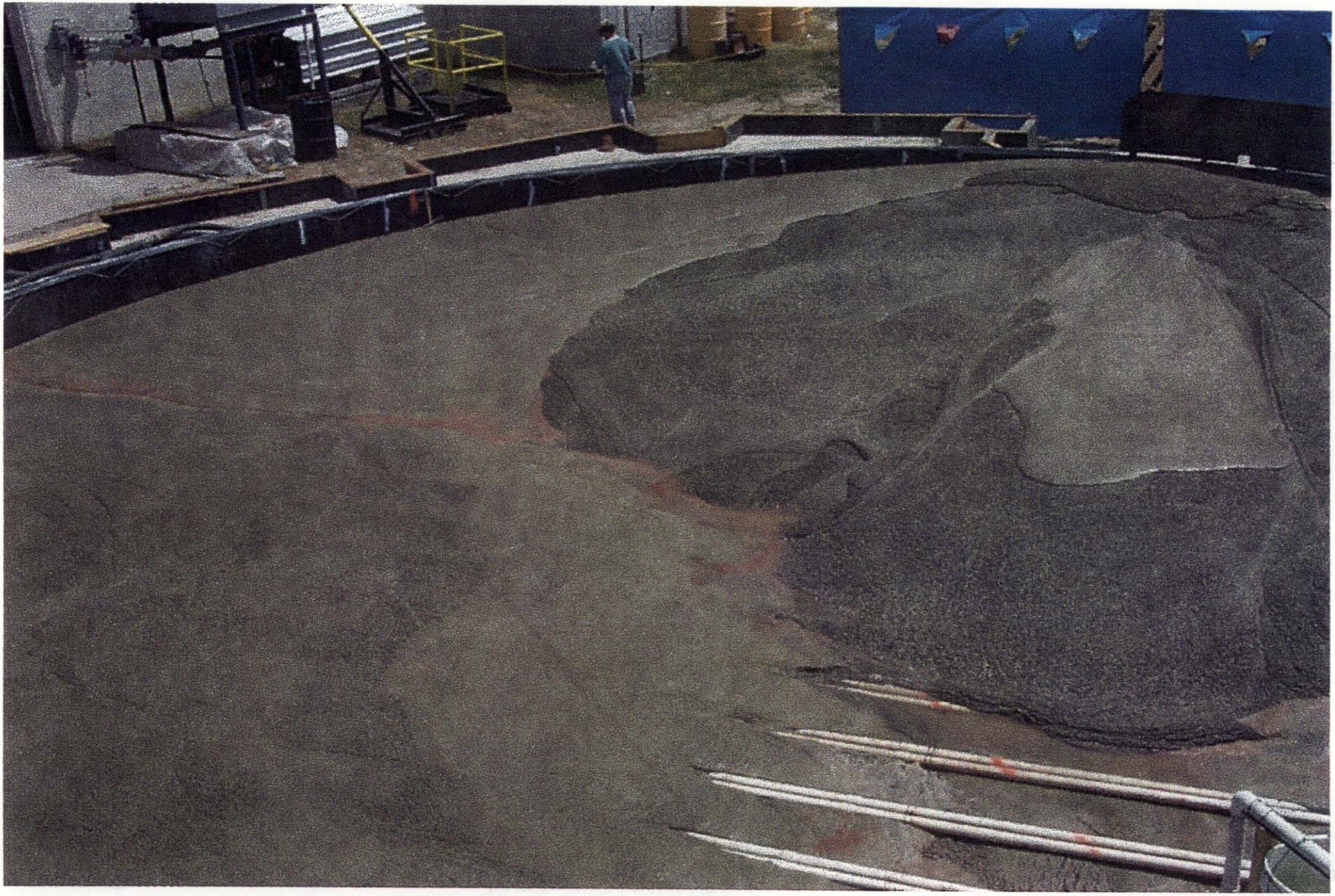

PLACEMENT 1
PLACEMENT 4
PUMP
TANK HEEL
PLACEMENT 2
PLACEMENT 3
TFF WM-182 GROUT MOCK-UP

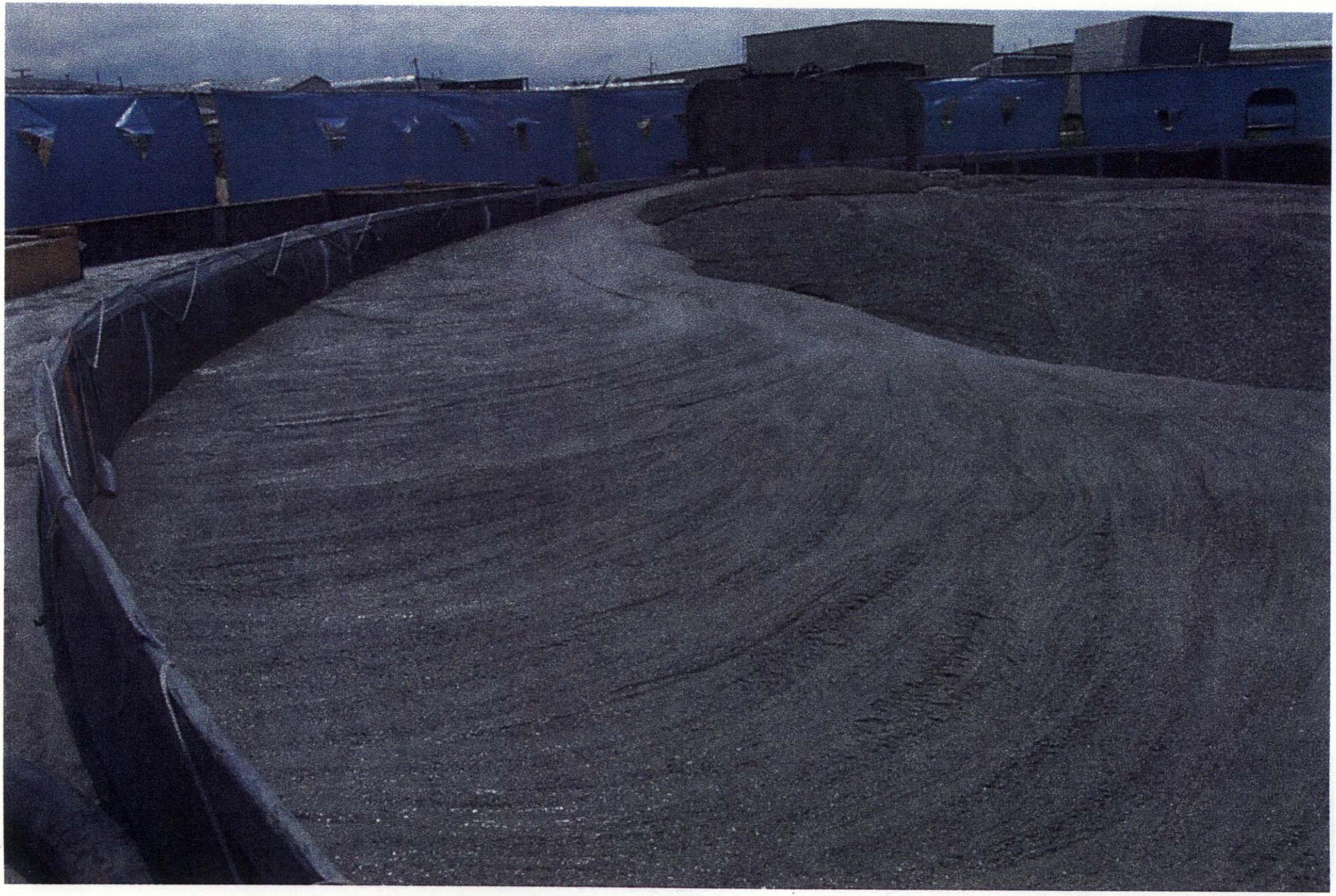


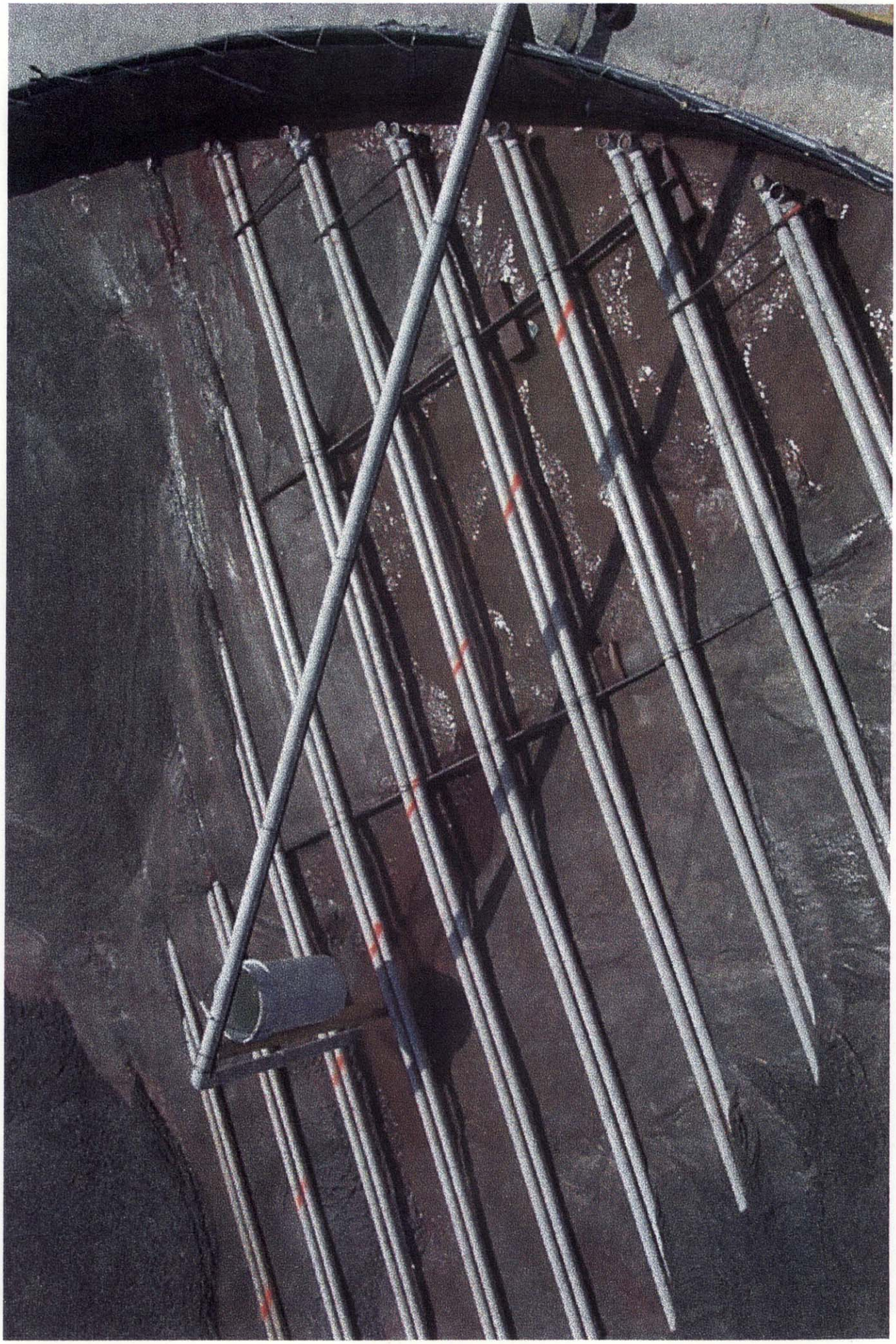




TFF WM-182 GROUT MOCK-UP

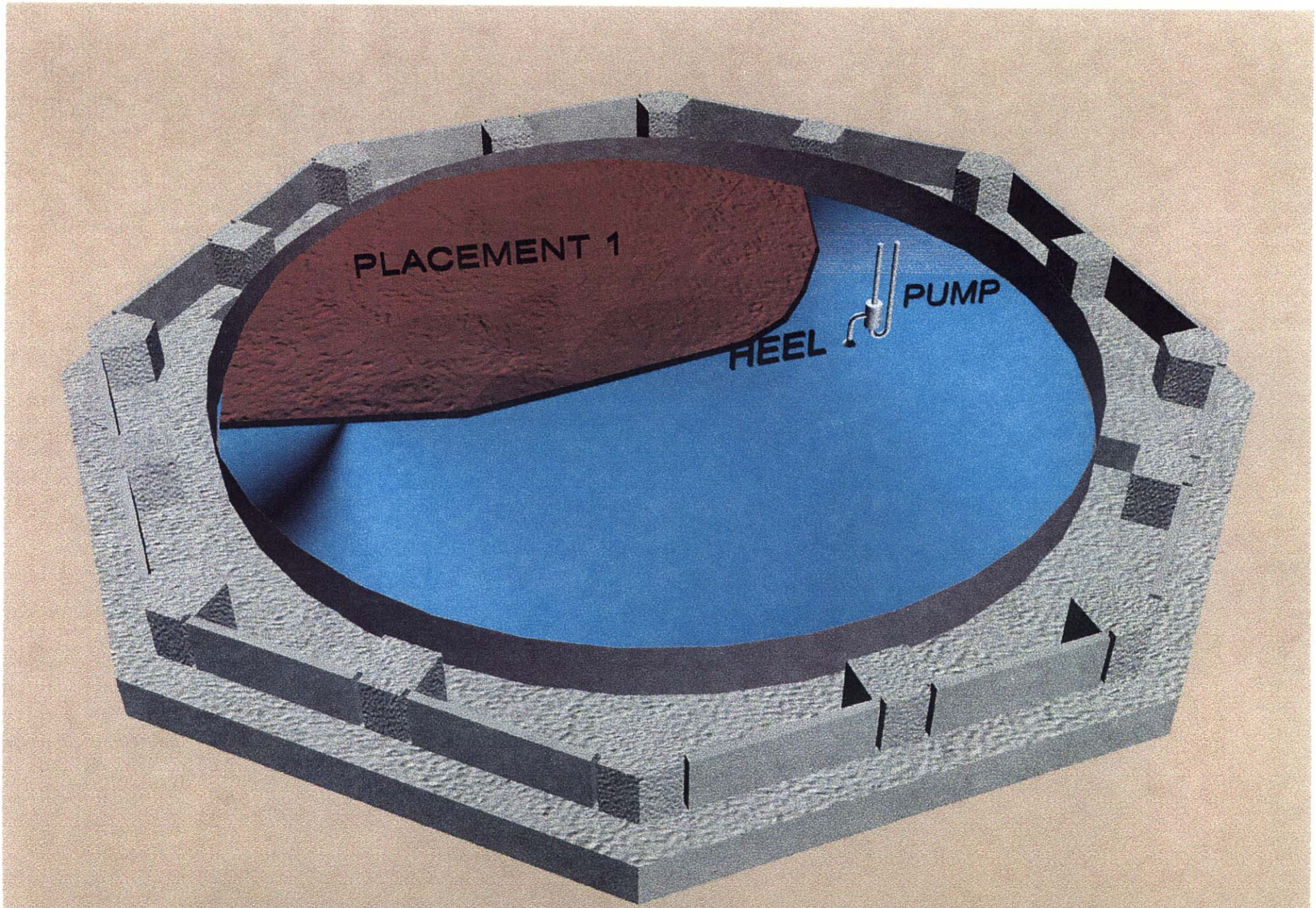






Appendix D

Appendix E



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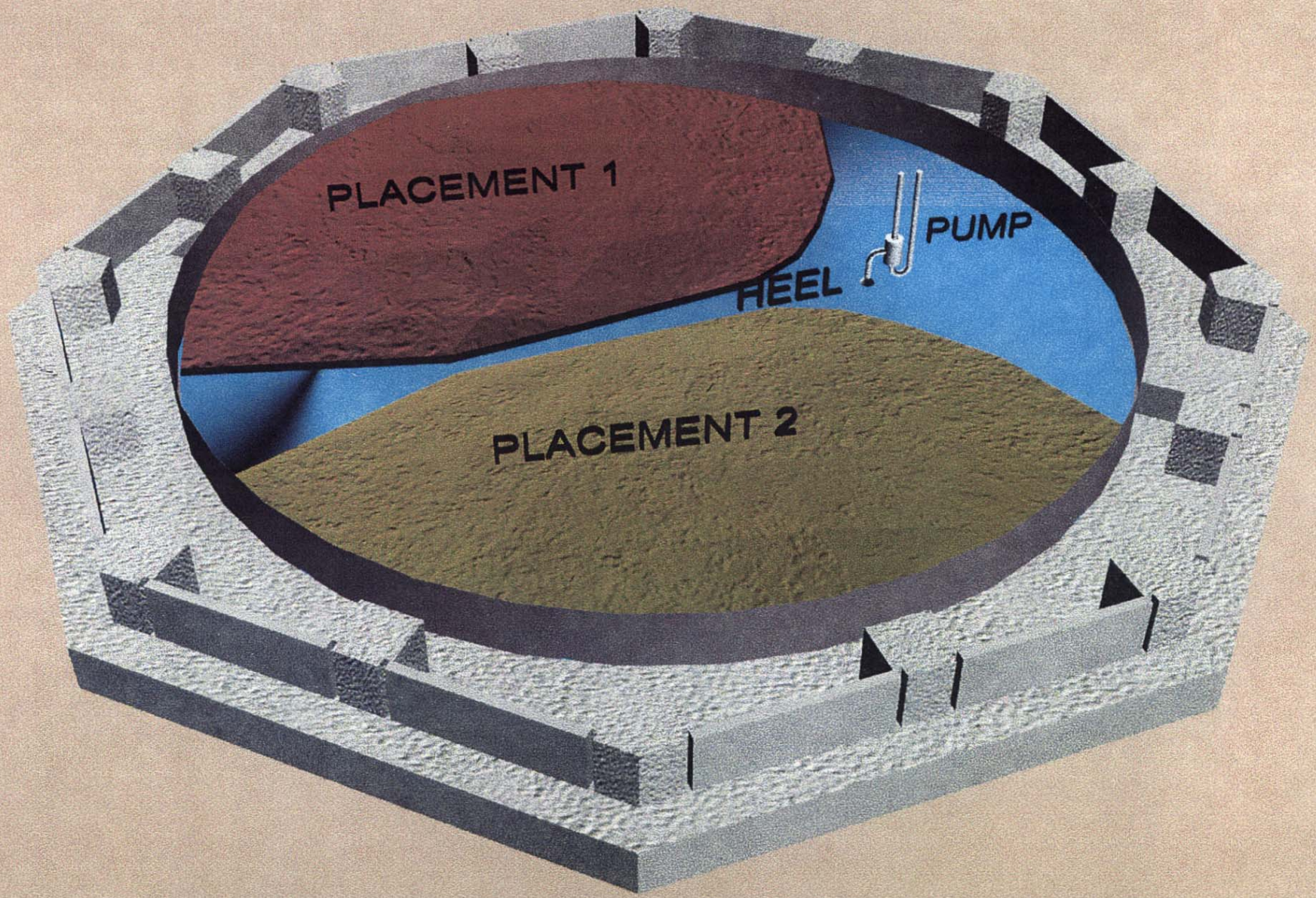

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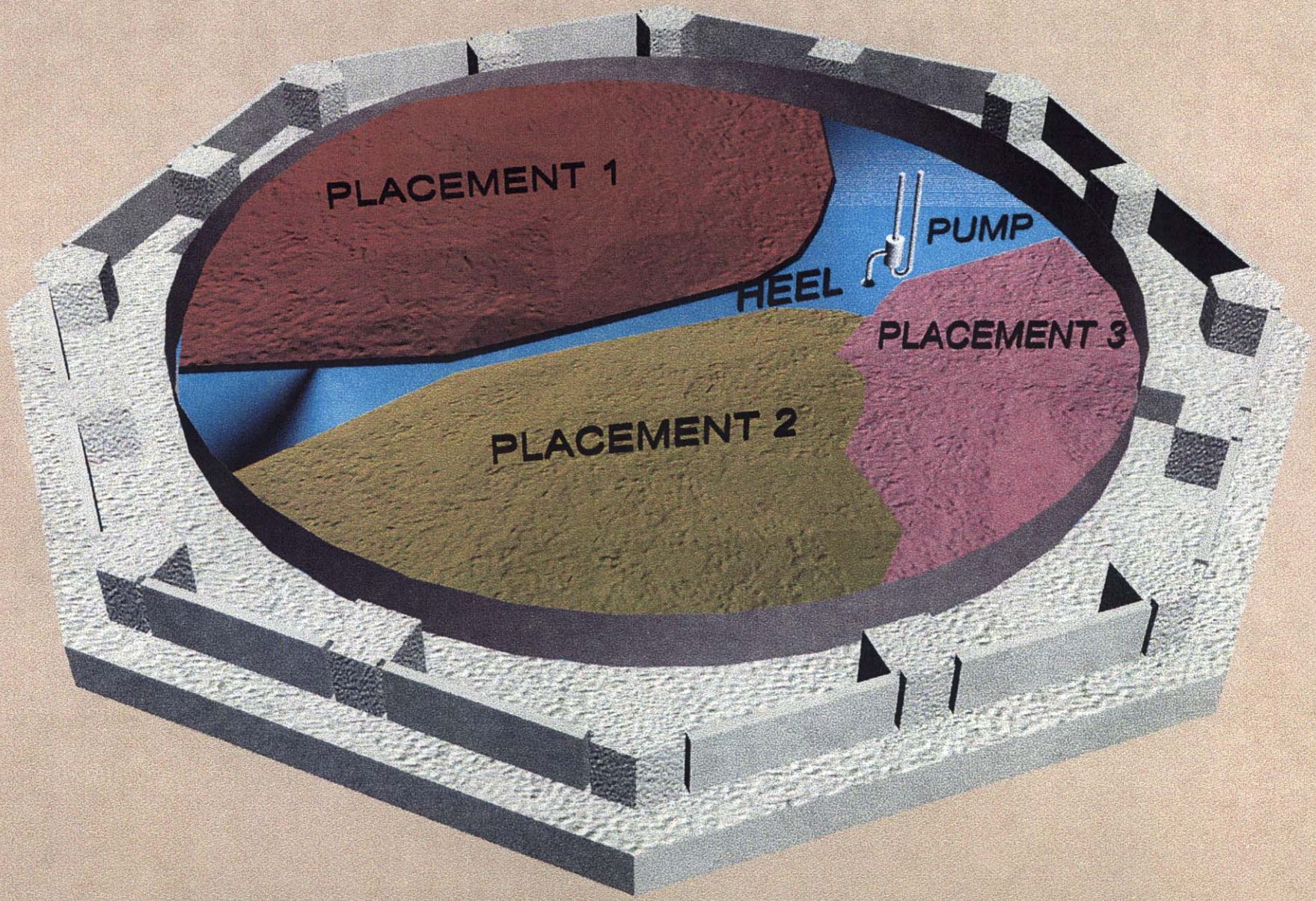

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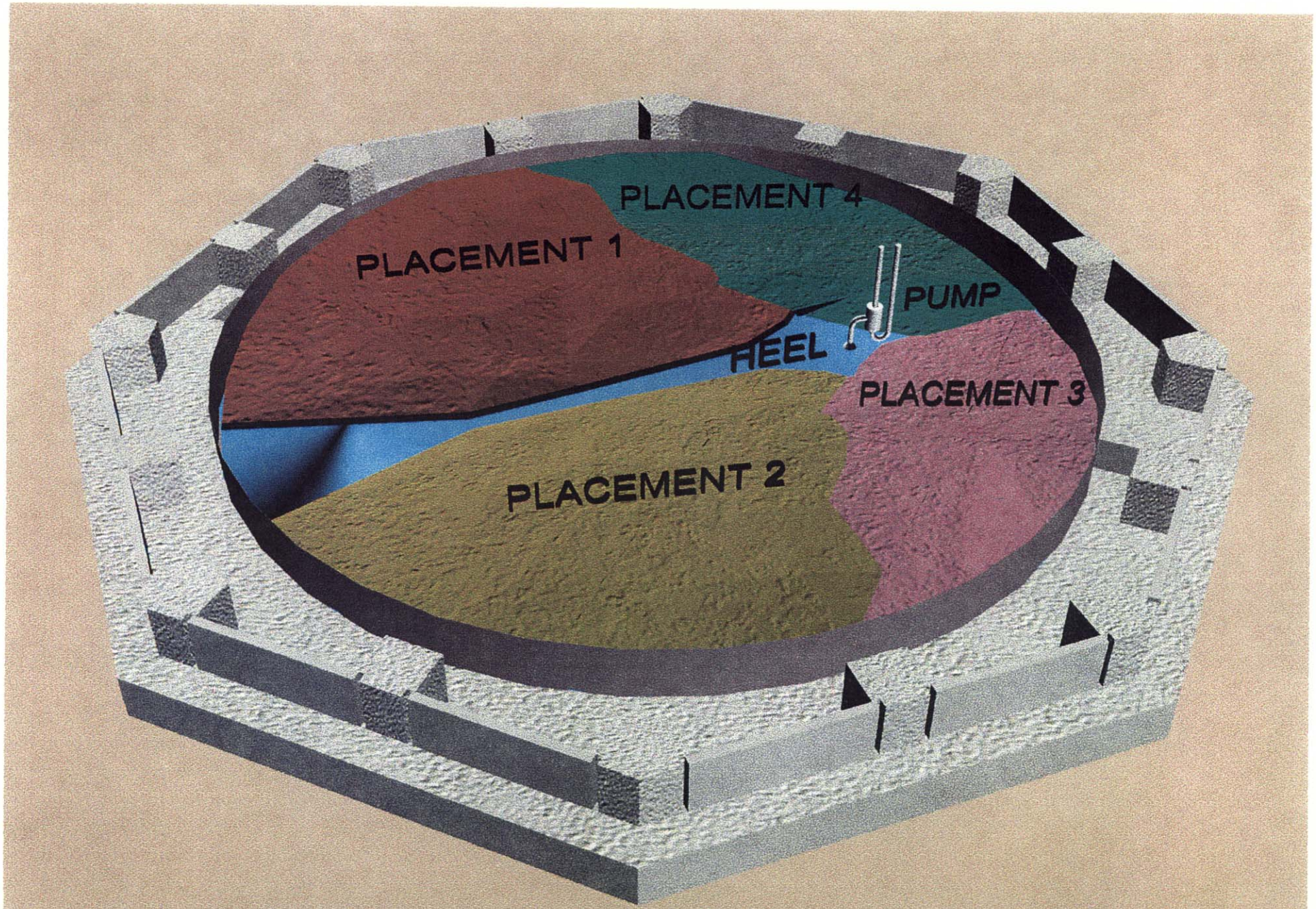

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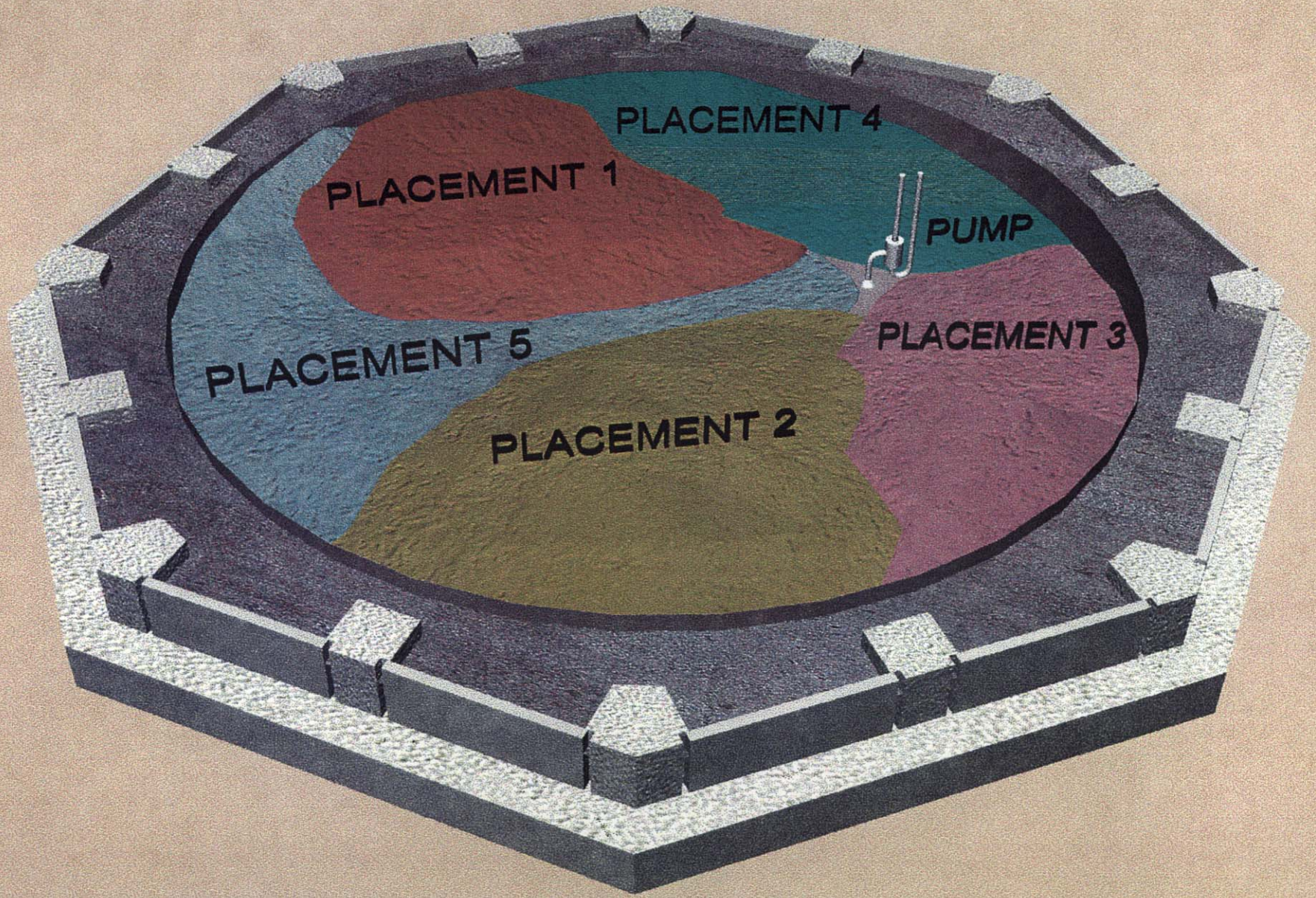

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