ANALYTICAL DATA REPORT

UL ORDER ID **1301319**

GLOSSARY OF TERMS AND ABBREVIATIONS

RL (Reporting Limit): The minimum levels, concentrations, or quantities of target analyte that can be reported with a specified degreee of confidence.Generally this number is near or equal to the lowest calibration standard run with the analytical batch.

MDL (Method Detection Limit): The constituent concentration that, when processed through the complete method, produces a signal with a 99% probability that it is different from the blank.

LCS (Laboratory Control Sample): is a sample matrix free from the analytes of interest, spiked with verified amounts of analytes.

MS (Matrix Spike): a sample prepared by adding a known mass of target analyte to a specific amount of sample for which an independant estimate of target analyte concentration is available.

MSD (Matrix Spike Duplicate): is a replicate matrix spike prepared in the laboratory and anlyzed to obtain a measure of the precision recovery for each analtye.

Surrogate is a substance with properties that mimic the analyte of interest.It is unlikely to be found in environmental samples and is added to them for quality control purposes

IS (Internal Standard): is a known amount of standard added to a test portion of the sample as a reference for evaluation and controlling the precsion and bias of the applied analytical method.

RPD (Relative Percent Difference) is the difference between a set of sample duplicates or sample spike duplicates

ICV (Initial Calibration Verification) CCV (Continuing Calibration Verification) FCV (Final Calibration Verification)

Method Blank is a sample matrix smilar to the batch of associated samples that is free from analytes of interest and is processed simultaneously with and under the same conditions as samples.

Trip Blank is a sample of analyte free media collected in the same type of container that is required for the analytical test, taken from the laboratory to the sampling site and returned to the laboratory unopened. A trip blank is used to document contamination attributable to shipping and field handling procedures

Holding Time is the maximum times that samples may be held prior to analysis and still be considered valid or not compromised

ug/L=ppb ug/kg=ppb mg/kg=ppm mg/L=ppm

HAM= Analyzed in Hampton Lab

FRED= Analyzed in Fredericksburg Lab

QC Flag	Description
B	Analyte found in method blank
H	Holding time exceeded
L	LCS outside acceptable limits
V	ICV/CCV/FCV outside acceptable limits
D	RPD outside acceptable limits
MS	Matrix spike recovery outside acceptable limits
J	Result above calibration curve approximate value
QC	Method QC Critera not met
MI	Matrix Interference
S	Surrogate outside acceptable limits
IS	Internal standard outside acceptable limits

Primary Laboratories, Inc.
7423 Lee Davis Road, Mechanicsville, VA 23111 ▪ Telephone (804) 559-9004 ▪ Fax (804) 559-9306

ANALYTICAL LABORATORY REPORT

7-Feb-13

Universal Laboratories
Attn: Mike Jennings
20 Research Drive
Hampton, Virginia 23666

Date Received: 25-Jan-13
Date Sampled: 15-Jan-13
Work Order No: 1301228-21
Client ID: **1301319-002 GB-1 @ 8-12'**

Test Description	Final Result	Reporting Limit	Units of Measure	Method Numbers*	Date Analyzed	Tech. Initials
TPH, Gasoline Range	<5	5	mg/Kg	8260 B	29-Jan-13 at 12:53	PB

Units of Measure: mg/Kg
Method Numbers*: SW-846 8260 B
Date Analyzed: 29-Jan-13
Technician: PB
Date Sampled: 15-Jan-13
Work Order No: 1301228-21
Client ID: **1301319-002 GB-1 @ 8-12'**

Test Description	Final Result	Reporting Limit
Acetone	<0.100	0.100
Benzene	<0.005	0.005
Bromobenzene	<0.005	0.005
Bromochloromethane	<0.005	0.005
Bromodichloromethane	<0.005	0.005
Bromoform	<0.005	0.005
Bromomethane	<0.010	0.010
2-Butanone	<0.100	0.100
n-Butylbenzene	<0.010	0.010
sec-Butylbenzene	<0.010	0.010
tert-Butylbenzene	<0.010	0.010
Carbon Disulfide	<0.010	0.010
Carbon tetrachloride	<0.005	0.005
Chlorobenzene	<0.005	0.005
Chloroethane	<0.010	0.010

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Units of Measure:	mg/Kg
Method Numbers*:	SW-846 8260 B (con't)
Date Analyzed:	29-Jan-13
Technician:	PB
Date Sampled:	15-Jan-13
Work Order No:	1301228-21
Client ID:	**1301319-002 GB-1 @ 8-12'**

Test Description	Final Result	Reporting Limit
Chloroform	<0.005	0.005
Chloromethane	<0.010	0.010
2-Chloroethyl vinyl ether	<0.010	0.010
2-Chlorotoluene	<0.005	0.005
4-Chlorotoluene	<0.005	0.005
Dibromochloromethane	<0.005	0.005
1,2-Dibromoethane	<0.005	0.005
Dibromomethane	<0.010	0.010
1,2-Dichlorobenzene	<0.005	0.005
1,3-Dichlorobenzene	<0.005	0.005
1,4-Dichlorobenzene	<0.005	0.005
Dichlorodifluoromethane	<0.005	0.005
1,1-Dichloroethane	<0.005	0.005
1,2-Dichloroethane	<0.005	0.005
1,1-Dichloroethene	<0.005	0.005
cis-1,2-Dichloroethene	<0.005	0.005
trans-1,2-Dichloroethene	<0.005	0.005
1,2-Dichloropropane	<0.005	0.005
1,3-Dichloropropane	<0.005	0.005
2,2-Dichloropropane	<0.015	0.015
1,1-Dichloropropene	<0.005	0.005
cis-1,3-Dichloropropene	<0.010	0.010
trans-1,3-Dichloropropene	<0.010	0.010
Ethylbenzene	<0.005	0.005
Hexachlorobutadiene	<0.005	0.005
2-Hexanone	<0.050	0.050
Iodomethane	<0.005	0.005
Isopropylbenzene	<0.005	0.005
p-Isopropyltoluene	<0.050	0.050
4-Methyl-2-pentanone	<0.010	0.010
Methylene Chloride	<0.005	0.005
Naphthalene	<0.005	0.005

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Units of Measure: mg/Kg
Method Numbers*: SW-846 8260 B (con't)
Date Analyzed: 29-Jan-13
Technician: PB
Date Sampled: 15-Jan-13
Work Order No: 1301228-21
Client ID: **1301319-002 GB-1 @ 8-12'**

Test Description	Final Result	Reporting Limit
n-Propylbenzene	<0.005	0.005
Styrene	<0.005	0.005
1,1,1,2-Tetrachloroethane	<0.005	0.005
1,1,2,2-Tetrachloroethane	<0.005	0.005
Tetrachloroethene	<0.005	0.005
Toluene	<0.010	0.010
1,2,3-Trichlorobenzene	<0.010	0.010
1,1,1-Trichloroethane	<0.005	0.005
1,1,2-Trichloroethane	<0.005	0.005
Trichloroethene	<0.005	0.005
Trichlorofluoromethane	<0.005	0.005
1,2,3-Trichloropropane	<0.015	0.015
1,2,4-Trimethylbenzene	<0.005	0.005
1,3,5-Trimethylbenzene	<0.005	0.005
Vinyl Acetate	<0.050	0.050
Vinyl Chloride	<0.010	0.010
Xylene (total)	<0.015	0.015
MTBE	<0.005	0.005

Date Sampled: 14-Jan-13
Work Order No: 1301228-22
Client ID: **1301319-003 GB-2 @ 0-4'**

Test Description	Final Result	Reporting Limit	Units of Measure	Method Numbers*	Date Analyzed	Tech. Initials
TPH, Gasoline Range	<5	5	mg/Kg	8260 B	29-Jan-13 at 13:27	HV

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Units of Measure:	mg/Kg
Method Numbers*:	SW-846 8260 B
Date Analyzed:	29-Jan-13
Technician:	PB
Date Sampled:	14-Jan-13
Work Order No:	1301228-22
Client ID:	**1301319-003 GB-2 @ 0-4'**

Test Description	Final Result	Reporting Limit
Acetone	<0.100	0.100
Benzene	<0.005	0.005
Bromobenzene	<0.005	0.005
Bromochloromethane	<0.005	0.005
Bromodichloromethane	<0.005	0.005
Bromoform	<0.005	0.005
Bromomethane	<0.010	0.010
2-Butanone	<0.100	0.100
n-Butylbenzene	<0.010	0.010
sec-Butylbenzene	<0.010	0.010
tert-Butylbenzene	<0.010	0.010
Carbon Disulfide	<0.010	0.010
Carbon tetrachloride	<0.005	0.005
Chlorobenzene	<0.005	0.005
Chloroethane	<0.010	0.010
Chloroform	<0.005	0.005
Chloromethane	<0.010	0.010
2-Chloroethyl vinyl ether	<0.010	0.010
2-Chlorotoluene	<0.005	0.005
4-Chlorotoluene	<0.005	0.005
Dibromochloromethane	<0.005	0.005
1,2-Dibromoethane	<0.005	0.005
Dibromomethane	<0.010	0.010
1,2-Dichlorobenzene	<0.005	0.005
1,3-Dichlorobenzene	<0.005	0.005
1,4-Dichlorobenzene	<0.005	0.005
Dichlorodifluoromethane	<0.005	0.005
1,1-Dichloroethane	<0.005	0.005
1,2-Dichloroethane	<0.005	0.005
1,1-Dichloroethene	<0.005	0.005
cis-1,2-Dichloroethene	<0.005	0.005
trans-1,2-Dichloroethene	<0.005	0.005
1,2-Dichloropropane	<0.005	0.005
1,3-Dichloropropane	<0.005	0.005
2,2-Dichloropropane	<0.015	0.015

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Units of Measure:	mg/Kg
Method Numbers*:	SW-846 8260 B (con't)
Date Analyzed:	29-Jan-13
Technician:	PB
Date Sampled:	14-Jan-13
Work Order No:	1301228-22
Client ID:	**1301319-003 GB-2 @ 0-4'**

Test Description	Final Result	Reporting Limit
1,1-Dichloropropene	<0.005	0.005
cis-1,3-Dichloropropene	<0.010	0.010
trans-1,3-Dichloropropene	<0.010	0.010
Ethylbenzene	<0.005	0.005
Hexachlorobutadiene	<0.005	0.005
2-Hexanone	<0.050	0.050
Iodomethane	<0.005	0.005
Isopropylbenzene	<0.005	0.005
p-Isopropyltoluene	<0.050	0.050
4-Methyl-2-pentanone	<0.010	0.010
Methylene Chloride	<0.005	0.005
Naphthalene	<0.005	0.005
n-Propylbenzene	<0.005	0.005
Styrene	<0.005	0.005
1,1,1,2-Tetrachloroethane	<0.005	0.005
1,1,2,2-Tetrachloroethane	<0.005	0.005
Tetrachloroethene	<0.005	0.005
Toluene	<0.010	0.010
1,2,3-Trichlorobenzene	<0.010	0.010
1,1,1-Trichloroethane	<0.005	0.005
1,1,2-Trichloroethane	<0.005	0.005
Trichloroethene	<0.005	0.005
Trichlorofluoromethane	<0.005	0.005
1,2,3-Trichloropropane	<0.015	0.015
1,2,4-Trimethylbenzene	<0.005	0.005
1,3,5-Trimethylbenzene	<0.005	0.005
Vinyl Acetate	<0.050	0.050
Vinyl Chloride	<0.010	0.010
Xylene (total)	<0.015	0.015
MTBE	<0.005	0.005

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Date Sampled: 14-Jan-13
Work Order No: 1301228-23
Client ID: **1301319-004 GB-2 @ 8-12'**

Test Description	Final Result	Reporting Limit	Units of Measure	Method Numbers*	Date Analyzed	Tech. Initials
TPH, Gasoline Range	<5	5	mg/Kg	8260 B	29-Jan-13 at 14:38	PB

Units of Measure: mg/Kg
Method Numbers*: SW-846 8260 B
Date Analyzed: 29-Jan-13
Technician: PB
Date Sampled: 14-Jan-13
Work Order No: 1301228-23
Client ID: **1301319-004 GB-2 @ 8-12'**

Test Description	Final Result	Reporting Limit
Acetone	<0.100	0.100
Benzene	<0.005	0.005
Bromobenzene	<0.005	0.005
Bromochloromethane	<0.005	0.005
Bromodichloromethane	<0.005	0.005
Bromoform	<0.005	0.005
Bromomethane	<0.010	0.010
2-Butanone	<0.100	0.100
n-Butylbenzene	<0.010	0.010
sec-Butylbenzene	<0.010	0.010
tert-Butylbenzene	<0.010	0.010
Carbon Disulfide	<0.010	0.010
Carbon tetrachloride	<0.005	0.005
Chlorobenzene	<0.005	0.005
Chloroethane	<0.010	0.010
Chloroform	<0.005	0.005
Chloromethane	<0.010	0.010
2-Chloroethyl vinyl ether	<0.010	0.010
2-Chlorotoluene	<0.005	0.005
4-Chlorotoluene	<0.005	0.005
Dibromochloromethane	<0.005	0.005
1,2-Dibromoethane	<0.005	0.005
Dibromomethane	<0.010	0.010

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Units of Measure:	mg/Kg
Method Numbers*:	SW-846 8260 B (con't)
Date Analyzed:	29-Jan-13
Technician:	PB
Date Sampled:	14-Jan-13
Work Order No:	1301228-23
Client ID:	**1301319-004 GB-2 @ 8-12'**

Test Description	Final Result	Reporting Limit
1,2-Dichlorobenzene	<0.005	0.005
1,3-Dichlorobenzene	<0.005	0.005
1,4-Dichlorobenzene	<0.005	0.005
Dichlorodifluoromethane	<0.005	0.005
1,1-Dichloroethane	<0.005	0.005
1,2-Dichloroethane	<0.005	0.005
1,1-Dichloroethene	<0.005	0.005
cis-1,2-Dichloroethene	<0.005	0.005
trans-1,2-Dichloroethene	<0.005	0.005
1,2-Dichloropropane	<0.005	0.005
1,3-Dichloropropane	<0.005	0.005
2,2-Dichloropropane	<0.015	0.015
1,1-Dichloropropene	<0.005	0.005
cis-1,3-Dichloropropene	<0.010	0.010
trans-1,3-Dichloropropene	<0.010	0.010
Ethylbenzene	<0.005	0.005
Hexachlorobutadiene	<0.005	0.005
2-Hexanone	<0.050	0.050
Iodomethane	<0.005	0.005
Isopropylbenzene	<0.005	0.005
p-Isopropyltoluene	<0.050	0.050
4-Methyl-2-pentanone	<0.010	0.010
Methylene Chloride	<0.005	0.005
Naphthalene	<0.005	0.005
n-Propylbenzene	<0.005	0.005
Styrene	<0.005	0.005
1,1,1,2-Tetrachloroethane	<0.005	0.005
1,1,2,2-Tetrachloroethane	<0.005	0.005
Tetrachloroethene	<0.005	0.005
Toluene	<0.010	0.010
1,2,3-Trichlorobenzene	<0.010	0.010
1,1,1-Trichloroethane	<0.005	0.005
1,1,2-Trichloroethane	<0.005	0.005

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Units of Measure: mg/Kg
Method Numbers*: SW-846 8260 B (con't)
Date Analyzed: 29-Jan-13
Technician: PB
Date Sampled: 14-Jan-13
Work Order No: 1301228-23
Client ID: **1301319-004 GB-2 @ 8-12'**

Test Description	Final Result	Reporting Limit
Trichloroethene	<0.005	0.005
Trichlorofluoromethane	<0.005	0.005
1,2,3-Trichloropropane	<0.015	0.015
1,2,4-Trimethylbenzene	<0.005	0.005
1,3,5-Trimethylbenzene	<0.005	0.005
Vinyl Acetate	<0.050	0.050
Vinyl Chloride	<0.010	0.010
Xylene (total)	<0.015	0.015
MTBE	<0.005	0.005

Date Sampled: 15-Jan-13
Work Order No: 1301228-24
Client ID: **1301319-005 GB-5 @ 0-4'**

Test Description	Final Result	Reporting Limit	Units of Measure	Method Numbers*	Date Analyzed	Tech. Initials
TPH, Gasoline Range	<5	5	mg/Kg	8260 B	29-Jan-13	PB

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Units of Measure:	mg/Kg
Method Numbers*:	SW-846 8260 B
Date Analyzed:	29-Jan-13
Technician:	PB
Date Sampled:	15-Jan-13
Work Order No:	1301228-24
Client ID:	**1301319-005 GB-5 @ 0-4'**

Test Description	Final Result	Reporting Limit
Acetone	<0.100	0.100
Benzene	<0.005	0.005
Bromobenzene	<0.005	0.005
Bromochloromethane	<0.005	0.005
Bromodichloromethane	<0.005	0.005
Bromoform	<0.005	0.005
Bromomethane	<0.010	0.010
2-Butanone	<0.100	0.100
n-Butylbenzene	<0.010	0.010
sec-Butylbenzene	<0.010	0.010
tert-Butylbenzene	<0.010	0.010
Carbon Disulfide	<0.010	0.010
Carbon tetrachloride	<0.005	0.005
Chlorobenzene	<0.005	0.005
Chloroethane	<0.010	0.010
Chloroform	<0.005	0.005
Chloromethane	<0.010	0.010
2-Chloroethyl vinyl ether	<0.010	0.010
2-Chlorotoluene	<0.005	0.005
4-Chlorotoluene	<0.005	0.005
Dibromochloromethane	<0.005	0.005
1,2-Dibromoethane	<0.005	0.005
Dibromomethane	<0.010	0.010
1,2-Dichlorobenzene	<0.005	0.005
1,3-Dichlorobenzene	<0.005	0.005
1,4-Dichlorobenzene	<0.005	0.005
Dichlorodifluoromethane	<0.005	0.005
1,1-Dichloroethane	<0.005	0.005
1,2-Dichloroethane	<0.005	0.005
1,1-Dichloroethene	<0.005	0.005
cis-1,2-Dichloroethene	<0.005	0.005
trans-1,2-Dichloroethene	<0.005	0.005
1,2-Dichloropropane	<0.005	0.005
1,3-Dichloropropane	<0.005	0.005
2,2-Dichloropropane	<0.015	0.015

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Units of Measure:	mg/Kg
Method Numbers*:	SW-846 8260 B (con't)
Date Analyzed:	29-Jan-13
Technician:	PB
Date Sampled:	15-Jan-13
Work Order No:	1301228-24
Client ID:	**1301319-005 GB-5 @ 0-4'**

Test Description	Final Result	Reporting Limit
1,1-Dichloropropene	<0.005	0.005
cis-1,3-Dichloropropene	<0.010	0.010
trans-1,3-Dichloropropene	<0.010	0.010
Ethylbenzene	<0.005	0.005
Hexachlorobutadiene	<0.005	0.005
2-Hexanone	<0.050	0.050
Iodomethane	<0.005	0.005
Isopropylbenzene	<0.005	0.005
p-Isopropyltoluene	<0.050	0.050
4-Methyl-2-pentanone	<0.010	0.010
Methylene Chloride	<0.005	0.005
Naphthalene	<0.005	0.005
n-Propylbenzene	<0.005	0.005
Styrene	<0.005	0.005
1,1,1,2-Tetrachloroethane	<0.005	0.005
1,1,2,2-Tetrachloroethane	<0.005	0.005
Tetrachloroethene	<0.005	0.005
Toluene	<0.010	0.010
1,2,3-Trichlorobenzene	<0.010	0.010
1,1,1-Trichloroethane	<0.005	0.005
1,1,2-Trichloroethane	<0.005	0.005
Trichloroethene	<0.005	0.005
Trichlorofluoromethane	<0.005	0.005
1,2,3-Trichloropropane	<0.015	0.015
1,2,4-Trimethylbenzene	<0.005	0.005
1,3,5-Trimethylbenzene	<0.005	0.005
Vinyl Acetate	<0.050	0.050
Vinyl Chloride	<0.010	0.010
Xylene (total)	<0.015	0.015
MTBE	<0.005	0.005

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Date Sampled: 15-Jan-13
Work Order No: 1301228-25
Client ID: **1301319-006 GB-5 @ 8-12'**

Test Description	Final Result	Reporting Limit	Units of Measure	Method Numbers*	Date Analyzed	Tech. Initials
TPH, Gasoline Range	<5	5	mg/Kg	8260 B	29-Jan-13	PB

Units of Measure: mg/Kg
Method Numbers*: SW-846 8260 B
Date Analyzed: 29-Jan-13
Technician: PB
Date Sampled: 15-Jan-13
Work Order No: 1301228-25
Client ID: **1301319-006 GB-5 @ 8-12'**

Test Description	Final Result	Reporting Limit
Acetone	<0.100	0.100
Benzene	<0.005	0.005
Bromobenzene	<0.005	0.005
Bromochloromethane	<0.005	0.005
Bromodichloromethane	<0.005	0.005
Bromoform	<0.005	0.005
Bromomethane	<0.010	0.010
2-Butanone	<0.100	0.100
n-Butylbenzene	<0.010	0.010
sec-Butylbenzene	<0.010	0.010
tert-Butylbenzene	<0.010	0.010
Carbon Disulfide	<0.010	0.010
Carbon tetrachloride	<0.005	0.005
Chlorobenzene	<0.005	0.005
Chloroethane	<0.010	0.010
Chloroform	<0.005	0.005
Chloromethane	<0.010	0.010
2-Chloroethyl vinyl ether	<0.010	0.010
2-Chlorotoluene	<0.005	0.005
4-Chlorotoluene	<0.005	0.005
Dibromochloromethane	<0.005	0.005
1,2-Dibromoethane	<0.005	0.005
Dibromomethane	<0.010	0.010

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Units of Measure:	mg/Kg
Method Numbers*:	SW-846 8260 B (con't)
Date Analyzed:	29-Jan-13
Technician:	PB
Date Sampled:	15-Jan-13
Work Order No:	1301228-25
Client ID:	**1301319-006 GB-5 @ 8-12'**

Test Description	Final Result	Reporting Limit
1,2-Dichlorobenzene	<0.005	0.005
1,3-Dichlorobenzene	<0.005	0.005
1,4-Dichlorobenzene	<0.005	0.005
Dichlorodifluoromethane	<0.005	0.005
1,1-Dichloroethane	<0.005	0.005
1,2-Dichloroethane	<0.005	0.005
1,1-Dichloroethene	<0.005	0.005
cis-1,2-Dichloroethene	<0.005	0.005
trans-1,2-Dichloroethene	<0.005	0.005
1,2-Dichloropropane	<0.005	0.005
1,3-Dichloropropane	<0.005	0.005
2,2-Dichloropropane	<0.015	0.015
1,1-Dichloropropene	<0.005	0.005
cis-1,3-Dichloropropene	<0.010	0.010
trans-1,3-Dichloropropene	<0.010	0.010
Ethylbenzene	<0.005	0.005
Hexachlorobutadiene	<0.005	0.005
2-Hexanone	<0.050	0.050
Iodomethane	<0.005	0.005
Isopropylbenzene	<0.005	0.005
p-Isopropyltoluene	<0.050	0.050
4-Methyl-2-pentanone	<0.010	0.010
Methylene Chloride	<0.005	0.005
Naphthalene	<0.005	0.005
n-Propylbenzene	<0.005	0.005
Styrene	<0.005	0.005
1,1,1,2-Tetrachloroethane	<0.005	0.005
1,1,2,2-Tetrachloroethane	<0.005	0.005
Tetrachloroethene	<0.005	0.005
Toluene	<0.010	0.010
1,2,3-Trichlorobenzene	<0.010	0.010
1,1,1-Trichloroethane	<0.005	0.005
1,1,2-Trichloroethane	<0.005	0.005

VELAP# 460173
DCLS# 237

Primary Laboratories
Results

7-Feb-13

Units of Measure: mg/Kg
Method Numbers*: SW-846 8260 B (con't)
Date Analyzed: 29-Jan-13
Technician: PB
Date Sampled: 15-Jan-13
Work Order No: 1301228-25
Client ID: **1301319-006 GB-5 @ 8-12'**

Test Description	Final Result	Reporting Limit
Trichloroethene	<0.005	0.005
Trichlorofluoromethane	<0.005	0.005
1,2,3-Trichloropropane	<0.015	0.015
1,2,4-Trimethylbenzene	<0.005	0.005
1,3,5-Trimethylbenzene	<0.005	0.005
Vinyl Acetate	<0.050	0.050
Vinyl Chloride	<0.010	0.010
Xylene (total)	<0.015	0.015
MTBE	<0.005	0.005

Date Sampled: 14-Jan-13
Work Order No: 1301228-26
Client ID: **1301319-001**

Test Description	Final Result	Reporting Limit	Units of Measure	Method Numbers*	Date Analyzed	Tech. Initials
TPH, Gasoline Range	<5	5	mg/Kg	8260 B	29-Jan-13 at 16:20	PB

VELAP# 460173
DCLS# 237

Primary Laboratories
Results

7-Feb-13

Units of Measure:	mg/Kg
Method Numbers*:	SW-846 8260 B
Date Analyzed:	29-Jan-13
Technician:	PB
Date Sampled:	14-Jan-13
Work Order No:	1301228-26
Client ID:	**1301319-001**

Test Description	Final Result	Reporting Limit
Acetone	<0.100	0.100
Benzene	<0.005	0.005
Bromobenzene	<0.005	0.005
Bromochloromethane	<0.005	0.005
Bromodichloromethane	<0.005	0.005
Bromoform	<0.005	0.005
Bromomethane	<0.010	0.010
2-Butanone	<0.100	0.100
n-Butylbenzene	<0.010	0.010
sec-Butylbenzene	<0.010	0.010
tert-Butylbenzene	<0.010	0.010
Carbon Disulfide	<0.010	0.010
Carbon tetrachloride	<0.005	0.005
Chlorobenzene	<0.005	0.005
Chloroethane	<0.010	0.010
Chloroform	<0.005	0.005
Chloromethane	<0.010	0.010
2-Chloroethyl vinyl ether	<0.010	0.010
2-Chlorotoluene	<0.005	0.005
4-Chlorotoluene	<0.005	0.005
Dibromochloromethane	<0.005	0.005
1,2-Dibromoethane	<0.005	0.005
Dibromomethane	<0.010	0.010
1,2-Dichlorobenzene	<0.005	0.005
1,3-Dichlorobenzene	<0.005	0.005
1,4-Dichlorobenzene	<0.005	0.005
Dichlorodifluoromethane	<0.005	0.005
1,1-Dichloroethane	<0.005	0.005
1,2-Dichloroethane	<0.005	0.005
1,1-Dichloroethene	<0.005	0.005
cis-1,2-Dichloroethene	<0.005	0.005
trans-1,2-Dichloroethene	<0.005	0.005
1,2-Dichloropropane	<0.005	0.005
1,3-Dichloropropane	<0.005	0.005
2,2-Dichloropropane	<0.015	0.015

VELAP# 460173
DCLS# 237

Primary Laboratories
Results

7-Feb-13

Units of Measure:	mg/Kg
Method Numbers*:	SW-846 8260 B (con't)
Date Analyzed:	29-Jan-13
Technician:	PB
Date Sampled:	14-Jan-13
Work Order No:	1301228-26
Client ID:	**1301319-001**

Test Description	Final Result	Reporting Limit
1,1-Dichloropropene	<0.005	0.005
cis-1,3-Dichloropropene	<0.010	0.010
trans-1,3-Dichloropropene	<0.010	0.010
Ethylbenzene	<0.005	0.005
Hexachlorobutadiene	<0.005	0.005
2-Hexanone	<0.050	0.050
Iodomethane	<0.005	0.005
Isopropylbenzene	<0.005	0.005
p-Isopropyltoluene	<0.050	0.050
4-Methyl-2-pentanone	<0.010	0.010
Methylene Chloride	<0.005	0.005
Naphthalene	<0.005	0.005
n-Propylbenzene	<0.005	0.005
Styrene	<0.005	0.005
1,1,1,2-Tetrachloroethane	<0.005	0.005
1,1,2,2-Tetrachloroethane	<0.005	0.005
Tetrachloroethene	<0.005	0.005
Toluene	<0.010	0.010

VELAP# 460173
DCLS# 237

Primary Laboratories
Results

7-Feb-13

Units of Measure:	mg/Kg
Method Numbers*:	SW-846 8260 B (con't)
Date Analyzed:	29-Jan-13
Technician:	PB
Date Sampled:	14-Jan-13
Work Order No:	1301228-26
Client ID:	**1301319-001**

Test Description	Final Result	Reporting Limit
1,2,3-Trichlorobenzene	<0.010	0.010
1,1,1-Trichloroethane	<0.005	0.005
1,1,2-Trichloroethane	<0.005	0.005
Trichloroethene	<0.005	0.005
Trichlorofluoromethane	<0.005	0.005
1,2,3-Trichloropropane	<0.015	0.015
1,2,4-Trimethylbenzene	<0.005	0.005
1,3,5-Trimethylbenzene	<0.005	0.005
Vinyl Acetate	<0.050	0.050
Vinyl Chloride	<0.010	0.010
Xylene (total)	<0.015	0.015
MTBE	<0.005	0.005

* All methods are Standard Methods 18th Edition unless otherwise noted.
Note: All analyses are NELAC certified except where noted with a (#).

Signature: Parry L. Bragg Date: 2/7/13

Parry L. Bragg
Laboratory Manager

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VELAP# 460173
DCLS# 237

Universal Laboratories
Subcontract Chain of Custody

20 Research Drive
Hampton, Va 23666
Phone: 757-865-0880
Fax: 757-865-8014

Friday, January 25, 2013

Purchase Order: 130125002

U.L. Contact: ☐ Mike Jennings ☐ Dan Thronton

To:

primary

1301228

	Sample #	Sample ID	Test		Method	Matrix	Collection Date	Time
1	1210095-001	OF-009 Grab	TPHGRO	Gasoline Range Organics	SW-846 8260 B	Wastewater	1/17/2013	09:25 AM
2	1210095-003	Trip Blank	TPHGRO	Gasoline Range Organics	SW-846 8260 B	Wastewater	10/4/2012	03:20 PM
3	1301111-001	OF-005 Grab	TPHGRO	Gasoline Range Organics	SW-846 8260 B	Stormwater	1/14/2013	07:40 PM
4	1301111-003	OF-006 Grab	TPHGRO	Gasoline Range Organics	SW-846 8260 B	Stormwater	1/14/2013	07:20 PM
5	1301111-005	OF-022 Grab	TPHGRO	Gasoline Range Organics	SW-846 8260 B	Stormwater	1/14/2013	07:00 PM
6	1301174-001	Tank 619	BTEX	BTEX by EPA 624	EPA 624	Wastewater	1/11/2013	09:57 AM
7	1301206-001	#1 (Total Flow) Grab	BTEX	BTEX by EPA 624	EPA 624	Wastewater	1/12/2013	09:30 AM
8	1301207-001	#1 (Total Flow) Grab	BTEX	BTEX by EPA 624	EPA 624	Wastewater	1/13/2013	08:40 AM
9	1301208-001	#1 (Total Flow) Grab	BTEX	BTEX by EPA 624	EPA 624	Wastewater	1/14/2013	10:45 AM
10	1301221-001	OF-002 Grab	TPHGRO	Gasoline Range Organics	SW-846 8260 B	Stormwater	1/14/2013	06:35 PM
11	1301225-001	#1 (Total Flow) Grab	BTEX	BTEX by EPA 624	EPA 624	Wastewater	1/15/2013	10:50 AM
12	1301229-001	OF-001 Grab	TPHGRO	Gasoline Range Organics	SW-846 8260 B	Stormwater	1/14/2013	03:15 PM
13	1301229-003	OF-003 Grab	TPHGRO	Gasoline Range Organics	SW-846 8260 B	Stormwater	1/14/2013	03:25 PM
14	1301236-003	OF-003 grab	TPHGRO	Gasoline Range Organics	SW-846 8260 B	Stormwater	1/14/2013	04:10 PM
15	1301254-001	#1 (Total Flow) Grab	BTEX	BTEX by EPA 624	EPA 624	Wastewater	1/16/2013	09:10 AM
16	1301262-001	OF-001 Grab	TPHGRO	Gasoline Range Organics	SW-846 8260 B	Stormwater	1/16/2013	02:00 PM
17	1301267-001	Tank 615 Hydrostatic Water T	BTEXN	Volatile Aromatics (BTEX & Naphthalene	SW-846 8260 B	Wastewater	1/16/2013	10:00 AM
18	1301267-001	Tank 615 Hydrostatic Water T	TPHGRO	Gasoline Range Organics	SW-846 8260 B	Wastewater	1/16/2013	10:00 AM
19	1301271-001	#1 (Total Flow) Grab	BTEX	BTEX by EPA 624	EPA 624	Wastewater	1/17/2013	10:15 AM
20	1301290-001	OF-002 Grab	TPHGRO	Gasoline Range Organics	SW-846 8260 B	Stormwater	1/17/2013	02:50 PM
21	1301319-002	GB-1 @ 8-12'	8260B	Volatile Organic Compounds	SW-846 8260 B	Soil	1/15/2013	09:05 AM
22	1301319-002	GB-1 @ 8-12'	TPHGRO	Gasoline Range Organics	SW-846 8260 B mod	Soil	1/15/2013	09:05 AM
23	1301319-003	GB-2 @ 0-4'	8260B	Volatile Organic Compounds	SW-846 8260 B	Soil	1/14/2013	10:35 AM

Friday, January 25, 2013

Purchase Order: 130125002

U.L. Contact: ☐ Mike Jennings ☐ Dan Thronton

To:

primary

1301228

22	1301319-003	GB-2 @ 0-4'	TPHGRO	Gasoline Range Organics	SW-846 8260 B mod	Soil	1/14/2013	10:35 AM
23	1301319-004	GB-2 @ 8-12'	8260B	Volatile Organic Compounds	SW-846 8260 B	Soil	1/14/2013	11:10 AM
23	1301319-004	GB-2 @ 8-12'	TPHGRO	Gasoline Range Organics	SW-846 8260 B mod	Soil	1/14/2013	11:10 AM
24	1301319-005	GB-5 @ 0-4'	8260B	Volatile Organic Compounds	SW-846 8260 B	Soil	1/15/2013	02:25 PM
24	1301319-005	GB-5 @ 0-4'	TPHGRO	Gasoline Range Organics	SW-846 8260 B mod	Soil	1/15/2013	02:25 PM
25	1301319-006	GB-5 @ 8-12'	8260B	Volatile Organic Compounds	SW-846 8260 B	Soil	1/15/2013	02:40 PM
25	1301319-006	GB-5 @ 8-12'	TPHGRO	Gasoline Range Organics	SW-846 8260 B mod	Soil	1/15/2013	02:40 PM

Shipped By: ☑ UL_Courier ☐ Federal Express

Comments:

Cooler Temp @ Log-in 4.3°C

Preservation

Relinquished By Signature:	**Company:** UL	**Date/Time:** 1/25/13	11:00
Received By Signature:	**Company:** U	**Date/Time:** 1/25/13	1100
Relinquished By Signature:	**Company:** U	**Date/Time:** 1/25/13	1228
Received By Signature:	**Company:**	**Date/Time:**	
Relinquished By Signature:	**Company:**	**Date/Time:**	
Received By Signature: Rachel Burnus	**Company:** PLI	**Date/Time:** 1-25-13	12:28

Primary Laboratories, Inc.
7423 Lee Davis Road, Mechanicsville, VA 23111 ▪ Telephone (804) 559-9004 ▪ Fax (804) 559-9306

ANALYTICAL LABORATORY REPORT

6-Feb-13

Universal Laboratories
Attn: Mike Jennings
20 Research Drive
Hampton, Virginia 23666

Date Received: 25-Jan-13
Date Sampled: 15-Jan-13
Work Order No: 1301229-01
Client ID: **1301319-001 GB-1 @ 0-4'**

Test Description	Final Result	Reporting Limit	Regulatory Level	Units of Measure	Method Numbers*	Date Analyzed	Tech. Initials
Metals							
Mercury, Total	<0.050	0.050	-	mg/Kg	3112 B	5-Feb-13 at 14:16	HV
Mercury, TCLP	<0.002	0.002	0.2	mg/L	1311/7470 B	5-Feb-13 at 13:51	HV

* All methods are Standard Methods 18th Edition unless otherwise noted.
Note: All analyses are NELAC certified except where noted with a (#).

Signature: _____ Date: 2-6-13
Parry L. Bragg
Laboratory Manager

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VELAP# 460173
DCLS# 237

Primary Laboratories, Inc.
7423 Lee Davis Road, Mechanicsville, VA 23111 ▪ Telephone (804) 559-9004 ▪ Fax (804) 559-9306

ANALYTICAL LABORATORY REPORT

6-Feb-13

Universal Laboratories
Attn: Mike Jennings
20 Research Drive
Hampton, Virginia 23666

Date Received: 25-Jan-13
Date Sampled: 15-Jan-13
Work Order No: 1301229-02
Client ID: **131319-002 GB-1 @ 8-12'**

Test Description	Final Result	Reporting Limit	Regulatory Level	Units of Measure	Method Numbers*	Date Analyzed	Tech. Initials
Metals							
Mercury, Total	<0.050	0.050	-	mg/Kg	3112 B	5-Feb-13 at 14:18	HV

* All methods are Standard Methods 18th Edition unless otherwise noted.
Note: All analyses are NELAC certified except where noted with a (#).

Signature: _____ Date: 2-6-13
Parry L. Bragg
Laboratory Manager

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ANALYTICAL LABORATORY REPORT

6-Feb-13

Universal Laboratories
Attn: Mike Jennings
20 Research Drive
Hampton, Virginia 23666

Date Received: 25-Jan-13
Date Sampled: 14-Jan-13
Work Order No: 1301229-03
Client ID: **1301319-003 GB-2 @ 0-4'**

Test Description	Final Result	Reporting Limit	Regulatory Level	Units of Measure	Method Numbers*	Date Analyzed	Tech. Initials
Metals							
Mercury, Total	<0.050	0.050	-	mg/Kg	3112 B	5-Feb-13 at 14:19	HV
Mercury, TCLP	<0.002	0.002	0.2	mg/L	1311/7470 B	5-Feb-13 at 13:53	HV

* All methods are Standard Methods 18th Edition unless otherwise noted.
Note: All analyses are NELAC certified except where noted with a (#).

Signature: Date: 2-6-13
Parry L. Bragg
Laboratory Manager

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ANALYTICAL LABORATORY REPORT

6-Feb-13

Universal Laboratories
Attn: Mike Jennings
20 Research Drive
Hampton, Virginia 23666

Date Received: 25-Jan-13
Date Sampled: 14-Jan-13
Work Order No: 1301229-04
Client ID: **1301319-004 GB-2 @ 8-12'**

Test Description	Final Result	Reporting Limit	Regulatory Level	Units of Measure	Method Numbers*	Date Analyzed	Tech. Initials
Metals							
Mercury, Total	<0.050	0.050	-	mg/Kg	3112 B	5-Feb-13 at 14:20	HV

* All methods are Standard Methods 18th Edition unless otherwise noted.
Note: All analyses are NELAC certified except where noted with a (#).

Signature: _____ Date: 2-6-13
Parry L. Bragg
Laboratory Manager

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DCLS# 237

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ANALYTICAL LABORATORY REPORT

6-Feb-13

Universal Laboratories
Attn: Mike Jennings
20 Research Drive
Hampton, Virginia 23666

Date Received: 25-Jan-13
Date Sampled: 15-Jan-13
Work Order No: 1301229-05
Client ID: **1301319-005 GB-5 @ 0-4'**

Test Description	Final Result	Reporting Limit	Regulatory Level	Units of Measure	Method Numbers*	Date Analyzed	Tech. Initials
Metals							
Mercury, Total	<0.050	0.050	-	mg/Kg	3112 B	5-Feb-13 at 14:22	HV
Mercury, TCLP	<0.002	0.002	0.2	mg/L	1311/7470 B	5-Feb-13 at 13:54	HV

* All methods are Standard Methods 18th Edition unless otherwise noted.
Note: All analyses are NELAC certified except where noted with a (#).

Signature: _____ Date: 2-6-13
Parry L. Bragg
Laboratory Manager

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ANALYTICAL LABORATORY REPORT

6-Feb-13

Universal Laboratories
Attn: Mike Jennings
20 Research Drive
Hampton, Virginia 23666

Date Received: 25-Jan-13
Date Sampled: 15-Jan-13
Work Order No: 1301229-06
Client ID: **1301319-006 GB-5 @ 8-12'**

Test Description	Final Result	Reporting Limit	Regulatory Level	Units of Measure	Method Numbers*	Date Analyzed	Tech. Initials
Metals							
Mercury, Total	<0.050	0.050	-	mg/Kg	3112 B	5-Feb-13 at 14:23	HV

* All methods are Standard Methods 18th Edition unless otherwise noted.
Note: All analyses are NELAC certified except where noted with a (#).

Signature: Date: 2-6-13
Parry L. Bragg
Laboratory Manager

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VELAP# 460173
DCLS# 237

1301314

CHAIN-OF-CUSTODY

UNIVERSAL LABORATORIES

20 Research Drive
Hampton, VA 23666

Phone: (757) 865-0880
Fax: (757) 865-8014

Company	GER, INC.
Street/Box	2712 SOUTHERN BLVD STE 101
City/State	VA BEACH VA 23452
Phone	7574633200 Fax 7574633080
Contact:	CHAS. CRAWLEY
Job No.	110-6133 / P.O. No. P677 TECOM

Analysis Required

Sample ID	Date/Time	Sampled By	Matrix	Sample Type	Field Notes	Preservative ICE TPH - DRO (8015)	Preservative ICE TPH - GRO (8015)	Preservative ICE TOTAL METALS (6010/7470)	Preservative ICE TCLP METALS (6010/7470)	Preservative ICE VOCS (8260)	Preservative ICE PCBS (8082)	Preservative	Preservative	Log Number
GB-1 @ 0-4'	1/15/13 08:50	CFC	SO	C G		X	X	X	X	X	X			
GB-1 @ 8-12'	1/15/13 09:05			C G		X	X	X		X	X			
GB-2 @ 0-4'	1/14/13 10:35			C G		X	X	X	X	X	X			
GB-2 @ 8-12'	1/14/13 11:10			C G		X	X	X		X	X			
GB-5 @ 0-4'	1/15/13 14:25			C G		X	X	X	X	X	X			
GB-5 @ 8-12'	1/15/13 14:40			C G		X	X	X		X	X			
				C G										
				C G										
				C G										
				C G										
				C G										
				C G										

Comments: EMAIL RESULTS TO CFPCRAWLEY@GERONLINE.COM
PROJECT ID: P677 TECOM Cooler Temp at LI 12 Pres √ —

Possible Hazards: Disposal: Lab ☐ Client ☐ Charge ☐

Due Date:
Express Service
Express Service Approval

Relinquished By	Signature Chas. P. Crawley III	Company GER	Date/Time 1/18/13 12:20
Received By	Signature	Company UL	Date/Time 1-18-13 1220
Relinquished By	Signature	Company	Date/Time
Received By	Signature	Company	Date/Time
Relinquished By	Signature	Company	Date/Time
Received By	Signature	Company	Date/Time

Work Order No.
Delivery Order
Trans ☐ P.U. ☐ Grab ☐ Comp ☐
Shipping/Delivery Charges
Composite Start / Composite Stop

APPENDIX D

PROCEDURES

GEOTECHNICAL EXPLORATION PROCEDURES

Boring, Sampling & Standard Penetration Testing

Standard penetration testing and split barrel sampling are conducted at regular intervals in a borehole in accordance with ASTM D 1586. Standard practice on most **GER** projects is to perform this testing and sampling continuously within the upper 10 feet of the subsurface, and then at maximum 5-foot center-to-center intervals thereafter. At the desired test depth, the drilling tools are removed and a split barrel sampler is connected to the drilling rods and lowered back into the borehole. The sampler is first seated six inches into the bottom of the hole to penetrate any loose cuttings from the drilling operations. It is then driven an additional 12 inches by the impact of a 140 pound hammer free-falling 30 inches. The number of hammer blows required to drive the sampler for each 6-inch interval is recorded. The combined number of blows required to drive the sampler the final 12 inches is designated *standard penetration resistance* or *N-value*. Representative portions of soil from each split barrel sample are placed in air tight glass jars or plastic bags and transported to a laboratory.

Undisturbed Sampling

Split barrel samples are used for visual examination and simple laboratory classification tests; however, they are disturbed and not sufficiently intact for quantitative laboratory testing such as strength or consolidation. When such laboratory testing is desired, relatively undisturbed samples are obtained by slowly pushing a 3-inch diameter, thin-walled (16 gauge) galvanized steel tube into the soil at desired sampling depths. This is followed by carefully removing the soil-filled tube from the borehole and sealing the ends to prevent moisture loss. The procedure is described in ASTM D 1587. Undisturbed tube samples are most frequently used for sampling cohesive soils (clay and silt), but may be used to sample fine grained cohesionless soils with the aid of a piston sampling head.

Excavation

When explorations do not require machine-drilled borings, excavations, test pits, hand auger borings and other means described in ASTM D 4700 may be used to observe shallow subsurface conditions and to collect soil samples. The maximum depth of these methods is generally limited by the depth of groundwater. These methods are useful in obtaining bulk samples for laboratory classification, compaction and other remolded tests.

Rock Coring

Core drilling methods described in ASTM D 2113 are used to advance boreholes into rock or extremely dense soils which are not penetrable by conventional boring methods and typically exhibit more than 100 blows per foot by ASTM D 1586. Core drilling methods employed by **GER** use double tube swivel-type designed equipment with a drilling fluid, in which an outer tube rotates and performs the cutting while the inner tube remains stationary and collects a continuous sample of rock.

In-Situ Methods

In-situ tests are sometimes used on projects to obtain additional subsurface data. These methods provide direct and empirical measurement of various soil properties without collection of actual samples. Because samples are not collected, it is not common practice in the U. S. to

utilize in-situ tests alone to accomplish geotechnical investigations. On projects where in-situ testing is used, it is customary to perform them in conjunction with borings.

Soil Classification

Soil classification tests provide a general guide to the engineering properties of various soil types. Samples obtained during drilling operations are examined and visually classified by an engineer or geologist according to consistency, color and texture. These classification descriptions are included on the boring records. The classification system is primarily qualitative and for detailed soil classification, two laboratory tests are necessary; grain size tests and plasticity tests. Using these test results, the soil can be classified according to the AASHTO or Unified Classification System (ASTM D 2487). Each of these classification systems and the in-place physical soil properties provides an index for estimating the soil's behavior. The soil classification and physical properties obtained are presented on the following sheets.

Grain Size Tests

Grain size tests are performed to determine the soil classification and the grain size distribution. The soil samples are prepared for testing according to ASTM D 421 (dry preparation) or ASTM D 2217 (wet preparation). The grain size distribution of soils coarser than the #200 U.S. Standard Sieve (0.074 mm opening) is determined by passing the samples through a standard set of nested sieves. Materials passing the No. 200 sieve are suspended in water and the grain size distribution calculated from the measured settlement rate. These tests are conducted in accordance with ASTM D 422.

Plasticity Tests

Plasticity tests are performed to determine the soil classification and plasticity characteristics. The soil plasticity characteristics are defined by the Plastic Index (PI) and the Liquid Limit (LL). The PI is related to the volume changes which occur in confined soils beneath foundations. The PI and LL are determined in accordance with ASTM D 4318.

Physical Properties

The in-place physical properties are described by the specific gravity, wet unit weight, moisture content, dry unit weight, void ratio and percent saturation of the soil. The specific gravity and moisture content are determined by ASTM D 854 and D 2216, respectively. The wet unit weight is found by obtaining a known volume of soil and dividing the wet sample weight by the known volume. The dry unit weight, void ratio and percent saturation are calculated values.

California Bearing Ratio

The California Bearing Ratio (CBR) test is a comparative measure of the shearing resistance of a soil. It is used with empirical curves to design asphalt pavement structures. The test is performed in accordance with ASTM D 1883 or Virginia Test Method Designation VTM-8. A representative bulk sample is compacted in a six-inch diameter CBR mold in five (5) equal layers, using 45 evenly spaced blows per layer with a 5.5 lb. hammer falling 12 inches. CBR tests may be run on the compacted samples in either soaked or unsoaked conditions, with samples penetrated at the rate of .05 inches per minute to a depth of 0.5 inches. The CBR value is the percentage of the load it takes to penetrate the soil to a specified depth compared to the load it takes to penetrate a standard crushed stone to the same depth.

Consolidation Tests

Consolidation tests determine the change in height of a soil sample with increasing load. The results of these tests are used to estimate the settlement and time rate of settlement of structures constructed on similar soils. The test is run in accordance with ASTM D 2435 on a single element of an extruded undisturbed sample. The test sample is trimmed into a disk approximately 2½ inches in diameter and one inch thick. The disk is confined in a stainless steel ring and sandwiched between porous plates and subjected to incrementally increasing vertical loads, with the resulting deformations measured with micrometer dial gauges. Void ratios and percent strain deformation are then calculated from these readings. The test results are presented in the form of a stress-strain or vertical pressure versus void ratio curve.

Triaxial Shear Tests

Triaxial shear tests are used to determine the strength characteristics and elastic properties of a soil sample. Triaxial shear tests are conducted either on relatively undisturbed samples of virgin material or on remolded-compacted samples of representative site materials. The samples are then trimmed into cylinders and encased in rubber membranes. Each is then placed into a compression chamber and confined by hydrostatic cell pressure. An axial load is applied until the sample fails in shear. Test results are presented in the form of stress-strain curves and stress paths to failure.

Various types of triaxial tests may be performed. The most suitable type of triaxial test is determined by the loading conditions imposed on the soil in the field and by drainage characteristics of the site. Types of triaxial tests normally performed include:

- Consolidated-Isotropic-Undrained (CIU test)
- Consolidated-Anisotropic-Undrained (CK_oU test)
- Consolidated-Isotropic-Drained (CID test)
- Consolidated-Anisotropic-Drained (CK_oD test)
- Unconsolidated-Undrained (UU test)

GeoEnvironmental Resources, Inc.

PUBLIC WORKS/FLSS

UTILITIES OUTAGE REQUEST FORM

PUBLIC WORKS/FLSS
UTILITES OUTAGE REQUEST

DATE:

From: DPWO
To: FLSS

Subject: **REQUEST FOR OUTAGE OF ELECTRIC, STEAM, GAS, SEWAGE, WATER (HOT/COLD) to Include Water Permit #_____.**

1. **SECURE UTILITY**: From: (Hour) Date:
   To: (Hour) Date:

Outage **WILL/WILL NOT** be postponed due to any inclement weather. If postponed, date and time of re-scheduling will be:
From: (Hour) Date:
To: (Hour) Date:

2. **POINT OF CONTACT**:

3. **CONTRACT NUMBER AND TITLE**:

4. **BUILDINGS AND AREAS AFFECTED**:

5. **REASON FOR OUTAGE**:

STAFF CONCURRENCE	**INITIALS**	**DATE**
DPWO	_____	_____
SHOP 61	_____	_____
SHOP 51	_____	_____
UTILITIES	_____	_____
DIR., M & R	_____	_____
AMERESCO	_____	_____
PRODUCTION CONTROL	_____	_____

HEAD, FLSS **APPROVED/DISAPPROVED**

_____**DATE**_____

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REMOVABLE BOLLARD

REQUIREMENTS

Cal Pipe manufacturing

CAL PIPE SECURITY BOLLARDS

SECURITY

Cal Pipe Security Bollards

CPSB Home

Fixed Post Bollards

Lighted Bollards

Removable Bollards

Retractable Bollards

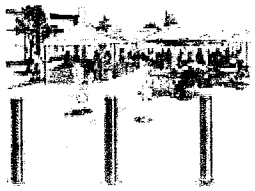
Bollard Accessories

Resources

Purchase ONLINE

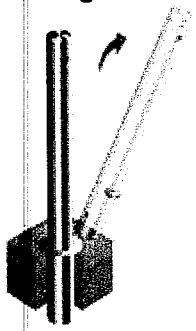
Site Map

REMOVABLE BOLLARDS



Perfect for medium security installations where only occasional access to vehicles or pedestrians is needed, this versatile security bollard is manually removable with either external or internal locking when the bollard is inserted. Both systems have their advantages and both are engineered and manufactured to make security of the locking systems difficult to compromise.

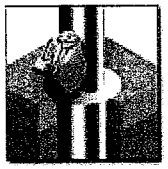
Internal Locking Security Bollard

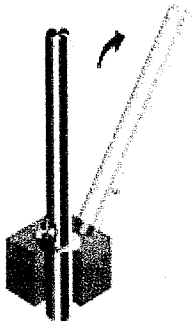


The Internal Locking Removable bollard is arguably our most flexible bollard. The removable security bollard cylinder locks into an embedment sleeve and can only be removed by unlocking the conveniently located, tamper-proof internal lock. When the bollard cylinder is removed a flip top, stainless steel lid covers the empty embedment sleeve. Internal Locking Removable bollards used in conjunction with fixed bollards creates a flexible barrier system that quickly allows large objects like promotional materials and vehicles to move through the barrier while maintaining superior stopping strength.

Carbon Steel	**Dimensions & Part Numbers**
	Dimensions & Part

External Locking Security Bollard





The External Padlocking Removable bollard is commonly used in industrial applications. The external padlock on the bollard allows relatively easy access to public service vehicles such as the fire or police into restricted areas. The External Padlocking Removable bollard offers the same versatility as the Internal Locking Removable bollard in a mixed barrier application of fixed and removable bollards to quickly and easily allow movement of large objects through the barrier. These bollards are ideal for use in college and university installations, access control for parking lots, and security and safety at military bases.

Carbon Steel	**Dimensions & Part Numbers**

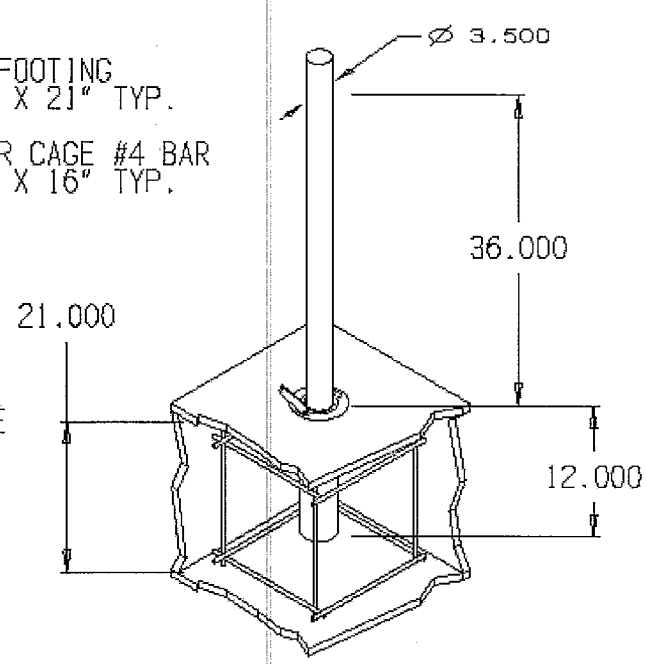
CAL PIPE SECURITY BOLLARDS

STANDARD FOOTING
21" X 21" X 21" TYP.

WITH REBAR CAGE #4 BAR
16" X 16" X 16" TYP.

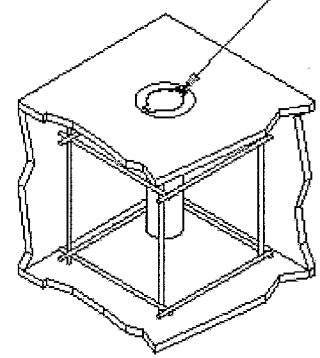
3" INTERNAL LOCKING REMOVABLE
PIPE BOLLARD MODEL #IBR-3000

ALSO AVAILABLE WITH
HEAVY DUTY INSERT
MODEL #IBR-3080



BOLLARD IN INSTALLED POSITION

TAMPER PROOF SCREW PROVIDED FOR
SECURING THE COVER WHEN BOLLARD REMOVED

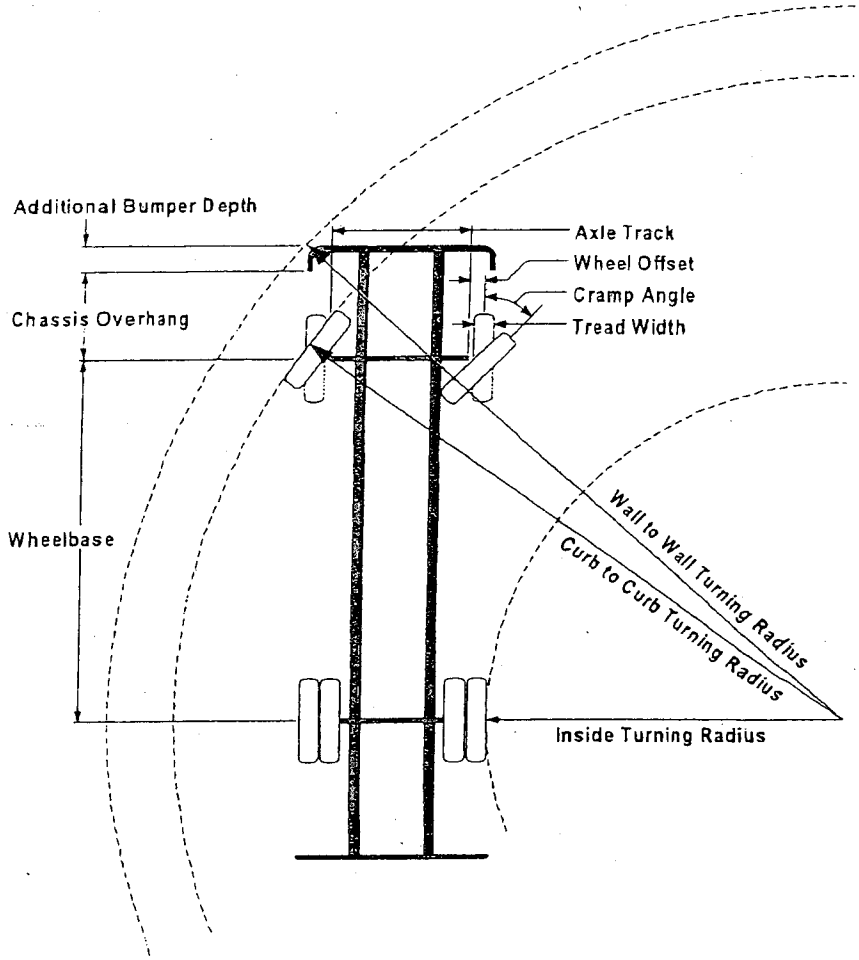


BASE WITH BOLLARD REMOVED

FIRE TRUCK TURNING PERFORMANCE ANALYSIS

Turning Performance Analysis

7/28/2003



Parameters:

Inside Cramp Angle:	33.00 °
Axle Track:	83.11 in.
Wheel Offset:	3.12 in.
Tread Width:	12.40 in.
Chassis Overhang:	65.80 in.
Additional Bumper Depth:	10.00 in.
Front Overhang	75.80 in.
Wheelbase:	240.00 in.

Calculated Turning Radii:

Inside Turn:	30 ft. 0 in.
Curb to Curb:	43 ft. 6 in.
Wall to Wall:	46 ft. 8 in.

Comments:

Aerial Application

TRUCK # E6841-02

Components	PRIDE #	Description
Front Axle	0000295	Axle, Front, Meritor FL-941, 21,000 lb
Chassis	0060010	Pierce Arrow Chassis, Glider, For (Refurb Only)
Front Bumper	0012242	Bumper, 10" extended - all chassis
Aerial Device	0006903	Aerial, 100' Medium Duty Ladder

Notes:

Actual Inside Cramp Angle may be less due to highly specialized options.

Curb to Curb turning radius calculated for a 9.00 inch curb.

Reduce turning radius by 33% if vehicle is equipped with all-wheel steer.

T-33

length- 20.3 ft.

width- 8 ft.

Turning Performance Analysis

7/28/2003

Definitions:

Inside Cramp Angle	Maximum turning angle of the front inside tire.
Axle Track	King-pin to king-pin distance of the front axle.
Wheel Offset	Offset from the center-line of the wheel to the king-pin.
Tread Width	Width of the tire tread.
Chassis Overhang	Distance from the center-line of the front axle to the front edge of the cab. This does not include the bumper depth.
Additional Bumper Depth	Depth that the bumper assembly adds to the front overhang.
Wheelbase	Distance between the center lines of the vehicle's front and rear axles.
Inside Turning Radius	Radius of the smallest circle around which the vehicle can turn.
Curb to Curb Turning Radius	Radius of the smallest circle inside of which the vehicle's tires can turn. This measurement assumes a curb height of 9 inches.
Wall to Wall Turning Radius	Radius of the smallest circle inside of which the entire vehicle can turn. This measurement takes into account any front overhang due to the chassis, bumper extensions and/or aerial devices.

QUANTICO EXCAVATION PERMIT PROCEDURES AND SAMPLE PERMIT

STANDARD OPERATING PROCEDURES (SOP)
FOR THE
MCB, QUANTICO EXCAVATION PERMIT

1. All organizations, units, occupants or contractors who plan to excavate aboard MCB, Quantico are required to obtain an approved excavation permit from Operations Section, Facilities Maintenance Branch, G-5, Bldg. 3252 prior to commencement of digging.

2. The occupant or contractor/unit representative will initiate the excavation permit by bringing a scale drawing of the area to be excavated to Bldg. 3252, Operations Section. The requester will fill out and sign the excavation permit form. The requester is also required to stake or flag the excavation route every 10 feet.

3. Operations Section will assign a permit number in sequence. The number will consist of the current FY number, a dash, and then a sequential number (i.e. 0-001 would be the first permit issued in FY 00).

4. Operations Section will make 2 copies of the permit and provide them to the requester. The requestor will obtain signatures of approval from G-6 and GTE (the 2 copies can be used to drop off to each organization). **Any organization that has utilities in the area will sign the permit only after they have marked their utilities on-site.**

5. The requestor will contact Miss Utility for the marking of any other non-Government utility. Miss Utility will provide the requester with a Work Order Number which the requester will write on one of the permit copies.

6. Operations Section will make 2 copies of the permit request and forward them to the 2 Facilities Maintenance Branch shops that maintain utilities, the plumbing shop and the electrical shop. These shops will sign the permit when they have completed the on-site marking of utilities.

7. The requester will deliver to Operations Section the copy/copies with signatures from G-6, GTE, and a Miss Utility Work Order Number.

8. When Operations Section has all signatures obtained from the requester and from the Facilities Maintenance Branch shops, the permit will be reviewed by Operations Section and approved or disapproved. If the permit is approved, Operations Section will assign an excavation risk

based on any precautionary measures identified and will check the approval block and sign the permit. An approved permit will be good for 30 days from the date of approval. If the 30-day period ends before the excavation work is completed, the requester must request and obtain an extension approval from the Operations Section.

9. If the permit is disapproved for any reason, the reason for disapproval will be discussed with the requester. Some cases may require a slight change to the area of excavation due to interference of existing utilities.

10. When the permit is approved, **the requester will be given a copy and will be required to have the copy on-site at all times during excavation.** The requestor is also required to maintain all on-site utility markings during the entire excavation process.

11. If a utility is damaged during the excavation process, the requester must notify Operations Section immediately at (703) 784-2089. It may be determined that the requester is liable for the damaged utilities and may be required to reimburse the Government or Miss Utility.

12. For any questions concerning excavation permits, contact Operations Section, Facilities Maintenance Branch at (703) 784-2089.

SAMPLE EXCAVATION PERMIT

Expiration date
Of permit:_____ Permit # _____ Date: _____

MARINE CORPS BASE, QUANTICO EXCAVATION PERMIT

1. REQUESTER:	**2. EXCAVATION RISK:**		**3. TYPE OF REQUEST:**	
POC: _____	CLASS I (SEVERE)	_____	EMERGENCY*	_____
Tele #: _____				
Contract # _____	CLASS II(MINIMAL)	_____	ROUTINE	_____

4. LOCATION OF AREA TO BE EXCAVATED:
(NOTE: A to-scale drawing of the excavation site must be submitted along with this form. Excavation route must be staked or flagged by the requester every 10 feet.)

5. TYPE OF WORK TO BE PERFORMED:

6. MISC INFORMATION:

a. This excavation permit is used for any work that may disrupt underground utilities, communications, right of ways or any routine activities.

b. Processing of this permit will take approximately 10-14 days. Requester must have an approved excavation permit prior to commencement of work and permit must be kept on-site.

c. If utilities or communications have been located in the area to be excavated, hand digging will be used within a 10-foot radius until the exact location of all lines have been determined. It is the responsibility of the requester to maintain the markings once the locates are done.

d. The Government reserves the right to have on-site personnel present during any excavation and will specify on this permit under precautionary measures if needed.

e. The requester shall take reasonable precautions to protect from damage all existing improvements, utilities, communications, and vegetation at or near the work site. The requester shall be liable for all damages to persons or property that occur as a result of the requester's fault or negligence.

***** f. Emergency requests are delivered directly to Director, Maintenance and Repair (M&R) or the Electro/Mechanical Shop General Foreman for expeditious action. Requester is still required to contact Miss Utilities, G-6, and GTE.

ENCLOSURE (2)

g. Any questions regarding this excavation permit may be directed to the Facilities Maintenance Operations (FMB Ops) Section at (703) 784-2089.

I HAVE FULLY READ AND UNDERSTAND THE ABOVE NOTES.

_____ _____
Signature of requester/POC Date

7. REQUESTER ACTION:

a. FMB Operations _____ c. G-6_____
Ticket #: _____ d. GTE_____
b. FMB
Plumbing Shop _____ e. Miss Utility_____
Electrical Shop _____ Work Order #_____
Date for Clearance_____

PRECAUTIONARY MEASURES:_____
_____

DIRECTIONS FOR REQUESTER ACTION:

1. FMB Ops (703) 784-2089	3252 Barnett Ave., Initiate Excavation Permit at least 14 days prior to commencement of work.
2. M&R (703) 784-2372	3252 Barnett Ave., see Director, M&R for directions to to respective shops.
3. G-6 (703) 784-2500	1999 Elliot Rd., Obtain signature from Assistant Chief of Staff, G-6.
4. GTE (703) 784-2500	1999 Elliot Rd., Obtain signature from GTE liaison office.
5. Miss Utility (800) 257-7777	Call Miss Utility at least 48 hrs in advance of excavation. Provide all information items A & C on the front of this form. A control number will be provided by Miss Utility. Must be updated every 15 days.
6. FMB Ops (703) 784-2089	3252 Barnett Ave., Contractor must obtain approval of excavation permit prior to commencement of work.

8.

Approved: _____ Name and title of Authorizing Official

Disapproved: _____

_____ _____

HEAD,FMB OPERATIONS DATE

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NAVRAMP GUIDEBOOK

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U.S. NAVY RADON ASSESSMENT AND MITIGATION PROGRAM

GUIDEBOOK

FOR

RADON MANAGEMENT IN NONRESIDENTIAL BUILDINGS

July 26, 2010

DRAFT

prepared for
NAVAL FACILITIES ENGINEERING COMMAND, PACIFIC
Environmental Compliance Product Line
Pearl Harbor, Hawaii 96860-7300
prepared by
OAK RIDGE NATIONAL LABORATORY
Oak Ridge, Tennessee 37831
managed by
UT-BATTELLE, LLC
for the
U.S. DEPARTMENT OF ENERGY
under contract DE-AC05-00OR22725

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ABBREVIATIONS

ACH	air change rate
ASD	active soil depressurization
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
ATD	alpha track detector
BEIR	Biological Effects of Ionizing Radiation (Committee on)
CA	charcoal absorption
cfm	cubic foot per minute
CRM	continuous radon monitor
DoDDS	Department of Defense Dependent Schools
DoDEA	Department of Defense Education Activity
DOE	U.S. Department of Energy
DP	differential pressure
EACM	episodic air change measurement
EPA	U.S. Environmental Protection Agency
ER	equilibrium ratio
ERV	energy recovery ventilation
FAS	forced air system
HAZWRAP	Hazardous Waste Remedial Action Program
HEPA	high-efficiency particulate air
IRAA	Indoor Radon Abatement Act
LFE	lateral field extension
LLD	lower level of detection
MMM	multimedia mitigation
MSDS	Material Safety Data Sheet
NAVFACENGCOM	Naval Facilities Engineering Command
NEHA	National Environmental Health Association
NRSB	National Radon Safety Board
O&M	operation and maintenance
ORNL	Oak Ridge National Laboratory
OSHA	Occupational Safety and Health Administration
PFET	pressure field extension test
PQL	practical quantization limit
QA/QC	quality assurance/quality control
RAC	relative air change
RDP	radon decay product
REP	radon entry pathway
RMP	radon management plan
RPC	radon potential category
RPD	relative percent difference
RRNC	radon resistant new construction
SAM	supplemental air makeup
SMD	submembrane depressurization

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SP	shell pressurization
SPT	subslab permeability test
SSD	subslab depressurization
UFC	Unified Facilities Guide Specification
USGS	U.S. Geological Survey
WHO	World Health Organization
WL	working level
WLM	working level month

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DEFINITIONS AND TERMS

assessment: The testing of all ground-contact rooms.

atypical building: A building with unique construction that is different from all other buildings at the site (e.g., underground command bunker).

blank: A radon detector that is returned to the laboratory unexposed in order to measure the background of the device.

closed building conditions: During the radon test, the unit's windows and exterior doors are closed except for routine entrances and exits.

collocated: Radon test devices that are placed within 12 in. of each other during a simultaneous measurement.

duplicate: Radon measurements that are performed using two radon testing devices at the same time.

mitigation: The corrective action taken in buildings or rooms that have been found to have radon levels ≥4 pCi/L.

normal testing conditions: The building is occupied, and the building's mechanical systems (e.g., heating and cooling systems) are operating under typical seasonal conditions.

occupied: A room or building in which one or more people spend > 4 h/day on average per year.

occupiable: A room not currently occupied but that could be occupied easily. Examples are bachelor quarter rooms, vacant offices, or offices used as storage rooms that could easily be converted to office space.

picocurie per liter (pCi/L): A common unit of measurement of the concentration of radioactivity in a fluid (liquid or gas). A picocurie per liter corresponds to 0.037 radioactive disintegrations per second in every liter of fluid. For radon testing purposes, pCi/L is the unit of measure of radon gas. EPA and NAVRAMP have set an action level of 4 pCi/L.

picocurie per liter per day (pCi/L-day): A measure of the detector dose; 1 pCi/L-day is the dose a detector receives if it is exposed to 1 pCi/L for 1 day.

screening: Radon testing in a representative statistical subset of rooms in a building.

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site: The subdivision of an activity into smaller geographical areas based on geology, building types, or remoteness.

spike: A radon detector exposed at a laboratory to a known radon concentration. When used in conjunction with field-testing, spikes measure the accuracy of the survey radon results.

testable building: A building which is enclosed, occupied and in ground contact.

testable room: A room in a building either in ground contact or over an untested basement or crawlspace and occupied on average for > 4 h/day.

Radon potential category (RPC): A dynamic category assigned by NAVFACENGCOM-HQ based on historical radon testing data to an activity or site which designates its radon potential and the level of testing required to meet NAVRAMP. Briefly the designations are

- RPC-1 means proven elevated radon potential exists,
- RPC-2 means the potential is unknown, and
- RPC-3 means a low potential for elevated radon exists.

radon: A naturally occurring, odorless, colorless, radioactive gas caused by the breakdown of uranium. Studies have shown that many years of exposure to elevated indoor levels of radon increase the risk of contracting lung cancer.

renovation: Repairs or upgrades that have an impact on the radon level within a building or room.

test type: A two-letter code assigned to a specific radon measurement to document the reason why the radon test was performed.

valid radon data: Radon measurements which meet the NAVRAMP QA/QC requirements.

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INTRODUCTION

This project was conducted in support of the Pacific Division, Naval Facilities Engineering Command (NAVFAC Pacific), under U.S. Department of Energy (DOE) Proposal 2172-S515-A1 for the performance of radon technical support. DOE assigned the project to its Oak Ridge National Laboratory (ORNL) Buildings Technology Center, managed by UT-Battelle, LLC, to assist with this agreement with NAVFAC Pacific.

The purpose of this document is to provide current radon policy for U.S. Navy personnel and to provide guidance for the implementation of radon-resistant new construction, radon testing, radon mitigation, and radon system maintenance activities within nonresidential buildings. In addition, where needed, the document also contains sections that document the rationale behind certain policy decisions. Therefore, this document should be used as the primary reference for all nonresidential radon projects within the U.S. Navy.

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1. BACKGROUND AND REFERENCE INFORMATION

1.1 OVERVIEW OF RADON GAS

Radon is a naturally occurring, odorless, colorless, radioactive gas caused by the breakdown of uranium (Fig. 1). Because uranium is a common substituent found in soil and rock matrixes throughout the world (on average about 3 g of natural uranium per ton), detectable quantities of radon can be measured everywhere. However, within certain rock formations (limestone, granite, shale, phosphate, and pitchblende), higher levels of uranium and its decay product radon are present. When radon is generated, it immediately begins diffusing toward the surface. In the outdoors, radon rarely reaches concentrations of concern; however, within enclosed spaces, such as buildings, radon can accumulate to levels in excess of federally mandated exposure limits for radiation workers. Because these geological formations are fairly common within the United States, measurable quantities of radon have been detected and reported in all 50 states. In fact, the U.S. Environmental Protection Agency (EPA) has estimated that 1 in every 15 homes has elevated radon levels (*A Citizen's Guide to Radon, Fourth Edition*, June 2001). Because of the prevalence of indoor elevated radon, radon exposure represents over half of the average annual radiation exposure for the typical U.S. citizen (Fig. 2).

1.1.1 The Radon Decay Series

Radon, the only gas in the uranium decay series, has a radioactive half-life of 3.82 days. The subsequent radioactive decay products, more commonly referred to as radon progeny, consist of four short-lived radon progeny [polonium-218 (^{218}Po), lead-214 (^{214}Pb), bismuth-214 (^{214}Bi), and polonium-214 (^{214}Po) (Fig. 1)] and three long-lived radon progeny [lead-210 (^{210}Pb), bismuth-210 (^{210}Bi), and polonium-210 (^{210}Po)]. Of these seven, typically only the short-lived progeny are considered a health risk. Unlike radon, which is chemically inert, radon progeny are chemically reactive metals that can attach to walls, floors, and airborne particles, or combine with water vapor and other gases in the air. The portion of the radon progeny attached to particles in the ambient atmosphere is called the *attached fraction*, whereas *unattached fraction* refers to suspended individual atoms or ultrafine particle clusters. Radon progeny that attach to walls or other surfaces are considered to be "plated out" and therefore removed from the air and can no longer be inhaled. When the short-lived radon progeny are inhaled, a portion of them can attach to the lining on the bronchioles of the lung. Because of their short half-lives, the lung cannot clear itself of these materials before they undergo radioactive decay. Of particular importance are ^{218}Po and ^{214}Po, which emit highly energetic alpha particles. These alpha particles can strike sensitive cells in the bronchial tissue and cause damage that could lead to lung cancer. It is these two polonium radionuclides that produce the bulk of the radiation dose to the lung and create the greatest source of risk of lung cancer from exposure to radon and radon progeny.

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1.2 RADON AND GEOLOGY

In 1995, the U.S. Geological Survey (USGS) in cooperation with EPA published a series of reports (USGS Open File Reports 93-292-A through K) that generalized radon potential within specific EPA regions. The evaluation and conclusions were based upon available USGS geological data and soil survey data collected by the Soil Conservation Service and also included radon data collected by EPA during the 1986–1987 national residential radon survey. Practically speaking, one would expect that a precursor for having elevated radon would be the presence of appreciable amounts of surface uranium or thorium concentrations (Figs. 3 and 4) Although the correlation was good between high indoor radon levels and significant levels of uranium and thorium in the soil, it was noted that similar levels of radon were also found in areas of the country with only trace levels of these elements. In addition, some areas that were known radiological "hot spots" exhibited a significantly lower than expected percentage of buildings with elevated radon. After further review and study, the conclusion was reached that the geologic radon potential was only part of predicting radon levels in a particular area. Factors such as the type and state of the geological formation (e.g., solid, layered, or fractured), local building codes, soil moisture content, depth and permeability, and weather all played a contributing role. Therefore, in 1993, the EPA and USGS included with the release of the radon potential map a disclaimer that the map should not be used as an indicator whether to test and recommended that all homes and buildings be tested regardless of geographic location.

1.2.1 National Radon Potential Map

In the early 1980s, little was understood about the mechanisms of radon transport and its retention inside buildings. The key assumption made at that time was that for a building to have an indoor radon problem, a significant uranium source needed to be close at hand. It was therefore postulated that a radiological potential map showing uranium deposits would greatly assist in identifying areas of the United States that would require radon testing. Limited studies conducted in Colorado and Pennsylvania in the mid 1980s tended to support this hypothesis. However, these studies were performed mostly in areas with high levels of uranium covered with moderately to highly permeable soils. Because of this assumed correlation between geology and radon potential, the Indoor Radon Abatement Act (IRAA) of 1988 (Public Law 100-551, Sections 307 and 309) directed the EPA to identify areas of the United States and its territories that have the potential to produce harmful levels of indoor radon. These characterizations were to be based on both geological data and indoor radon levels in homes and other structures. To assist with the geological requirements of the law, EPA entered into an Interagency Agreement with the USGS. From 1989 through 1992, EPA and USGS reviewed existing radiological maps, performed radon and geological surveys, and summarized all available radon data sets. The culmination of this effort was the publication in 1993 of the first EPA Map of Radon Zones (a more recent updated edition of the map is shown in Fig. 5). On the radon map, each county was placed into one of 3 categories:

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- Zone 1 High Potential (red): counties that have a predicted average indoor radon concentration > 4 pCi/L.
- Zone 2 Moderate Potential (orange): counties that have a predicted average indoor radon concentration between 2 and 4 pCi/L.
- Zone 3 Low Potential (yellow): counties that have a predicted average indoor radon concentration < 2 pCi/L.

A common misunderstanding by the public and others in interpreting the map was the use of the word "average," which brought into question the need to test buildings in Zone 2 and 3 counties. Later, EPA clarified the meaning of "average" to mean that if all the homes in this county were tested, the average would be expected to fall within those ranges. In addition, EPA stated that some homes in Zone 2 and 3 counties would test > 4 pCi/L, and the only way to know the radon level of a particularly building is to test it.

1.2.2 Radon Emanation within Rock and Soil

Radon is a naturally occurring, odorless, colorless, radioactive gas caused by the breakdown of uranium. In nature, uranium is found in varying amounts throughout the earth's crust, primarily in the mineral form of tyuyamunite [$Ca(UO_2)_2(VO_4)_2 \cdot 6(H_2O)$]. However, certain rock formations—primarily light-colored volcanic rocks, granites, dark shales, sedimentary rocks that contain phosphate, and metamorphic rocks derived from these rocks—contain higher than average uranium content (e.g., >3 ppm of natural uranium per ton). Because soil is essentially weathered rock mixed with organic matter, tyuyamunite is also found in soil at the same concentration as in the rock from which the soil was derived.

Because radon is a gas, it has much greater mobility than uranium and radium, which are fixed in the solid matrix of rocks and soils. However, for radon to be a concern, it has to migrate (diffuse or flow) from the rock or soil and become entrapped within a building. The term "radon emanation efficiency" refers to the overall ease with which radon moves from its natural matrix into the environment by a diffusion and/or flow mechanism. This efficiency is dependent upon the density of the matrix, the degree of fracture, the size of the pore spaces between the grains, and the moisture content. In addition, the efficiency is also time-sensitive, because the most common isotope of indoor radon (radon-222) has a relatively short half-life of 3.8 days. Therefore, in most cases, if radon is going to make a measurable contribution to the indoor levels, it must escape from the matrix and enter the building within less than 5 half-lives (*Relationships Between Geology, Equivalent Uranium Concentration, and Radon in Soil Gas, Fairfax County, Virginia,* USGS Report 1988-18). If radon is generated within a dense rock with minimal pore size, at most it could migrate only a few centimeters (Tanner 1964). Therefore, in this type of rock, only radon generated within the top few centimeters of the surface could escape and potentially migrate into a building. Conversely, if the rock has a low density and a large pore size and is fractured, the migration of radon can be on the order of hundreds or thousands of feet (Akerblom 1984, Sextro 1987, and Wilson 1991).

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Regardless of the primary source of radon (e.g., rock or soil grain), before radon can enter a building, it usually must past through a layer of soil. The method (e.g., flow or diffusion) and speed of radon's movement through soils are controlled by the amount of water present in the pore space (the soil moisture content), the percentage of pore space in the soil (the porosity), and the interconnectedness of the pore spaces, which determines the soil's ability to transmit water and air (USGS, Otton 1992). The term *soil permeability* refers to the overall air flow characteristics of a particular soil and is an indicator of the relative ease with which radon moves from its natural matrix into the environment by a diffusion and/or flow mechanism. As with radon transport through rock, extremely dense, nonporous soils (e.g., low-permeability soils, <1.5 cm/h) can significantly reduce the amount of radon available for incorporation into a building. Likewise, if radon is able to move easily in the pore space (e.g., high-permeability soils, >15 cm/h), then it can travel a greater distance before it decays, and it is more likely to collect in high concentrations inside a building (Nagada 1994 and USGS, Otton 1992).

In summary, the presence of high levels of uranium in the soil and/or rock is not the sole precursor of elevated indoor radon potential. Radon must first emanate from the rock or soil grain and find a pathway through the soil to the building. In dense rock and nonporous compacted soils, the reservoir of radon available for transport into a building can be limited to just the first few inches of rock and/or soil under a building. However, in high-emanation-efficiency rock and/or soil matrixes in contact with a permeable soil, even negligible levels of uranium can produce a high soil gas concentration.

1.2.3 Geological Features that Enhance Radon Transport

In addition, certain geological features such as karst topography have also demonstrated the capacity for seasonal variation (Gammage et al. 1992). "Karst" is a term used to describe a topography in which surface water or groundwater has dissolved sedimentary rocks such as limestone. The result of the erosion is a subterranean network of shafts, tunnels, cavities, and caves (Mammoth Cave in Kentucky being a good example). Also, in most cases, the shafts, tunnels, and cavities connect to the surface. In solid rock, radon can at most diffuse a few centimeters (Tanner 1964). Therefore, for all practical purposes, radon availability is limited to the surface of the rock. However, a karst network greatly increases the surface area of a given formation, resulting in much greater emanation efficiency. The network of caves, tunnels, and shafts then serve as a means to both concentrate and transport the radon from considerable depths to the surface. Another characteristic of karst networks is that they breathe: whenever the ambient outdoor temperature is different from the ground temperature, the network will exhaust air or draw it in. The driving force is simply that warm air rises and cool air sinks. In flat karst areas, winter levels of indoor radon average 2–3 times those observed in the summer months. However, in cases in which a karst network is inside a hill, ridge, or mountain, the effect is even more enhanced by the stack or chimney effect. For example, a building built on the top of a hill connected to a karst network will see an order of magnitude increase in indoor radon concentration in the winter. Those located at the bottom of the hill will have a similar order of magnitude increase, but only in the summer months.

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Another example of a geological feature that causes seasonal variation and higher than expected indoor radon levels is sheared fault zones (common in the Appalachian region of the Eastern United States). Like karst, these faults result in higher radon emanation from the uranium-bearing formation (rocks with cracks have more surface area than solid rocks) and allow the radon to migrate from considerable depths (upward of 1,000 ft) and distances (several miles).

As for soils, certain types of glacial deposits also enhance the indoor radon concentrations. Many areas of the United States underlain by soils derived from continental glacial deposits generate elevated indoor radon levels (> 4 pCi/L). For example, Iowa (71 percent), North Dakota (63 percent), and Minnesota (46 percent) have some of the highest percentages of homes with elevated indoor radon levels in the State/EPA Residential Radon Survey. Determining the radon potential of glaciated areas is complicated by several problems:

1. Surface radioactivity is generally uncharacteristically low in glaciated areas and does not appear to correlate well with indoor radon values.
2. Because glaciers redistribute the bedrock they override and entrain, the composition and physical properties of till soils do not necessarily reflect those of the underlying bedrock (transport distances were much further for the continental glaciers of the Great Plains and Great Lakes regions than for glaciers in New England or for valley glaciers.
3. Where glacial cover is thin, the radon potential may be a complex product of the glacial cover and the underlying bedrock. Crushing and grinding of rocks by glaciers increases the mobility of uranium and radium in the resulting tills, allowing them to move readily downward through the soil profile with other mobile ions as the soils are leached.

Because of these day-to-day and seasonal variations, BEIR VI (1998) conceded that although all exposure to radon increases the risk of contracting lung cancer, the need for corrective action should be based on an integrated 1-year average, not on short-term excursions.

1.3 HOW RADON ENTERS A BUILDING

Radon, a gas at ambient temperatures and pressures, migrates from the surrounding soil into buildings through cracks in concrete slabs and basement foundation blocks, through pores in concrete masonry units, and through air spaces around pipes (ASHRAE *Indoor Air Quality Guide*, 2010). It can also collect in crawl spaces and then flow into living and work areas. The flow of radon into the living area of a building is caused by both natural diffusion and pressure-assisted flow. However, natural diffusion usually contributes only a small amount of radon within a building; in most cases, radon above ambient levels can be attributed to pressure-assisted flow.

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The process of pressure-assisted flow can be either natural or man-made. The rising and exiting of warm air within a building causes natural pressure-assisted flow, or thermal stack effect. As warm air rises, makeup air is pulled into the building through slab and wall imperfections. If the imperfections are in contact with soil, the building radon concentration increases. Man-made enhancement of radon entry is primarily the result of slight negative pressure created by the operation of a furnace, air-conditioning system, ventilation fan, or air exhaust system.

The physics of radon transport and retention in a building are very complex. The radon source term is the total quantity of radon entering the structure per unit of time (pCi/h). Studies by EPA and DOE have identified more than ten variables that contribute to the source term (e.g., radium content of the soil, emanation efficiency of the soil matrix, soil permeability, soil water content, various temperatures, and shell and subslab pressures). After radon has entered a structure, many other variables either enhance or dilute it. The term relative air change (RAC) refers to the rate at which outdoor air infiltrates into the building shell and inside air is exhausted (because of both natural and man-made causes). Generally speaking, if the radon source term is greater than the RAC, then elevated radon will result. Because of these variables, there is no certain way to predict the radon level of a particular building; the only sure way is to test.

1.3.1 Indoor Radon Retention

Although radon diffusing through and, in rare cases, from concrete can contribute to the indoor radon level, the main driving force for most buildings is the pressure differential caused by the stack effect (the rising and escape of warm air in a building through the upper floors) and the negative pressures caused by the operation of mechanical exhaust systems within a building (e.g., bathroom exhausts, fume hoods, combustion furnaces). In addition, episodic weather conditions, such as wind and rain, can induce a pressure differential resulting in transient increases in the building radon level.

Although the physics of radon transport into and retention in a building are complex (more than ten variables have been identified to date), it can be approximated as a simple dilution ventilation problem using a source term (pCi/h) into a fixed volume (ft^2), with a known ventilation rate (h^{-1}). Because the volume of a structure is fixed, the equation can be further simplified to demonstrate that elevated radon in a building is strongly linked to the overall ventilation rate of the building, meaning that buildings with high ventilation rates have lower elevated radon potential. Conversely, buildings with lower ventilation rates have higher elevated radon potential. However, the relationship between ventilation rate and radon concentration is not 1 to 1; at a constant source term, halving the ventilation rate doubles the radon concentration (EPA, *Radon Reduction Techniques for Detached Housing*, EPA/625/5-87/017, 1988). This variable, ACH, is a function of how tightly the building was constructed and is regulated by the requirements of local building and energy codes. Nationally, the ACH ranges for residential and nonresidential construction are from 0.25 h^{-1} in colder (e.g., Minnesota) or hot and humid (e.g., Florida) climates to over 1.5 h^{-1} in the temperate tropical areas (e.g., Hawaii). The significance of the relationship between indoor radon levels and a building's ACH is as follows.

Assume for a source term that you have 500 pCi/L of soil gas (average for most parts of the United States) under a slab that results in a 2-pCi/L radon level (the approximate indoor national average) for a house with an ACH of 1 h^{-1} (typical for homes built in Hawaii). The same home in Tennessee, under identical conditions but with a typical ACH of 0.5 h^{-1}, would have a radon level of 4 pCi/L. However, if the home were located in the upper Midwest, at a typical ACH of 0.25 h^{-1}, the home would have 8 pCi/L. Therefore, when considering elevated indoor radon potential, in addition to the geological variables found in soil and rock, local building practices must be taken into account.

As can be seen in Fig. 6, a rain event that lasted only a few hours resulted in an order of magnitude increase in the radon concentration. The time required for the dissipation of this radon spike is mostly dependent upon the ventilation rate of the building. For example, if the building has an air change rates of 0.5 h^{-1}, the spike would usually dissipate within 6 h (assume in this example that 3 air volumes are required to remove a gas pollutant). However, in some cases (e.g., buildings with tight envelopes or buildings with fresh-air makeup greatly reduced), the radon spike may require days or even weeks to fully dissipate. As a result, the integrated concentration in the room over time would vary significantly depending upon the frequency (how often) and quantity (how much) of rainfall within a certain time period.

1.3.2 Episodic Events that Impact Indoor Radon Levels

Unlike other common indoor environmental concerns (e.g., lead-based paint and asbestos), indoor radon concentration can vary significantly from day to day and from season to season. The day-to-day variation in radon concentration is usually caused by episodic weather events such as rain and wind but can also be caused by actions of the building occupants (e.g., leaving doors or windows open; see Fig. 6). For these reasons, EPA recommends that all short-term testing (testing for < 90 days) be performed during normal weather patterns and under closed building conditions. With respect to seasonal variation (e.g., heating vs. cooling season), the range observed is dependent upon the geographical region and climate. For example, in the northeastern United States, radon concentrations are typically 50% higher than normal in the winter, vs. 25% higher in the Southeast. Opinions vary as to why this is observed (e.g., increased stack effect in the winter, prolonged periods of closed building conditions, ground freeze, and snow cover), but most experts agree it results from a combination of many things and not just a single cause.

1.3.3 Distribution of Radon within Nonresidential Buildings

Residential studies by EPA have shown that on the same level, the radon concentration does not vary significantly from room to room in most homes. It is for these reasons that other than recommending that the test be performed on the lowest occupied level, EPA protocols do not specify which rooms to test (EPA 402-R-92-003, May 1993). However, unlike in residential buildings, the distribution of radon within nonresidential buildings does vary significantly from room to room. In fact, studies by DOE have found that for buildings >2000 ft^2 with elevated radon, over 95% of the time, only one in four rooms

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tested positive (Wilson et al 1991). With respect to using statistical means to estimate the extent of elevated radon potential in large buildings, statistical analysis of large nonresidential data sets (Wilson et al.) has found that over 70% of the time, the elevated result(s) would not have been predicted at a 95% confidence. Further modeling of the radon data, whereby the objective was to predict the presence of one room with elevated radon in a building, found with 95% confidence that 95% of the rooms needed to be tested (DOE, DOE/HWP-96, 1990). It is for all these reasons that EPA recommends the testing of all occupied ground-contact rooms in its nonresidential testing protocol (EPA 402-R-92-014, July 1993).

As to why this disparity in room-to-room concentration occurs, there are many accepted reasons. For one, slabs in nonresidential buildings are larger, meaning a greater volume of radon can accumulate in the fill area under the slab. In addition because of higher load considerations, large buildings typically have more internal footings and expansion joints per unit area of slab than residential construction. Also, large buildings tend to have more numerous floor penetrations for water, sanitary, electrical, and communications. Another difference is interior design; to prevent the spread of smoke during a fire, floor-to-ceiling fire walls are typically used throughout the building. This design feature tends to isolate rooms and areas from each other within the building by reducing the natural flow of air from one zone to another. Finally, large buildings have larger mechanical systems, which move significant volumes of air. If these systems are not balanced, certain areas of the building may become depressurized relative to the soil beneath it. If openings are present within the slab in those rooms, the concentration of radon soil gas entering those rooms will increase significantly. In fact, DOE studies have found that in nonresidential buildings with elevated radon, only about one-third of the higher radon concentration is directly attributed to the elevated radon. Another third was attributed to a combination of mechanical and building design features. In summary, the distribution of room-to-room radon concentrations in large buildings is different from the distribution in residential buildings simply because the buildings are designed and conditioned differently. (Additional information about radon distribution in large buildings is included in Section 1.6.5.)

1.3.4 Surface Radon Potential and Indoor Radon Levels

In the late 1980s and 1990s, considerable effort was expended by USGS, EPA, and DOE in attempting to correlate radon soil gas concentrations and indoor radon levels (Tanner 1986 and 1992). The primary hypothesis of these studies was that if the radon flux at the surface could be measured accurately, the number of homes in a given area with elevated radon could be estimated. This would assist state and local governments in coordinating their respective radon programs and determining if radon-resistant features in new construction were needed. Unfortunately, during these studies, many variables at the surface/building interface were identified which proved difficult to estimate in advance (e.g., estimating the total leakage surface are of the slab for all crack, joints, and plumbing fixture openings). In addition, order of magnitude changes in the radon soil gas concentration were observed at some of the sites because of variations in microgeology. Estimating the building's shell natural ventilation rate and the stack effect of the structure

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proved difficult as well. In light of all these uncertainties, EPA concluded that radon surface flux or soil gas measurements at a given location did not provide sufficient assurance whether indoor elevated radon would be present. In addition, the costs of such measurements were orders of magnitude higher than simply incorporating radon-resistant features into new construction and testing afterward.

1.3.5 Radon from Building Materials

The precursors for radon—uranium, radium, and thorium—are found naturally in all geological formations. Therefore, in any building where concrete (processed limestone) or decorative stone (e.g., marble, granite, shale) is present, radon is being emitted. In the case of concrete, in the 1970s, homes located in Durango and Grand Junction, Colorado, were found to contain high levels of radon in addition to high radiation levels. The source of the radon and radiation was later determined to be from processed uranium mill tail sand that had been used as aggregate in the concrete and cement block in the homes. In response to the health hazards posed by this exposure, Congress enacted the Uranium Mill Tailings Radiation Control Act of 1978 (UMTRCA). This Act established two programs to protect the public and the environment from uranium mill tailings and prohibited the use of uranium mill tailing sands in building construction. In the 1980s similar problems with radon and elevated radiation were also found in the southeastern United States, where processed phosphate slag had also been used as an aggregate within concrete and cement block manufacturing. A series of environmental regulations were then enacted which prohibited the use of these materials in building construction as well.

As for concrete that came from gypsum, fly ash, and limestone, studies by EPA in the late 1980s found minimal contribution to the indoor radon level. As for decorative stone, a series of news articles in 2008 indicated that high levels of indoor radon were linked to granite countertops. Studies by the decorative stone and radon industry and by EPA concluded that this claim was false for almost all granites on the commercial market.

More recently, however, the issue of elevated indoor radon linked to building materials has emerged within buildings that have had significant weatherization upgrades or in new construction with a high energy efficiency rating. The common denominator in all cases observed thus far has been extremely low ventilation rates ($< 0.1\ h^{-1}$) within buildings made of concrete (floor, walls, and ceilings). Although the emanation rate of radon from the concrete was found to be low (buildings at the same site made from the same concrete but without the weatherization tested extremely low for radon), the low ventilation rate allowed the radon to concentrate (empirically speaking, if you halve the air change rate you double the radon concentration). These findings, although rare (>99% of all elevated indoor radon is directly linked to radon soil gas), are predicted to become more common in the future as building codes require tighter buildings to address climate change concerns.

Another example of elevated radon from nontraditional sources is cases in which radon is emanating from materials stored within the building. For example, a storage facility containing approximately 1,000 tons of river sand (radon activity 0.07 pCi/g) gave rise to

8.5 pCi/L within the occupied areas of the building. Another facility that warehoused thorium lantern mantels was found to have elevated radon as well. Although these cases were extremely rare, the cause—substandard ventilation—was the same.

1.3.6 Radon from Groundwater Sources

The ^{222}Rn concentration in groundwater is due to the decay of ^{226}Ra contained within the rock and soil surrounding the aquifer. As radon gas is generated, it diffuses through the soil and rock and then percolates through the water. Because radon is soluble in water (230 cm^3/kg at 20°C), it can concentrate to levels much higher than that of the dissolved ^{226}Ra. Release of the radon into the indoor environment occurs at point sources wherever the water is used (showers, sinks, clothes washers) and from hot water heaters. According to EPA, approximately 10,000 pCi/L of radon in water is needed to increase the indoor radon level by 1 pCi/L. Because the average waterborne radon level in public groundwater supplies is 353 pCi/L (USEPA 520/5-85-008), radon in water is not considered a major contributor to airborne radon exposure. However, according to the Centers for Disease Control (CDC), 30 to 1,800 deaths per year are attributed to the ingestion of radon in water. Because of these health concerns, Congress included radon in the 1996 Amendments to the Safe Water Drinking Water Act (SDWA).

1.4 RADON EXPOSURE RISKS

For many years, radon was not considered a health problem in residential buildings; however, in 1984, private homes in the Reading Prong area of Pennsylvania were discovered to have levels of radon in excess of federally mandated exposure limits for radiation workers. Nero et al. (1986) estimated that about one million American homes have radon levels in excess of 8 picocuries per liter (pCi/L). In 1988, studies by the National Research Council and the Committee on Biological Effects of Ionizing Radiation (BEIR) found that excessive exposure to radon progeny resulted in a higher-than-predicted number of deaths from lung cancer in mining populations (BEIR et al. 1988). Based on this and other information, the EPA estimated that from 5000 to 20,000 lung cancer deaths per year are attributable to radon exposure (*A Citizen's Guide To Radon*, OPA-86-004, 1986). In 1996 the World Health Organization (WHO) acknowledged that worldwide, radon exposure was the second leading cause of lung cancer behind smoking (WHO April 1993). More recently, BEIR VI (1999) reinvestigated the health risks associated with radon exposure. Using information from previous studies and supplementing it with information from more recent laboratory studies, the committee estimated that approximately 11,000 lung cancer deaths per year were attributed to exposure to radon (BEIR VI, 1998). These mortality estimates make exposure to radon the second-leading cause of lung cancer behind smoking. However, statistically speaking, an individual's lifetime risk of dying from radon lies between the risks of being killed by a drunk driver and drowning (Fig. 7). Individual relative risk from radon exposure is summarized in Table 1. These findings were borne out by other studies noted by WHO in 2009 (WHO, 2009).

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1.4.1 EPA Corrective Action Guidelines

In 1986 EPA published the first of three subsequent editions of *A Citizen's Guide to Radon*. Unlike other EPA publications, the follow-up editions did not supersede or replace previous editions; they only provided additional information and, in the case of subsequent editions (the most recent is EPA 402/K-09/001, revised January 2009), a more user-friendly format. The key points in these documents are as follows:

1. There are no safe levels of radon. Exposure to the average outdoor level found in the United States is roughly equivalent to 20 chest X-rays per year.
2. Because of the cost of reducing the radon levels in homes, EPA established a guideline of 4 pCi/L as an action level based on reducing the radon risk to the general population at a reasonable cost.
3. In the subsequent editions, the significantly increased risks of radon exposure and smoking were also included.

In the 1986 edition of *A Citizen's Guide to Radon*, EPA provided a recommended timeline for corrective action (Table 2). This timeline, although excluded from later editions, is still a useful guide in determining when to take corrective action. However, EPA recommends in all three editions that corrective action be taken as soon as possible.

Table 1. *A Citizen's Guide to Radon* corrective action schedule

EPA radon action levels (pCi/L)	Recommended actions
0 to < 4	No action required
4 to < 20	Mitigate within a few years
20 to < 200	Mitigate within a few months
≥ 200	Mitigate within several weeks

Source: U.S. Environmental Protection Agency, A Citizen's Guide To Radon, OPA-86-004, 1986.

1.5 RADON MEASUREMENT

As defined by EPA, radon measurements are of two distinct types: short term (2 to 90 days) and long term (91 to 365 days). The advantage of short-term measurements is that radon data can be collected quickly. In addition, because detectors are in the field for less time, the potential for field attrition is much lower. With respect to accuracy and cost, both types of measurements are comparable. However, unlike most pollutants, indoor radon levels are constantly changing. Studies by EPA and DOE have found that indoor radon levels can vary by as much as a factor of 10 from one season to another. Also, other studies have shown that the indoor concentration of radon can increase by a factor

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of 2 to 10 during short-duration weather events (e.g., rain, periods of high winds, and cold snaps; see Fig. 6). Because of these variations, EPA bases the health risks of radon exposure on an integrated annual average. When performing a short-term test, EPA recommends that the measurement be performed under closed building conditions, which means that in a heating climate, the test should be performed ideally at the season midpoint with the building closed (e.g., windows and doors kept closed at all times) and not during periods of abnormal weather conditions. In addition, if the test is <4 days in duration, the house must be closed for at least 12 h prior to the placement of the testing device.

A long-term measurement offers the advantage of integrating the impact of short-duration weather effects over a longer period of time. Also, a long-term measurement can be performed during normal living conditions, thus minimizing the impact of radon testing on either work or living activities.

Because of these and other considerations, EPA recommends that any radon test be performed for as long as possible in order to provide the most accurate representation of the annual average. Because corrective action can be expensive, EPA recommends that follow-up measurements be performed in cases where elevated radon was detected and, in particular, in cases where abnormal weather occurred during the test period. Generally speaking, the higher the initial radon result, the more confidence one has that elevated radon is present. For example, if the initial radon result is ≥ 8 pCi/L, EPA recommends immediate short-term measurements be performed or mitigation performed (EPA 402/K-09/001, January 2009).

1.5.1 Types of Radon Gas Detectors

EPA divides short-term measurement devices into two categories, continuous and integrating. Continuous radon monitors (CRMs) typically measure radon gas or radon decay products in air. These measurements are performed in real time, meaning that the radon concentration can be measured and studied at fixed time intervals. To measure radon, room air is either pumped or diffused into a counting chamber that detects the ion particles generated by the radioactive decay of radon and its progeny. The counts per unit of time measured by the detector are then transmitted to a recording device (electronic or printer), where they are converted into picocuries per liter. Detection methods for CRMs include ion-trap, pulse ion-chamber, scintillation cell, or silicone integrated circuit detector. The typical exposure period for CRMs, as for most short-term devices, is 2 to 7 days. However, the chief advantage of CRMs over passive devices is the ability to "see" what is occurring by recording radon concentration as a function of time. When the instrument is downloaded and the data plotted, the impact of episodic weather events and other nonstandard tests (e.g., doors and windows left open) can be measured and quantified (Fig. 8). If used properly, CRMs are the most accurate of all short-term radon measurement devices. For example, most commercially available instruments are typically within 5% of the true radon concentration (vs. 15 to 25% for integrating devices). However, the disadvantage is the high initial purchase cost, $500 to $25,000 per CRM. Also, CRMs must be maintained and require periodic calibration.

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Integrating devices average the radon exposure by absorption, physical damage to a film, or the loss of surface electrical potential. A key difference between integrating devices and continuous devices is that after the measurement has been performed, integrating devices are analyzed in an off-site laboratory. If integrating devices are used in high-priority, short-term measurements (e.g., real estate transactions or confirmation measurements), EPA recommends that the measurement be performed with collocated duplicate detectors. Common examples of integrating radon detectors for short-term measurements are charcoal canisters and electrets.

A charcoal canister consists of an airtight container with a known quantity of activated carbon. To sample radon, the carbon is exposed to the area tested (typically, by removing the lid) for a period of 2 to 7 days. During the exposure period, the radon in the air is absorbed into the charcoal granules. At the end of the sampling period, the canister is sealed and returned to the laboratory for gamma spectroscopy analysis. After analysis, the corrected gamma counts per minute divided by the time of exposure are proportional to the radon concentration. The main advantage of using charcoal is its low unit cost. In large quantities, charcoal test kits can be obtained for under $5 per measurement (price includes canister and analysis). However, certain technical and logistical considerations can negate this cost advantage. Because charcoal permits the continual absorption and desorption of radon, this device does not give a true, integrated measurement over the exposure time. This means that the reported result may be significantly biased by either episodic or random events during the last 8 to 12 h of exposure. Another consideration is that all charcoal-based radon detectors have a maximum exposure limit. Because absorption sites within the charcoal granules are not specific, water and certain organic vapors compete with radon. Over time, these active absorption sites become irreversibly saturated with water, preventing further radon absorption. If water saturation occurs, the test must be repeated. Another consideration is holding time. At the laboratory, gamma spectroscopy analysis measures the quantity of radon presently absorbed in the charcoal. Because ^{222}Rn (the most common isotope of radon) has a half-life of 3.8 days, it is imperative that the canister be read within 2 weeks of the conclusion of sampling.

Electret-based radon detectors consist of two distinct parts: the ion chamber and the electret (Fig. 9). The ion chamber is a specially designed holder for the electret, which is made of electrically conducting plastic. This feature permits the uniform discharge of any static energy generated by the decay of radon or radon daughters in the air inside the chamber. An electret consists of an electrically charged wafer of Teflon that has been treated to hold a stable electrostatic potential. This potential attracts oppositely charged ions that collect on the electret surface, thus neutralizing the surface charge and reducing the electrostatic potential. The surface potential is measured before and after exposure, using a specially designed voltage reader. The decrease in surface potential during exposure is proportional to the concentration of radon integrated over time. When new, the voltage of an electret is between 700 and 750 V, and the electret can be reused until the voltage drops below 200 V. The discharge rate, or volts per unit of time per radon concentration, depends on the volume of the ion chamber and on the sensitivity of the electret. High-sensitivity electrets discharge at a rate 11 times that of low-sensitivity

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electrets. For short-duration tests, such as 90 day tests, a higher discharge rate is needed for better accuracy. For example, a 90 day measurement conducted at 1 pCi/L of radon with a low-sensitivity electret would yield only a 6 V drop, whereas a high-sensitivity electret would yield a 66 V drop. The higher voltage drop results in an accuracy increase of about 50% in this example. Conversely, for longer exposures, such as 240 days, the drop in voltage for the high-sensitivity electret would be 176 V, or 35% of the usable voltage for the electret. The lower-sensitivity electret would drop by only 16 V, losing only 3% of its usable voltage.

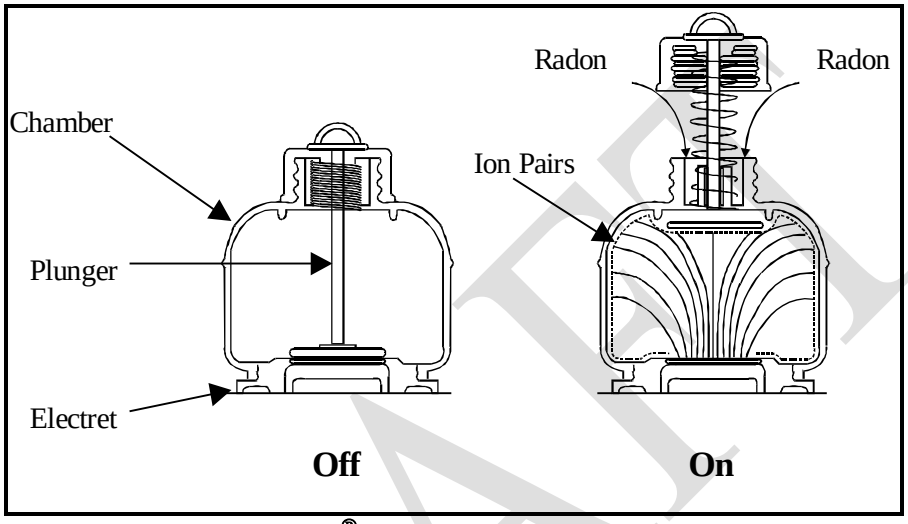

Fig. 1. E-Perm® electret-based radon detector.

As with charcoal, one of the major advantages of electret-based radon measurements is the low cost per measurement. Because electret-based detectors are reusable, electret measurements also can be performed for less than $5 (excluding field labor). Unlike charcoal canisters, electrets can be placed for more than 7 days and are insensitive to water and organic vapors. In addition, electrets are true integrating devices, meaning they are not dependent upon the last 8 to 12 hours of exposure. The total voltage discharge is proportional to the average radon concentration during the exposure period. Most important, electret readers are field portable; that is, detector analysis can be performed at the job location. However, unlike charcoal, an electret does have an upper limit for radon exposure. For new electrets, the maximum usable dose is approximately 250 pCi/L-days (1 pCi/L-day = 1 pCi/L exposure for 1 day). Therefore, each time an electret is used, care must be taken to ensure that sufficient usable voltage remains to perform the measurement.

For long-term measurements (>90 days), using CRMs is generally not considered cost-effective. Instead, either electrets or alpha track detectors (ATDs) are used (Picture 1). ATDs, the oldest and best understood of long-term measurements, work on the principle of counting physical damage (tracks) to an acrylic chip (CR-39) caused by alpha particles generated during the radioactive decay of radon. During the deployment of an ATD, radon diffuses through a filtered membrane (in the most common type of ATD). If radon undergoes radioactive decay while in the holder, the subsequent radon daughters are

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attracted to the CR-39. If the daughters deposit on the surface of the CR-39, subsequent alpha decay will leave a submicroscopic track on the surface of the CR-39. After the ATD is retrieved, it is returned to the laboratory for development and analysis. This is performed by disassembling the ATD, removing the CR-39 chip from the holder, and placing the CR-39 chip in a heated caustic solution (potassium or sodium hydroxide) for about 12 to 24 h (depending on the vendor). This caustic development or etching enlarges the alpha tracks so that they can be viewed and counted under a microscope. The tracks per unit of area (track density) as a function of time (days) are proportional to the radon concentration (pCi/L).

1.5.2 Measurement of Radon Decay Products

Although measuring radon gas in air is the most common method used today by radon testing companies within the United States, another method measures the radiological activity of radon progeny that have become attached to particles suspended in air. To perform this measurement, the equilibrium ratio (ER) must either be determined or assumed. Simply speaking, the ER is the percentage of radon daughters attached to particles that are suspended in air. The ER is calculated by dividing the total concentration of radon decay products (RDPs) present by the concentration that would exist if the RDPs were in radioactive equilibrium with the radon gas concentration present. Therefore, at equilibrium (i.e., at an ER of 1.0), one working level (WL) of RDPs would be present when the radon concentration was 100 pCi/L. However, because of ventilation and plate-out (the attachment of an RDP to the wall, floor, or object within the room), the ratio can never be 1.0. Residential studies performed by EPA found typically an average ER of 50% (the range was from 30% to 70%) for typical residential structures with average air recirculation rates.

In most nonresidential buildings, however, the ERs are consistently lower, ranging from 5% to 30% with an average ER of 25%. The exact reasons for the lower average ER are subject to debate. But most nonresidential buildings are nonsmoking, do not have pets, have more efficient heating and air-conditioning filters, and are usually cleaned more frequently. Therefore, for the most part, the common sources for residential particles in air are absent.

To convert from units of WL to equivalent gas concentration in pCi/L, the WL is multiplied by 100 and then divided by the ER [Eq.(1)]. For example, 0.02 WL (RDPs) × 100 / 0.5 (50% ER assumed) would equal an equivalent gas concentration of 4.0 pCi/L. It is important to note that if the ER is assumed, the gas concentration should be identified as “equivalent gas concentration” to avoid confusion. Table 3 shows equivalent gas concentration in picocuries per liter (pCi/L) at various WL concentrations and ER at a 4 pCi/L gas concentration.

$$\textbf{Radon (pCi/L)} = \frac{\textbf{WL} \times \textbf{100}}{\textbf{ER}}$$

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Equation 1. Conversion from gas to WL

Table 2. Equivalent gas concentrations at 4 pCi/L for various equilibrium ratios

Equilibrium ratio	Working level	Equivalent gas concentration (pCi/L)
0.05	0.002	0.4
0.1	0.004	0.8
0.2	0.008	1.6
0.3	0.012	2.4
0.4	0.016	3.2
0.5	0.02	4.0
0.6	0.024	4.8
0.7	0.028	5.6

For many years EPA set the action level for measuring RDP at 0.02 WL (EPA 402-R-92-003, 1993, and EPA 402-K-06-093, November 2006), which is equivalent to a 4.0 pCi/L gas concentration at an ER of 0.5 (the default value recommended by EPA if the ER is unknown). But in 2007 EPA lowered the action level from 0.02 to 0.016 WL (the gas concentration action level remained unchanged at 4.0 pCi/L) and decreased the assumed ER to 0.4 (EPA 402-K-07-009, revised May 2007). However, in the most recent *Citizen's Guide*, testing options using RDP were not included (EPA 402/K-09/001, January 2009). Instead, only radon gas measurement options were provided.

The most common WL measurement devices are CRMs or electrets which consist of a pump, filter paper, and detector. The basic principle of operation is that dust particles with the RDPs attached become trapped on the filter paper. The detector then measures the alphas emitted by ^{218}Po and ^{214}Po as a function of time and flow rate. Studies have shown that even common occurrences within buildings can change the ER and, in turn, affect the WL measurement. For example, simple routine occurrences such as smoking, lighting a candle, cooking, dusting, or vacuuming have resulted in doubling the response of the WL meter. Conversely, increasing the amount of air movement within a building by turning on a ceiling fan or the heating and air-conditioning blower can reduce the response of the WL meter by up to 1 order of magnitude.

As to why this is observed, in the first case, the generally accepted theory is that the generation of additional airborne particles increases the number of sites suitable for RDP attachment and their subsequent capture on the instrument's filter paper. This results in the increase in measured WL. In the latter case, the causes for the decrease in instrument response are not as clear. As a result, two divergent but viable theories have been proposed. In the first theory, it is assumed that the RDPs, once adhered to an airborne particle, become irreversibly attached. As these particles (including the attached RDP) collide with a fixed object in the room, they become "stuck" and become removed from the breathing zone. For RDPs that are not attached to particles, the increase in air velocity increases the probability that they will also collide with a fixed object in the room and become irreversibly attached. However, the other theory assumes that some of

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the RDPs are not irreversibly attached to airborne particles. By increasing the air velocity in the room, the frequency and the energy of collisions between air molecules and attached RDPs increase. As a result, some of the attached RDPs are dislodged and become unattached once again. Because these unattached RDPs (more accurately visualized as molecules) are small enough to pass through the filter paper on the WL meter and not become trapped, the instrument would not be able to measure the emitted alphas.

The importance of what exactly is happening with the unattached RDP is not academic. It has a direct bearing on the dose and hence the risk of contracting lung cancer. It is generally acknowledged that the respiratory system filters out a significant number of RDPs attached to large particles in the nose and throat. The greater risk comes from the RDP attached to smaller particles which manage to get past the body's natural defenses and penetrate deeper into the lung. In addition, it is also well known and accepted that unattached RDPs have a 20–30 times greater efficiency in delivering a dose to lung tissue. Therefore, any increase in unattached RDP concentration, no matter how small, in the breathing zone would significantly increase the dose to lung tissue.

Because of the higher risk associated with ERs >50% (an ER of 3 pCi/L at 0.65 is equivalent in risk to 4 pCi/L), EPA rationalized that WL measurements should continue to be listed as a viable testing method. However, these measurement uncertainties (in particular where the ER is unknown or highly variable) and the difficulty in interpreting the data were the primary reasons that WL measurements generally fell out of favor with the radon testing industry.

1.5.3 EPA Radon Testing Protocols for Nonresidential Buildings

Although considerable information is available for testing within family housing, the only document published by EPA for radon testing in nonresidential building is for schools (*Radon Measurement in Schools*, EPA 402-R-92-014). In this protocol, EPA states that because of room-to-room variation in radon concentration, the only way to know if an individual room or area has radon is to test. As a result, EPA recommends that all frequently occupied rooms in contact with the ground or over a crawlspace be tested for radon. In addition, rooms with walls in ground contact and rooms directly above a basement space that is not frequently occupied should be tested. Large open areas should be tested at an interval of one testing location for every 2000 ft^2. Areas such as restrooms, hallways, stairwells, elevator shafts, utility closets, and storage closets need not be tested.

1.5.4 EPA Radon Testing Requirements for Federal Agencies

In response to the requirements in the 1988 Indoor Radon Abatement Act, in June 1989, EPA 402-K-07-009, revised May 2007. In addition to providing guidance on how to conduct a radon testing program, the document also provided minimum criteria for quality assurance and quality control (QA/QC) for radon testing within federal buildings. Specifically the document called for each building tested to have

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- blanks (5% or 25, whichever was smaller),
- collocated duplicates (10% or 50, whichever was less), and
- spikes (no limits were provided, but 3% was recommended in reference document).

For analysis of the QC data, EPA stated that the procedures used in *Indoor Radon and Radon Decay Product Measurement Device Protocols* (EPA-520/1-89-009) should be used. However, in 1992, this document was superseded by *Indoor Radon and Radon Decay Product Measurement Device Protocols* (EPA 402-R-92-004, July 1992).

For blanks, EPA requires monitoring of the background exposure that may have accumulated during shipment and storage of the testing devices. Because each type of radon testing device (e.g., ATD, charcoal or electret ion chamber) responds differently to background exposure, the EPA protocol provides device specific corrective action if a reading is found to be significantly greater than the lower level of detection (LLD). For example, for electret ion chambers (ECs), EPA requires that 5% of the electrets or 10, whichever number is smaller, be set aside to track voltage drift. Any voltage loss found in the control electrets of more than one volt per week over a 3-week test period for ECs should be investigated. In addition, because ECs are sensitive to background gamma radiation, a correction must be multiplied by the gamma radiation level at the site (in µR/h) and the product (in equivalent pCi/L) subtracted from the apparent radon concentration. If the gamma radiation at the site is unknown, then a measurement would need to be performed directly using appropriate radiation detection instruments.

The objective of performing simultaneous or duplicate measurements is to assess the precision error of the measurement method, or how well two side-by-side measurements agree. This precision error is the "random" component of error (as opposed to the calibration error, which is systematic). The precision error, or the degree of disagreement between duplicates, can be composed of many factors. These include the error caused by the random nature of counting radioactive decay, slight differences between detector construction (for example, electret chamber volume), and differences in handling of detectors. With respect to collocated duplicates, EPA recommends using the relative percent difference [RPD, Eq. (2)] as the best indicator of overall precision in radon measurements.

$$\textbf{Relative percent difference} = \frac{\textbf{(Highest pCi/L – Lowest pCi/L)} \times \textbf{100\%}}{\textbf{Mean}}$$

Equation 2. Relative percent difference

(Quality Assurance Handbook for Air Pollution Measurement Systems: Volume I, EPA 600/9-76-005; U.S. EPA 1984)

Ideally, the results of duplicates should be assessed in a way that allows for determining the level of chance associated with a particular difference between duplicates. This will

allow for the pre-determination of limits for the allowable differences between duplicates before an investigation into the cause of large differences is made. For example, the warning level, or the level of discrepancy between duplicates which triggers an investigation, may be set at a 5% probability. This level is a difference between duplicates that is so large that, when compared with previous precision errors, should only be observed 5% of the time. A control limit, where further measurements should cease until the problem is corrected, may be set at 1% probability.

A control chart for duplicates is not as simple as a control chart used to monitor instrument performance, as for a check source. This is because the instrument's response to a check source should be fairly constant with time. Duplicates are performed at various radon concentrations, however, and the total difference between two measurements is expected to increase as radon levels increase. Because of the difficulties in measuring radon at low levels, EPA guidelines recommend that the acceptance criteria be based on the average of the two results relative to 4 pCi/L. After the RPD is calculated, its value is plotted on one of the two applicable control charts by date and average radon concentration (Figs. 10 and 11). Over time, the RPDs are evaluated based on the overall number of results in within the respected ranges (i.e., in control, warning level, and control limit). If the number of data points exceeds what would be predicted at the warning level, then investigation into the cause of the problem is warranted. If however, a significant number of data points are at or beyond the control limit, then measurements should cease until the problem has been identified and corrected [*Protocols for Radon and Radon Decay Product Measurements in Homes* **(**EPA 402-R-93-003, June 1993**)**]. As to what constitutes a significant number of RPD warnings and failures, EPA provides a statistical table (Table 4) for reference. The required action is

Table 3. Criteria for taking action for measurements outside the warning level[a]

Number of duplicate results outside the warning level	**Total number of duplicates**	
	Investigate, but continue operation A	**Stop operation until problem is corrected B**
2	8–19	2–7
3	17–34	8–16
4	29–51	17–28
5	41–67	29–40
6	54–84	41–53
7	67–100	54–66

[a]Modified from Goldin (Goldin 1984) and based upon cumulative probability tables of the binomial distribution.

Protocols for Radon and Radon Decay Product Measurements in Homes (EPA 402-R-93-003, June 1993).

based upon the number of failures and the total number of data available. For example, if two sets of duplicates had RPDs outside of the warning level and between 2 and 7 sets of data were within the control limit, EPA would recommend that analysis stop until the

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problem has been identified and corrected. However, if between 8 and 19 sets of acceptable data had been obtained, it would be necessary only to investigate the problem.

EPA addresses spikes by requiring laboratories (organizations that read electrets are considered laboratories) to maintain a performance ratio [Eq. (3)] between 0.75 and 1.25. If the performance ratio is outside the range, EPA recommends that the measurement cease until the problem has been identified.

$$\textbf{Performance Ratio} = \frac{\textbf{(Mean Measured Value)}}{\textbf{Target Value}}$$

Equation 3. Performance Ratio

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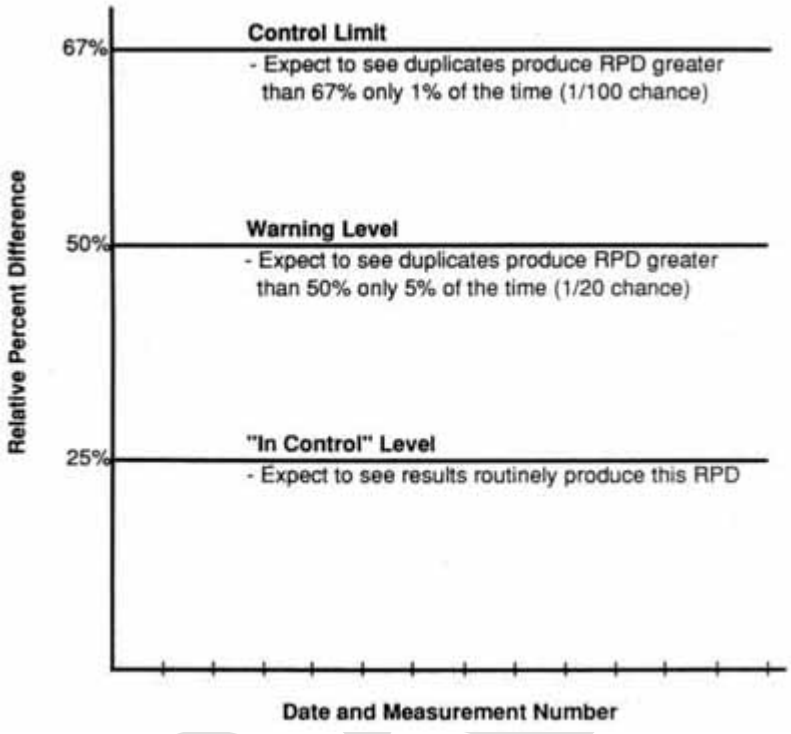
Exhibit B-3

Control Chart* for Relative Percent Difference (RPD)
Based on an "In Control" Level of 25% (=COV of 18%)
(For duplicates where average <4 pCi/L or 0.02 WL)



RPD=difference between two measurements divided by their average

Example: Detector A=2 pCi/L, B=3 pCi/L, RPD=40%

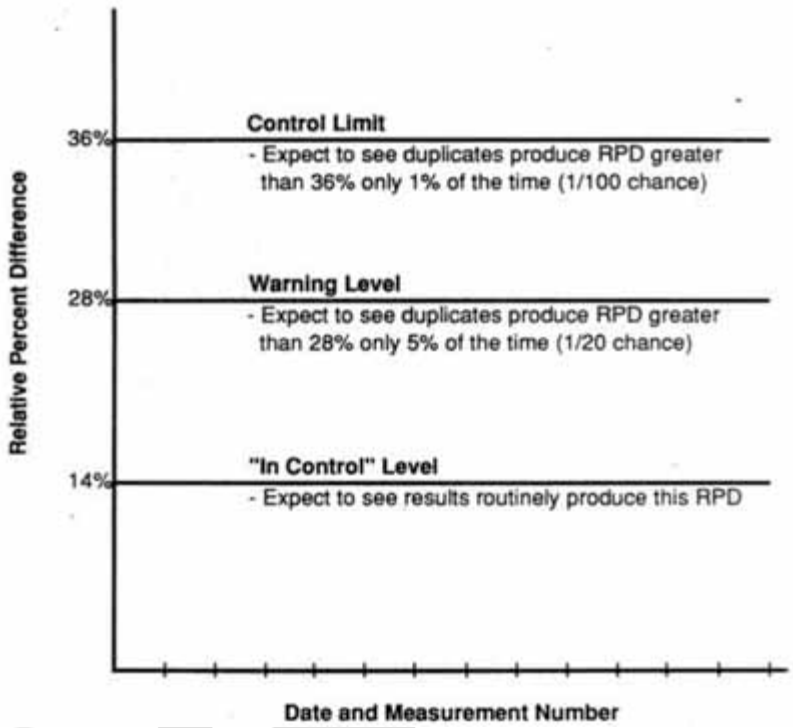
If RPD exceeds the *control limit*—cease measurements until the problem is identified and corrected.

If RPD exceeds the *warning level*—follow guidance in *Section B.3* and see Exhibit B-5.

Fig. 2. Control chart for RPD for average radon results <4 pCi/L.
[*Protocols for Radon and Radon Decay Product Measurements in Homes* (EPA 402-R-93-003, June 1993)]

Exhibit B-2

Control Chart* for Relative Percent Difference (RPD)
Based on an "In Control" Level of 14% (=COV of 10%)
(For duplicates where average ≥ 4 pCi/L or 0.02 WL)



RPD=difference between two measurements divided by their average

Example: Detector A=5 pCi/L, B=6 pCi/L, RPD=18%

If RPD exceeds the *control limit*—cease measurements until the problem is identified and corrected.

If RPD exceeds the *warning level*—follow guidance in *Section B.3* and see Exhibit B-5.

Fig. 3. Control chart for RPD for average radon results > 4 pCi/L.
[*Protocols for Radon and Radon Decay Product Measurements in Homes* (EPA 402-R-93-003, June 1993)]

1.5.5 Radon in Water

EPA has recommended two methods for routine measurements of radon in water. The emanation method, in which radon is degassed from the water and transferred into a Lucas scintillation cell, has a detection limit of approximately 0.05 Bq/L (1 pCi = 0.037 Bq) for a sample volume of 100 mL (Crawford 1989). In the liquid scintillation method, the water is injected directly into a scintillation solution and counted in an automated liquid scintillation device; this method has a detection limit of about 0.4 Bq/L using a sample volume of 10 mL (Prichard and Gesell 1977) and EPA Method 913 (EPA Report EMSL/LV, June 1991). All methods require careful sampling because of the rapid loss of radon from the water when it is agitated and open to the atmosphere. The EPA [*Fed. Regist.* **56**(138): 33050 (1991)] estimated a practical quantization limit (PQL) for radon in water (based on the ability of laboratories to measure radon within reasonable limits of precision and accuracy) to be about 10 or 11 Bq/L (1 pCi/L = 37 Bq/m^3).

1.6 OVERVIEW OF RADON MITIGATION

1.6.1 Types of Radon Mitigation

EPA divides radon mitigation into two basic categories: passive and active. Passive mitigation is defined as a non-mechanical means of radon abatement or control. Examples of passive mitigation include sealing cracks, balancing an existing mechanical system, or increasing the natural ventilation rate of the building substructure (i.e., crawl space). For the remaining lifetime of the building, passive radon techniques are generally considered the most cost-effective means of radon control. Typically, installation costs for a passive system are less than half those of an active system, and a passive system has no operation and maintenance (O&M) costs (i.e., energy for operation). Unfortunately, successful passive mitigation has proved difficult because all radon entry pathways within a house must be identified and negated. However, noted success has been observed in buildings with drainage sumps, French and perimeter drains, and major openings exposed to soil (e.g., wall pipe penetrations and beam pockets). For buildings in which these significant soil gas conduits are not present, the effectiveness of passive mitigation measures is greatly reduced.

Active mitigation entails the use of mechanical means, such as a fan or blower, to control radon entry into the living area. Generally speaking, all active mitigation methods can be grouped into two categories: pre-entry and post-entry mitigation. Pre-entry mitigation is a technique that retards radon entry into the living area. Typical examples are shell pressurization (SP) and active soil depressurization (ASD). SP, the oldest radon mitigation method, retards radon entry by mechanically introducing sufficient outdoor air to induce a positive pressure across the slab and into the soil (Fig. 12). ASD consists of two main types of mitigation techniques, subslab depressurization (SSD) and submembrane depressurization (SMD). For buildings with slabs or basements, SSD is a

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common means of radon control. This method uses a pipe that is inserted through the slab, and a fan is connected to the pipe (Fig. 13). When the fan is activated, the area beneath the slab (subslab) is depressurized. The resulting depressurization prevents radon entry into the living area by redirecting the subslab radon into the pipe for discharge into the atmosphere, where it is harmlessly diluted. However, the overall effectiveness of SSD is limited by pre-existing conditions under the slab that can impede the extension of the vacuum field.

For buildings with crawl spaces, SMD is usually used. By placing a polymeric membrane, such as a plastic sheet, on the floor of the crawl space and depressurizing underneath the membrane with a fan, the radon can be collected and discharged into the atmosphere away from the building.

Post-entry mitigation involves the treatment of the contaminated air inside the building. For example, energy recovery ventilation (ERV) involves the exchange of contaminated indoor air with fresh uncontaminated outdoor air (Fig. 14). Another post-entry mitigation method involves the use of high-efficiency air filtration systems that remove particulates from air (similar in design to the portable high-efficiency particulate air filtration used by asbestos abatement companies). Although studies have shown that these methods do reduce the concentration of radon daughters in air, there are questions in the scientific community as to whether there is an analogous reduction in risk. In addition, when one considers the initial cost of the filtration unit and the annual maintenance cost (the filters are expensive and must be changed monthly), the difference in cost for more traditional and proven mitigation methods is insignificant. It is for these reasons that EPA, recommended in 2008 (Jalbert 2008) that these methods ***not*** be used as a mitigation method.

For nonresidential buildings, additional mitigation methods include mechanical balance (i.e., restoring the forced air and exhaust systems to their original design specifications) and the sealing of subslab ductwork. However, caution should be exercised in making adjustments to the unit's make-up air damper to compensate for a negative shell pressure. Before any adjustments are performed, a review of the building mechanical plans (supply and exhaust) should be performed and an audit of the current mechanicals performed. If the installed mechanical components match the original designer's specification, then the fresh-air damper can be adjusted to match the specified flow. However, prior to the adjustments, it is recommended that temperature and relative humidity measurements (continuous is preferred) be made in all areas of the building to provide a baseline. These measurements should continue for an extended period of time (days or weeks as needed) to ensure that the forced air system (FAS) can handle the added heating, cooling, and dehumidification load. If significant changes in the humidity or temperature are observed, then the original fresh-air damper setting should be restored immediately to prevent mold and mildew formation. In cases where the mechanical audit finds mechanical components other than those specified in the mechanical drawings (e.g., the exhaust blowers have a higher capacity than those specified), or exhaust systems added after the original construction (e.g., fume or exhaust hoods) a heating, ventilation and air

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conditioning (HVAC) engineer should be consulted prior to any fresh-air damper adjustments.

For individual room mitigation, a supplemental air makeup (SAM) system can be installed to control radon by increasing a room's ventilation rate. Typically a SAM system draws 75 to 250 CFM of conditioned air from an adjoining hallway or large room known to have low levels of radon and discharges it into the room (Fig. 15).

Because of the diversity in style and construction of nonresidential buildings, it is unlikely that a single mitigation design would be applicable to all buildings at a given site. Because the installation and maintenance of a building's radon mitigation system can be costly, it is highly recommended that building-specific mitigation diagnostics (measurements that assist in the selection of a mitigation system) be conducted to ensure that a proper mitigation system selection is made.

It is acknowledged that a high-efficiency particulate air (HEPA) filter can remove significant particulate matter from the air and reduce the radon progeny from the ambient atmosphere in those areas being filtered. However, because the radon gas concentration is unaffected by the HEPA filter, the progeny are continually replaced by subsequent radioactive decay of the radon gas. Further, filtration of the air changes the distribution of the sizes of the particles in the air to lower sizes. Radon progeny attached to particles of decreased size present in the air may become more effective in delivering dose to the lung; thus the reduction in progeny filtration may not provide equal health risk reduction (P. Jalbert, E. Fisher, U.S. EPA correspondence to Douglas County School Board, Minden, Nevada, March 6, 2008). In summary, while HEPA or other high-efficiency filtration can be used to remove particulates and reduce radon progeny in the air, it does not affect the radon gas concentration; therefore, radon progeny will continue to be produced in the ambient air. The resulting shift in particle size distribution in the air will deliver an unknown dose from radon progeny to the lung. Further, radon gas measurements will be unaffected by filtering, and the assessment of the effect of filtration involves multiple measurements of radon progeny concentrations and particle size distributions throughout the building. Therefore, at this time EPA does not support the use of air filtration as a means of mitigating the health effects of radon.

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1.6.2 Considerations in Mitigation Selection

Two essential considerations in the selection of a radon mitigation system are initial installation costs and long-term maintenance costs. In addition, other cost variables may influence the choice and design of systems, including

- the quantity of systems and the difficulty of installing them;
- the selected systems' preventive and routine, long-term maintenance;
- the method by which the mitigation systems would be installed;
- the long-term impact of mitigation installation on proposed and planned renovations; and
- the type of contracting mechanism (e.g., economy of scale).

The costs associated with some of these issues can be minimized if, to the best extent possible, the mitigation system and design are standardized for each type of building identified as having elevated radon.

During the planning stages, other issues must be addressed before radon mitigation is initiated:

- energy consumption and long-term maintenance costs,
- aesthetics,
- noise reduction,
- minimal loss of living space,
- local and state requirements,
- proposed and pending renovations, and
- understanding of the occupants' concerns.

Before these concerns can be addressed, the most efficient and practical mitigation method must be selected for each building type with elevated radon. To assist in the selection of the mitigation system (e.g., SSD or SP), diagnostics are performed in each of the building types with elevated radon.

If all mitigation systems were equivalent in installation and O&M costs, the decisions would be greatly simplified. However, the three most common types of mitigation (SP, ERV, and SSD) differ significantly in installation and O&M costs. For example, using a simple intake grill, SP mitigation costs approximately $500 to install. However, the annual operation cost (e.g., energy costs associated with conditioning the air) and the maintenance costs (e.g., cleaning filters and rebalancing the system) are significantly higher than for ERV and SSD. Because O&M of a building's radon mitigation system is permanent for the remaining life cycle of the building, the true cost of mitigation must be looked at over a much longer period. Figure 16 compares the 10-year life-cycle energy consumption cost and the initial installation cost for each of the mitigation systems. For SP and ERV, the higher operation costs reflect the added cooling load for the intake of

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outside air and maintenance. Because of cost considerations like these, whenever feasible, SSD should be preferred over ERV and SP.

1.6.3 HVAC Mitigation in Nonresidential Buildings

Depending on their design and operation, HVAC systems can influence radon levels in nonresidential buildings by

- increasing ventilation (diluting indoor radon concentrations with outdoor air),
- decreasing ventilation (allowing radon gas to build up),
- pressurizing a building (keeping radon out), and
- depressurizing a building (drawing radon inside).

The frequency and thoroughness of HVAC maintenance can also play an important role. For example, if air intake filters are not periodically cleaned and changed, the amount of outdoor air ventilating the indoor environment can be significantly reduced. Less ventilation allows radon to build up indoors. An understanding of the design, operation, and maintenance of a building's HVAC system and how it influences indoor air conditions is essential for understanding and managing a radon problem as well as many managing other indoor air quality concerns in buildings. Although HVAC balancing, repair, and restoration to original design parameters are recognized radon mitigation techniques, it may be advantageous to consult an HVAC engineer prior to making any changes.

Although HVAC mitigation is effective in the short term, long-term studies conducted by DOE have found problems with sustaining mitigation. For example, in buildings that were mitigated by restoring the fresh air to the original design parameters, 50% of the buildings were found not to be mitigated after 5 years. The primary reasons are reduction in the fresh air make-up as a means of energy conservation, and lack of system maintenance (clogged intake filters). System labeling and education of maintenance staff resulted in only marginal improvements.

1.6.4 Radon Mitigation Diagnostic Measurements

There are many alternatives for radon mitigation. Selection of the correct mitigation system for a building is essential for a long-term, cost-effective solution. If a poor selection is made, the radon problem may not be abated, the operational expense (energy penalty) may be higher, the system may fail shortly after installation, and/or the radon level may increase. If any of these problems occurs, then the effort and funds expended for the task would be wasted. To assist in the selection process, EPA recommends that a series of scientific tests, called mitigation diagnostics, be performed before mitigation. These diagnostics gather technical information on the characteristics of the building, which can then be used to determine the most appropriate mitigation means for the building. Table 5 summarizes typical mitigation diagnostics performed to determine the best mitigation method in nonresidential buildings.

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Table 4. Mitigation diagnostic summary

Diagnostic test	Description	Mitigation system
Radon entry pathway	Performs continuous radon measurements in suspected entry pathways	Passive sealing
Air change	Measures the air turnover rate of the unit	Energy recovery ventilation
Shell leakage	Determines the quantity of outdoor air required to pressurize the building to 4 Pa	Shell pressurization
Lateral field extension and subslab permeability	Quantifies the amount of vacuum required to adequately evacuate the subslab. Assists in the selection of suction point locations and fan size	Subslab depressurization
Differential pressure	Measures the differential pressure across the building shell relative to the outside	Passive mitigation via balancing of existing mechanical systems
Mechanical balance	Quantifies the volume of air being supplied or discharged at a mechanical register	Passive mitigation via balancing of existing mechanical systems

1.6.5 Radon Measurement Results Diagnostic

As was shown in Table 5, there are six basic diagnostic tests typically used to assist with the selection and design of a radon mitigation system. To aid in the selection of diagnostics, a close examination of the building's radon data vs. flow plan is performed. Generally speaking, buildings with multiple rooms with elevated radon fall into one of the following categories (Fig. 17):

- random, no discernable pattern;
- uniform, all rooms are about the same;
- linear, all the elevated rooms are aligned;
- clustered, all the elevated rooms are in the same area of the building; and
- combinations of the four patterns in exceptionally large buildings.

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Analysis of historical data has shown that certain types of patterns sometimes indicate a potential problem in the building. For example, a uniform pattern in which all the rooms in the building are at or near the same concentration indicates that the radon is being

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mined and distributed by the building's mechanical system. Therefore, during the diagnostics a close examination of all the building's mechanical components should be performed. However, buildings with linear patterns tend to indicate rooms with substandard ventilation or a possible expansion joint in the slab. Consequently, in addition to consulting the building's structural plans, a mechanical diagnostic should be performed.

1.6.6 Episodic Air-Change Diagnostic

In a typical residential building, almost all of the ventilation is natural, which means air enters and exits the building through cracks in the building shell and through openings found around windows and doors. However, air exhaust systems, such as range and bathroom fans and clothes dryers, can make a sizable contribution to the building's ventilation. From a purely economic standpoint, the lower the ventilation rate, the lower are the energy costs. However, reducing a building's ventilation rate increases the buildup of moisture and indoor air pollutants that may cause health problems. To provide a healthy and comfortable indoor environment, the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) specifies minimum ventilation rates and indoor air quality requirements for commercial and institutional buildings (ANSI/ASHRAE Standard 62.1-2004, *Ventilation for Acceptable Indoor Air Quality*). The recommendations, based upon CFM/person, vary depending upon the use the room/building. However for radon mitigation, the building's ventilation rate must be known. To measure a building's ventilation rates, an episodic air change measurement (EACM) is performed. Trace quantities of non-chlorofluorocarbon containing tracers (1 to 5 ppm) are injected into the building, and the rate of loss of the tracer is monitored as a function of time (hours). To measure this loss per unit of time, instrumentation specific to the tracer gas and capable of measuring the gas in real time must be used. The data are recorded either on a strip chart recorder or to an electronic data logger. Resolution of data collection must be on the order of one data point for every 2 min. By calculating the inverse slope of the natural logarithm of the instrument voltage versus time in hours, the ACH of the area sampled can be estimated (Fig. 18). The duration of an EACM is dependent on the current building's ACH. In very tight houses (i.e., ACH < 0.1), one measurement of 1 to 2 h is sufficient. However, in houses with very high ventilation rates (i.e., ACH > 1), several measurements may have to be performed. The deciding factor for a successful EACM is the linearity of the data plot (Fig. 18). An acceptable EACM is one with at least 1 h of data with a linear correlation coefficient of at least 0.99.

With respect to ranges of ACH in residential buildings, joint studies performed in 300 homes by EPA and DOE in 1985 found that the prevailing ACH rate for homes was generally dependent on the age of the building, the local climate, building codes, and the cost for energy. The homes with the lowest ACH were typically found in the northern and southernmost parts of the United States. Rates in these areas ranged from 0.1 to 0.3 ACH. The homes with the highest rates were found in the Mid-south (e.g., Tennessee and Georgia), where rates ranged from 0.3 to 1.0 ACH.

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1.6.7 Blower Door Diagnostic

Blower door diagnostic tests quantify the leakage area (ft^2) of a building's shell. The fundamental principle of the measurement is that as pressure across the shell increases, the air flowing through cracks and crevices will increase in an attempt to balance the induced vacuum. Based on the flow and pressure data collected, one can calculate the average shell leakage under certain conditions.

To perform the blower door diagnostic, the blower doorframe and fan are inserted into the doorframe of an exterior door (Fig. 19). By adjusting the speed of the fan, the induced shell pressure at different fan pressures can be measured. The fan pressure is proportional to the volume of air removed from the building per minute (ft^3/min or cfm). The shell pressure is proportional to the area of leakage present within the building. By plotting the natural logarithm of the house pressure in Pascals (Pa) versus the natural logarithm of the fan air flow in cubic feet per minute, a line is generated. Using the equation for the generated line (i.e., $y = mx + b$), one can calculate the volume of air needed (cfm) to pressurize the house to a given pressure (Pa). The shell leakage area (in.) is then calculated by multiplying the cfm at 4 Pa by a fan-specific calibration constant.

1.6.8 Subslab Diagnostic Measurements

Knowing the radius of the lateral field extension (LFE) is an integral part of the design of an SSD system. In general, for an SSD system to be successful, the system pressure field (or, more precisely, the vacuum field) should cover at least 75% of the subslab surface area. At coverage less than this, the probability of a successful mitigation decreases. However, if the LFE is known before mitigation, the number of suction points, their locations, and the vacuum requirements for the SSD fan are easily determined.

To measure the LFE, a pressure field extension test (PFET) is performed. To conduct a PFET, a 1.5 in. diagnostic hole is drilled through the slab at a possible SSD suction point. Six to ten perimeter field extension holes (3/8 in.) are drilled at varying distances (1 to 20 ft) from the diagnostic hole. With the use of a small, variable-speed, wet/dry vacuum cleaner, a constant vacuum is applied across the slab (typical vacuums, depending on subslab conditions, are 500 Pa, 1000 Pa, or 5000 Pa). Using a micromanometer, the quantity of vacuum (Pa) present beneath the slab is then measured in the 3/8-in. extension holes. The extent of the vacuum field is then plotted on the building floor plan as a function of distance from the 1.5 in. diagnostic hole. To quantify the extent of the LFE, between 4 and 20 extension holes are usually required. Ideally, the depressurization field should extend concentrically beneath the slab around the 1.5 in. diagnostic hole, with the LFE limits being defined as areas of the slab with less than 2 to 5 Pa of vacuum. The distance in feet from the diagnostic hole to the 2 to 5 Pa line is the LFE radius. Figure 20 illustrates a typical subslab diagnostic apparatus.

In conjunction with PFET, a subslab permeability test (SPT) is usually performed. During the design of an SSD system, proper fan selection is critical for long-term continuous performance. A typical error many mitigation contractors make is selecting a

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fan with too high a flow demand for a given pressure. For all mitigation fans, a minimal air flow needs to be maintained to keep the fan motor cool. Fan manufacturers provide fan performance curves (pressure vs. flow) that indicate minimal flow requirements at a given pressure. SPT measures the ease with which air moves through the aggregate/soil beneath the slab (i.e., flow for a given vacuum). This property of porous materials is called permeability. To measure permeability beneath a slab, it is necessary to record the flows through a slab penetration. As in PFET, a 1.5 in. hole is drilled through the slab. A measurement stand, consisting of a 1 in. pipe in a wooden flange, is inserted into the hole. A small, variable-speed, industrial vacuum cleaner evacuates the subslab air through the 1 in. pipe, in which an anemometer (air velocity meter) and a micromanometer (pressure meter) are installed (Fig. 20). By varying the speed of the vacuum cleaner, the flow required to produce a given pressure can be measured. An *x/y*-data plot of the data pairs can be used then to select the proper fan for the SSD system. Figure 21 illustrates the most common mitigation fan performance curves.

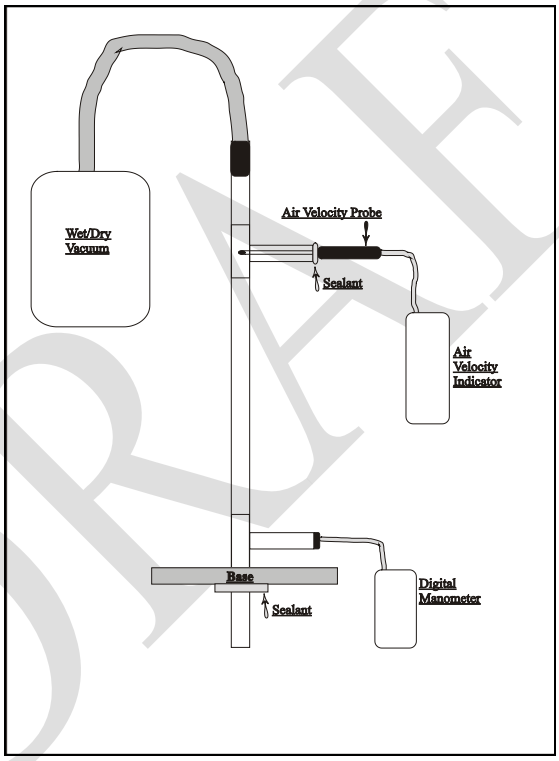

Fig. 4. Subslab diagnostic apparatus.

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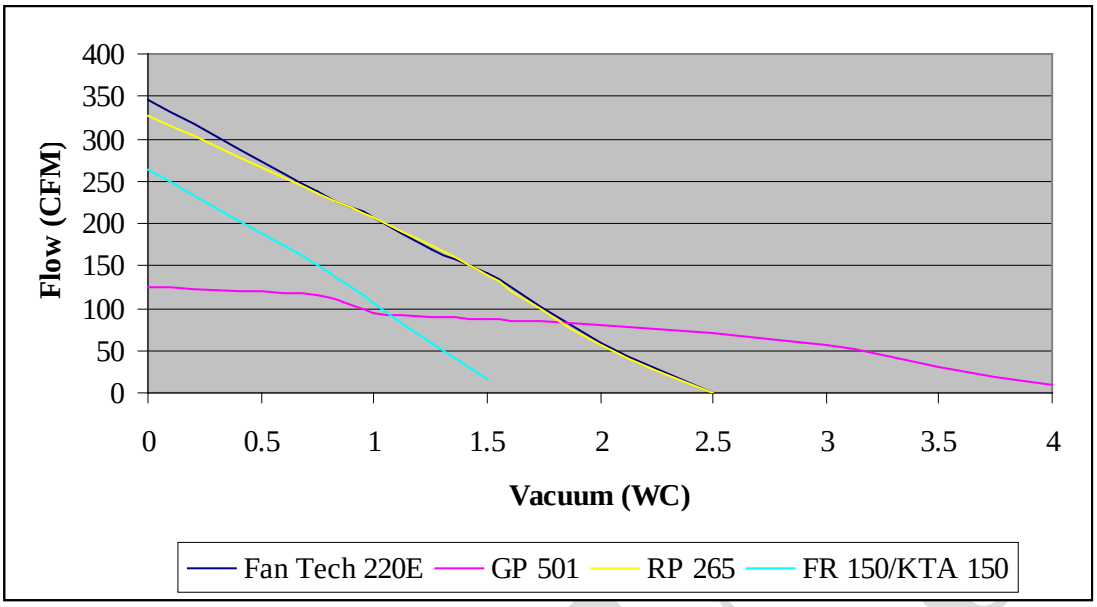

Fig. 5. Typical subslab fan performance curves.

1.6.9 Lateral Field Extension in Subslab Depressurization

For buildings with slabs or basements, SSD is the most common means of radon control. This method uses a pipe inserted through the slab, with a fan connected to the pipe. When the fan is activated, the area beneath the slab (subslab) is depressurized. The resulting depressurization prevents radon entry into the living area by redirecting the subslab radon into the pipe for discharge into the atmosphere, where it is harmlessly diluted. The most critical aspect of an SSD system is the ability to project a vacuum field beneath the slab. When vacuum is applied to a subslab, the vacuum field extends concentrically from the suction hole with decreasing vacuum as a function of distance. For most applications, if a minimum vacuum of 2 to 5 Pa is obtained under all parts of the slab, then radon reduction is achieved. However, the likelihood of achieving full reduction decreases as the vacuum coverage under the slab decreases (i.e., the percentage of subslab with <2 Pa vacuum). To compensate for the vacuum loss, additional suction points are added to the slab in areas where the vacuum field is low or nonexistent. To determine the number and location of suction points, a diagnostic is performed to measure the distance from the suction point to the 2 to 5 Pa contour (Fig. 22) at a constant vacuum. This distance to the 2 to 5 Pa contour is called the LFE.

LFE reduction as a function of distance is dependent on the resistance that the evacuating air encounters moving through the subslab material. The most permeable subslab material (e.g., subslab material that has the greatest LFE) is pre-washed, >0.5 in. stone. Fill material, such as ground coral and compacted soil, significantly reduces LFE. In materials such as these, LFE may be so short as to eliminate SSD as a practical mitigation option.

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Subslab obstructions such as interior footers can prevent the vacuum from reaching all areas of the slab (note 0 Pa in lower right room in Fig. 23). If obstructions are encountered, either an additional suction point or a jumper [Fig. 24(A)] is used. Essentially, a jumper is a tunnel through the slab and above the footer that allows the vacuum to extend into the enclosed area [Fig. 24(B)]. However, if interior footers have good aggregate beneath them, then the vacuum field will not be impeded and could extend for a considerable distance [Fig. 25(A)]. For nonresidental buildings, this sub-footer extension could result in achieving radon mitigation in one or more adjacent rooms. This type of mitigation, called collateral mitigation, is illustrated in Fig. 25.

If compact aggregate, compacted soil, or variable aggregate densities are present beneath the slab, then the LFE can become nonuniform or greatly reduced. Depending on the severity of LFE perturbation, the SSD system may become complicated, or the method may be eliminated as a mitigation option. In aggregates of varying densities, the vacuum gradient will bias toward the more permeable side (Fig. 26). For this problem, a second suction point would be required in the nonevacuated portion of the slab. In cases with highly compacted aggregate or compacted coral, the LFE may not extend sufficiently for successful mitigation (Fig. 27). However, in some cases, adding an additional suction point (Fig. 28) or a more powerful fan will provide the needed coverage. The most difficult of all vacuum fields to work with is the “doughnut” field extension (Fig. 29). In this case, the aggregate around the building’s foundation is loosely packed, but the center portion of the building has had its subslab fill compacted. This results in an elliptically shaped field extension pattern around the foundation but with no extension into the center of the subslab. However, mitigation can occur if the major radon source term is located in the more permeable foundation aggregate. If it is not, then radon reduction will not be complete. Note that it is not unusual for a large or complex subslab to have more than one LFE pattern. In these cases, each slab section is treated independently.

Before installing an SSD system, it is important to determine which of the previously mentioned vacuum extensions exists beneath the slab. More than anything else, this determination will establish the feasibility and flexibility of designing an SSD mitigation system.

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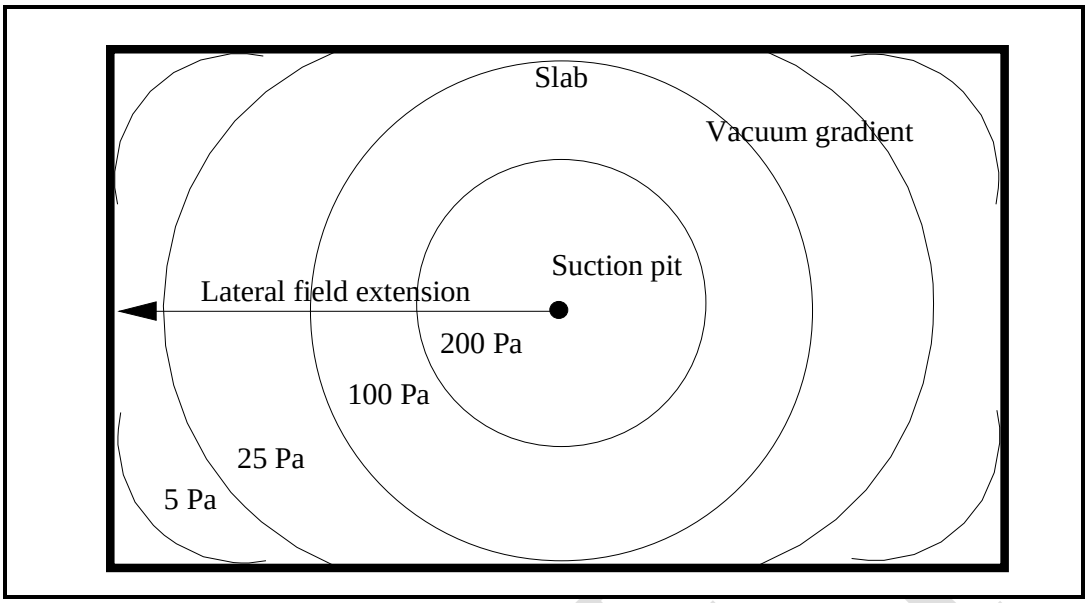

Fig. 6. Uniform vacuum gradient under the slab.

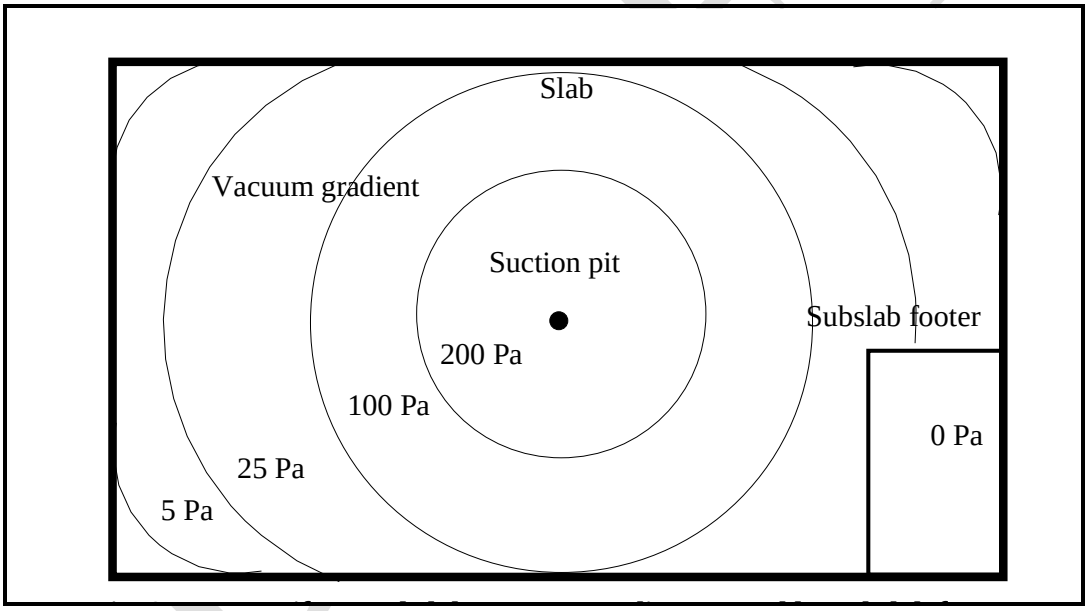

Fig. 7. Non-uniform vacuum gradients.

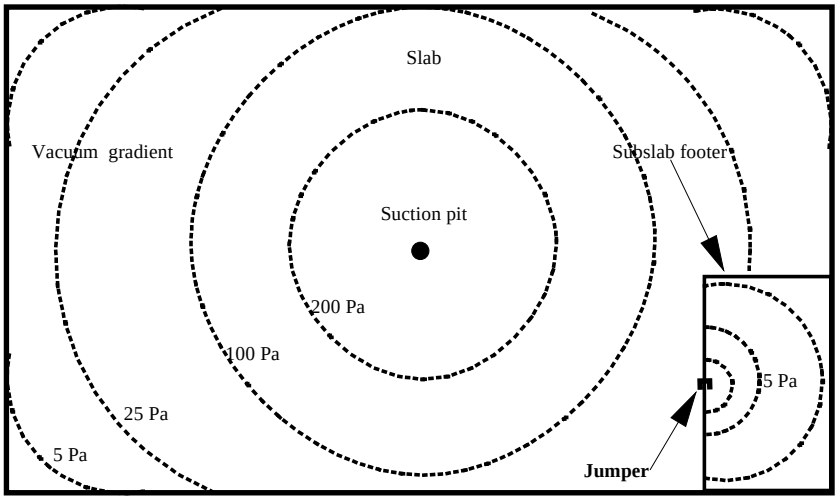

Fig. A. Increased field extension with jumper

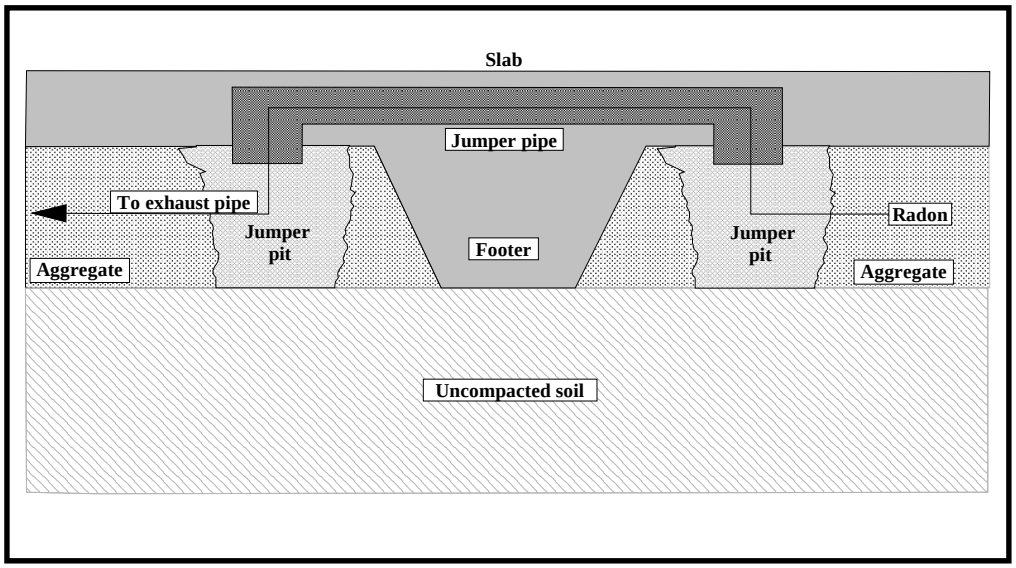

Fig. B. Cross-section of footer jumper

Fig. 8. Subslab jumpers.

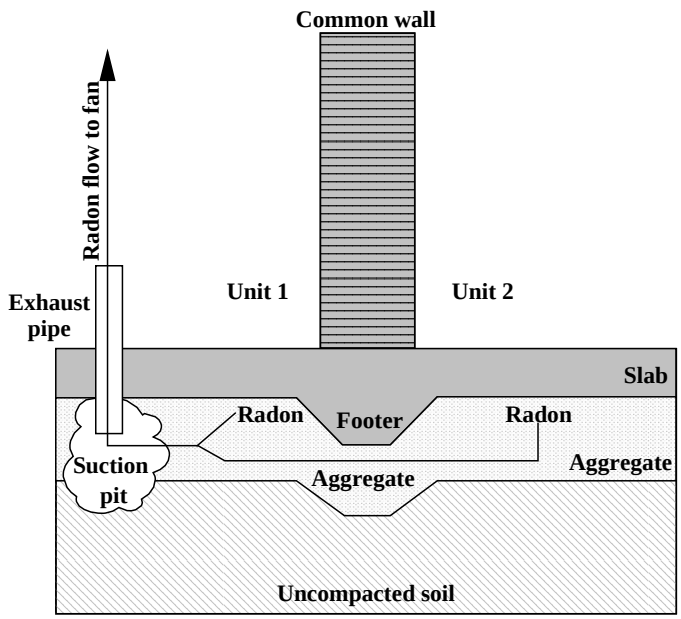

Fig. A. Collateral communication under the footer

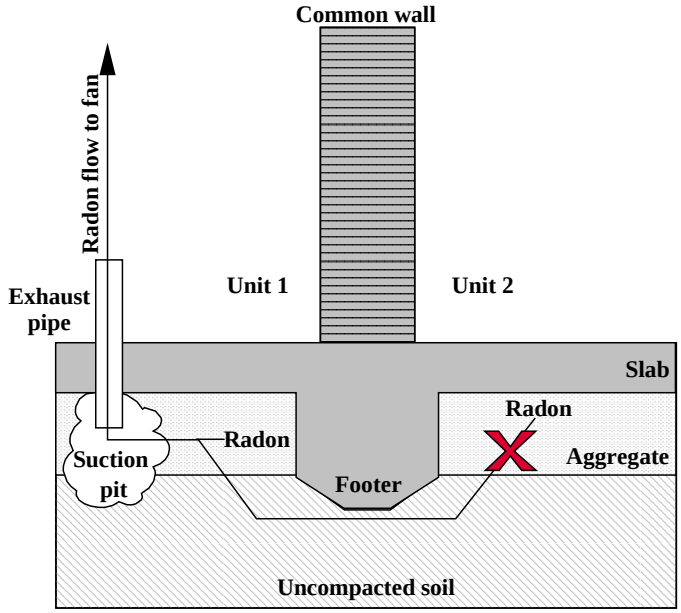

Fig. B. No communication under the footer

Fig. 9. Collateral mitigation.

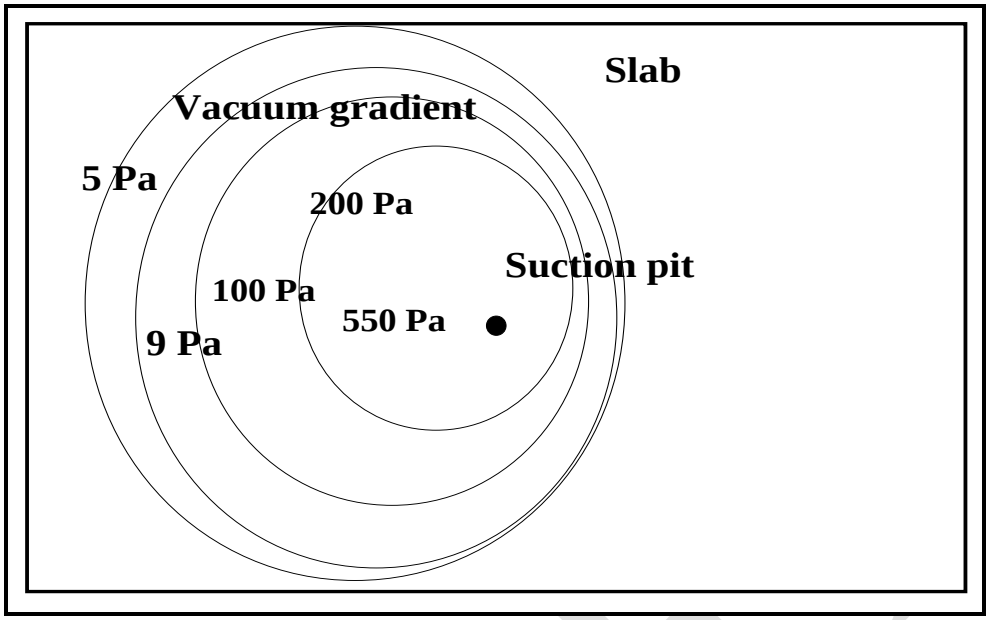

Fig. 10. Biased, uniform subslab gradient.

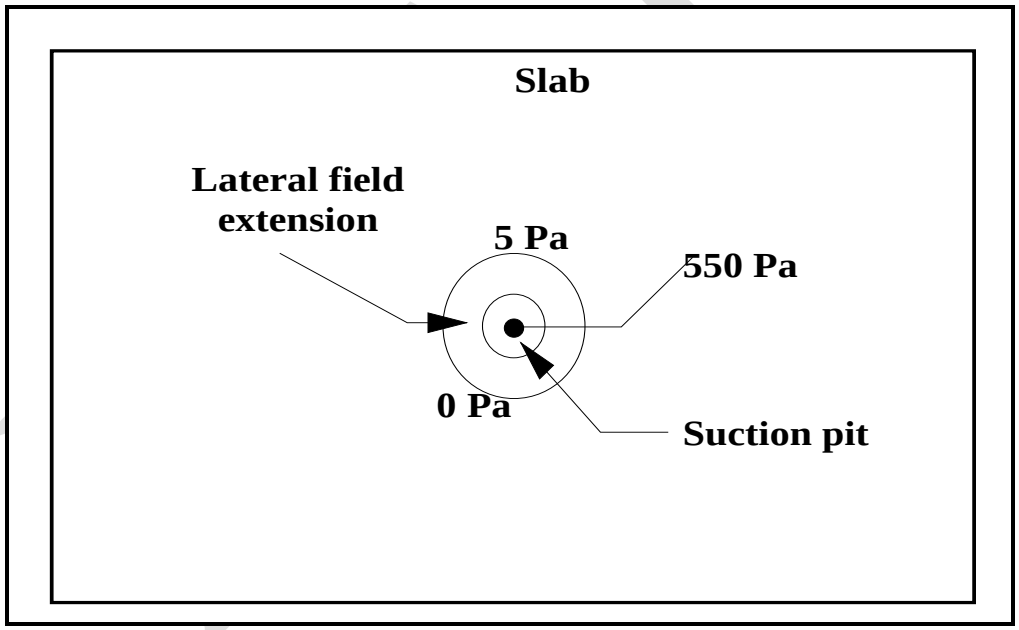

Fig. 11. Lateral field extension in tight soils or aggregate.

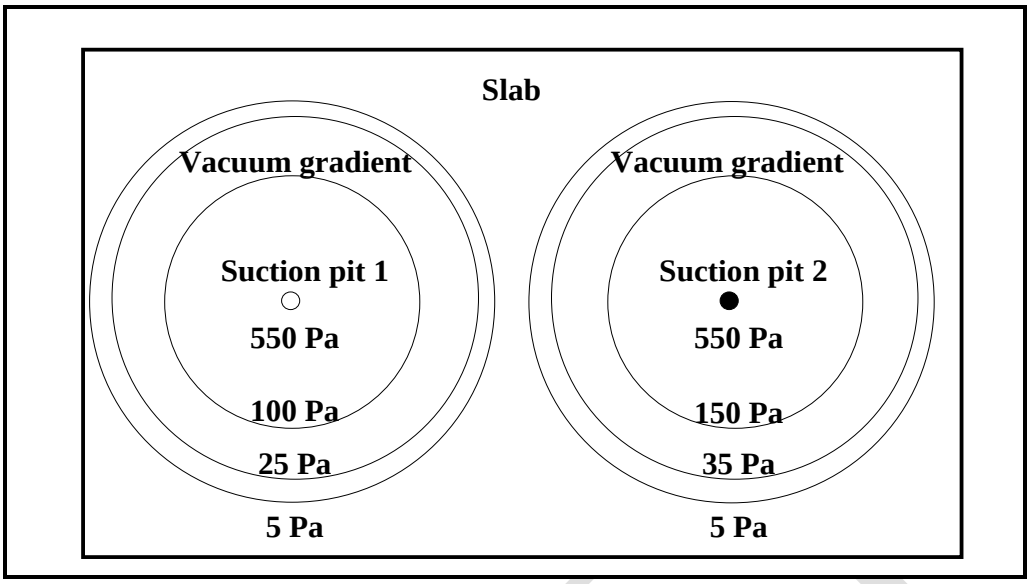

Fig. 12. Uniform vacuum gradients in tight aggregate.

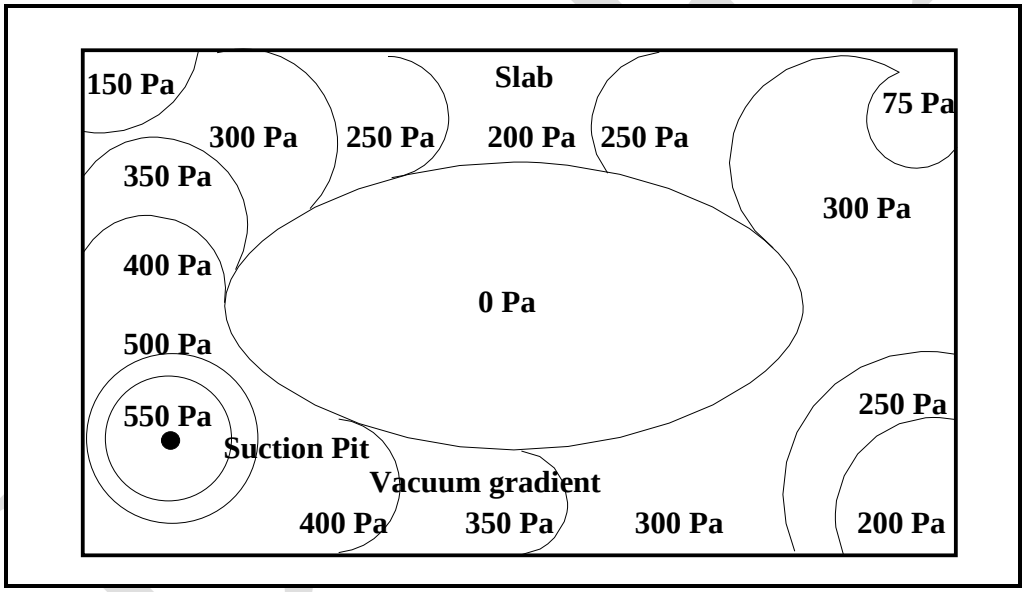

Fig. 13. Doughnut-shaped vacuum gradient.

1.6.10 Shell Differential Pressure

Under ideal conditions, a building with an FAS should be under neutral or slightly positive pressure with respect to the outdoors. If all rooms within the building have identical pressure with respect to the outdoors, then the system is balanced. If this is not true, then the FAS is called imbalanced. An imbalanced FAS results in higher operating costs and may decrease occupant comfort. If the imbalance results in certain rooms being depressurized with respect to the outdoors, increased radon entry into the room is the result.

To determine if an FAS is imbalanced, individual room pressure measurements relative to the outdoors [differential pressure (DP)] are performed. This measurement is performed using an electronic digital micronometer with <1 Pa sensitivity. To perform the measurement, with the FAS blower on, a reference DP measurement is made from one area to the outside. All other areas are then measured sequentially, relative to the last area measured. Once normalized to the outdoors, all room DP measurements should be neutral (i.e., DP = 0) or positive and be within 1 to 2 Pa of one another. Significant differences, particularly rooms with >10 Pa of vacuum relative to the outdoors, should be balanced and the radon remeasured before taking other mitigation measures.

With respect to SP mitigation, the shell pressure must be maintained at a minimum of 4 Pa to retard radon entry. Operation of exhaust systems can result in the shell pressure dropping below the 4 Pa minimum. To measure the impact of these air exhaust systems, DP measurements (referenced to the outdoors) are also performed by individually cycling the air exhaust systems found inside the house on and off. Using the pressure flow curve generated by the blower door diagnostic, air exhaust flows for each of the air handlers can be estimated. With this information, and estimating the duty cycle of each of the air movers, the volume of additional air loss is then estimated. By adding this volume to the 4 Pa CFM determined by the blower door diagnostic, the minimal volume of air needed to perform SP is estimated.

1.6.11 Mechanical Balance

Within a nonresidential building the FAS should maintain all rooms of the building at a neutral to slightly positive pressure relative to the outdoors. When significant pressure imbalances are noted during the shell DP diagnostics, the building's mechanical drawings should be consulted to verify the supply and exhaust specifications for the particular room or area. If the DP measurement is contrary to what the plans had specified, a flow-hood measurement should be performed on the room's supply and exhaust to determine if one or both are out of specification. To perform the diagnostic, a flow-hood apparatus (Fig. 30) is placed over the supply and the return grill, if one is present, and the flows measured. If the results are >15% of the volume listed in the plans and specifications, adjustments may be required. If adjustments are made, the flows in all rooms in line with that ductwork should be rechecked as well.

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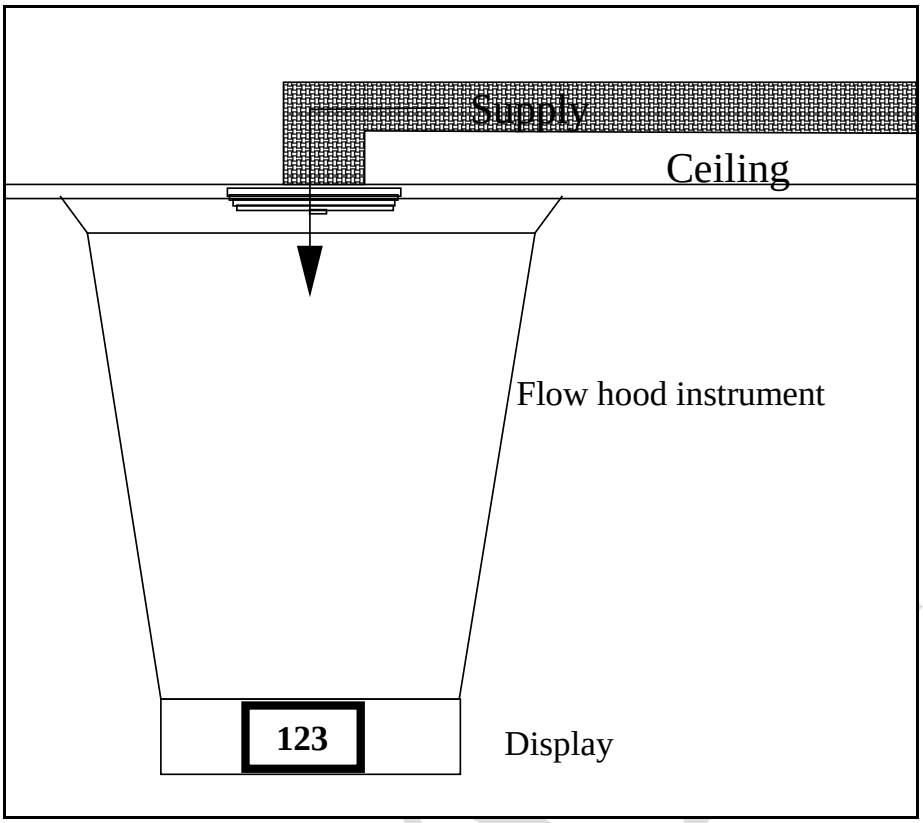

Fig. 14. Flow hood instrument.

1.6.12 Radon Entry Pathway Measurement

The classical radon entry mechanism is migration into the living area through cracks and holes at the soil/structural interface. In theory, if all entry pathways can be identified, then passive means (e.g., sealing the holes) can be used to reduce the radon levels in the living area. To identify these pathways, a radon entry pathway (REP) measurement is performed using a CRM equipped with an intake pump and flow cell. To perform the measurement, a hose is inserted into or passed over the suspected entry pathway. Significant increases in measured concentration (e.g., a factor of 100) relative to the room indicate a potentially significant pathway. Examples of potential pathways to inspect are soil/structural interfaces such as the wall/floor interface, floor drains, perimeter or French drains, and sumps. Small stress cracks (e.g., <1/8 in. across) found on walls and floors typically are not significant pathways. Figure 31 illustrates a typical REP measurement apparatus.

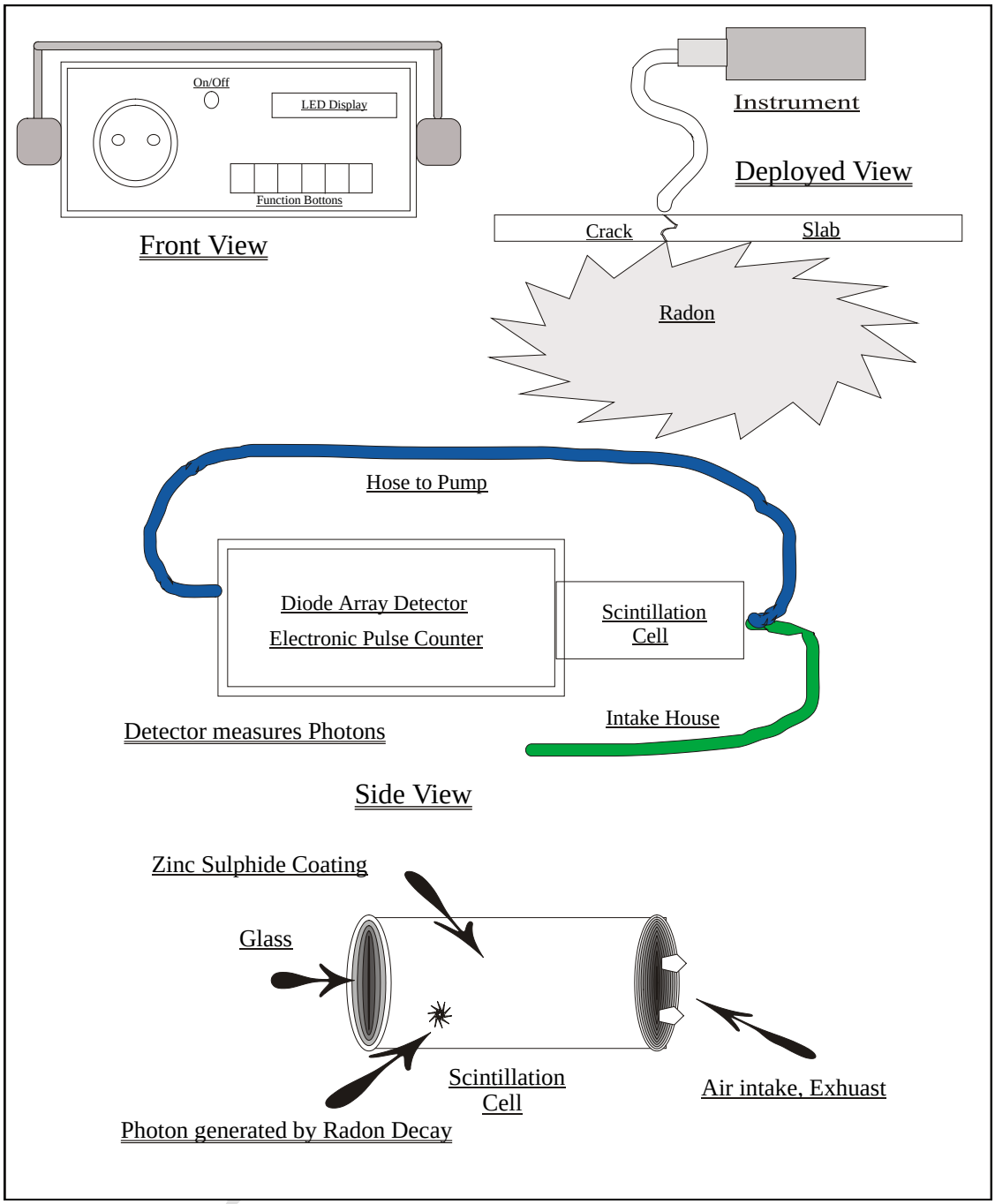

Fig. 15. Typical radon entry pathway apparatus.

1.6.13 Basic Subslab Depressurization System Designs

SSD mitigation uses a pipe inserted through the slab and connected to a fan (Fig. 32). Generally speaking, SSD systems are classified according to the location of the penetration point (e.g., internal or external) and the location of the fan. The three basic designs (with minor variations) are

1. Type 1: an externally mounted pipe/fan system with an exterior penetration (Fig. 32),
2. Type 2: an externally mounted pipe/fan system with an internal penetration (Fig. 33), and
3. Type 3: an interior pipe penetration with a roof- or attic-mounted fan (Fig. 34). Another consideration in selecting an SSD design is planning for future O&M of the radon system. Although SSD systems do not require any specific routine maintenance, some system components will need to be replaced in the future because of failure or as part of a preventive maintenance schedule. In addition, to verify that the system is working, EPA recommends periodic checks of the system performance indicator in addition to inspecting the system every 2 years.

Although the time required for these checks and repairs is minimal (typically just a few minutes), gaining access to the interior of the building can be a time-consuming process. For example, studies conducted by ORNL within DoD housing sites have found that one-third to one-half of the time expended for Type 3 SSD repairs and inspections was used contacting the resident to arrange for access. Conversely, minimal resident interaction was required for Type 1 and 2 SSD systems. Although access to nonresidential buildings is much simpler to obtain than family housing, the time required for attic or roof access is approximately the same. Another consideration is nonresidential roofing. Unlike traditional residential asphalt shingle roofing, commercial buildings usually have complex roofing systems and are warranted or bonded by the contactor for a fixed number of years. Installing a pipe through this roof without the support or permission of the contractor would void the warranty for not only the area where the penetration occurred but also potentially the entire roof. With these considerations in mind, a Type 1 or Type 2 SSD system would be preferred.

With respect to SSD system performance indicators, EPA (*Radon Mitigation Standards*, EPA 402-R-93-078, 1994) requires that they be simple to read or interpret and be located where they are easily seen or heard by building occupants and protected from damage or destruction. The simplest and most common performance indicator, the manometer, deflects a volume of oil in a U-tube. Others rely on an electrical pressure sensor to trigger either a warning light or audible alarm.

1.6.14 Shell Pressurization System Design

SP, the oldest mitigation method, retards radon entry by mechanically introducing sufficient outdoor air to induce a positive pressure across the slab and into the soil (Fig. 35). However, because the installation and long-term O&M cost of an SP system is approximately twice that of an SSD system, SP mitigation is generally considered the last mitigation alternative. Typically, SP systems are used only when

1. the LFE is insufficient to depressurize the subslab,
2. ERV is impractical because of the volume of air needed,
3. the building is under significant negative pressure, or

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4. the building's mechanical system has sufficient capacity to condition the outdoor makeup air.

SP systems consist of two basic types: Type 1 SP uses the existing mechanical system to provide the required volume of outdoor air (Fig. 12), and Type 2 uses an independent mechanical system to condition the outdoor air prior to its entry into the structure (Fig. 35).

The deciding factors for the selection of a Type 1 or Type 2 SP system are the volume of outdoor air needed and the reserve load capacity of the existing mechanical system. To determine the best selection, diagnostics followed by detailed mechanical inspections are performed. Load calculations are then performed on the existing conditions and with the added conditioning load. If the added load exceeds 80% of the current capacity, then an appropriate size of Type 2 system will be needed.

More recently, DoD has provided new requirements for ventilation systems equipped with fresh air makeups (UFC 4-010-01, *DoD Minimum Antiterrorism Standards for Buildings*, October 2003, updated 22 January 2007). Specifically, all fresh air makeups must have a low leakage damper and be located 10 ft above grade. In addition, the system must have an emergency cut-off switch located on the interior of the building.

1.6.15 Supplemental Air Makeup Systems Design

SAM mitigation is used to correct elevated radon problems in single nonresidential rooms by providing additional ventilation. Although the systems are easy to install and maintain, the technique is not widely employed because of its limited application. Typically, for SAM mitigation to be a viable option, the room in question must have radon levels <20 pCi/L, be <3500 ft^3 in volume, and have a low air-exchange rate (e.g., <0.2 ACH). In addition, the room must be located near a large room or common area in which 75 to 250 CFM of conditioned air containing low radon levels can be withdrawn without a significant risk of depressurization.

Although a SAM mitigation system is the least complex of all active mitigation systems (i.e., typically it only has a fan and two short pieces of ductwork), for it to work properly, significant pre-mitigation planning must be employed. To design a SAM mitigation system, one must first estimate or preferably measure the room's ACH rate and then perform a series of calculations that include the room's volume and its current radon level (EPA 625/5-87/019, 1988). From these calculations, the minimum capacity and hence required size of the in-line ventilator can be ascertained. Then by using ASHRAE design standards, the proper duct size can then be estimated. Because SAM systems pull air from inside the building, the most recent DoD requirements (*DoD Minimum Antiterrorism Standards for Buildings*, UFC 4-010-01, October 2003, update 22 January 2207) are not applicable.

In addition to the design parameters, particular attention must be paid to noise and occupant comfort. Because these systems are usually used in single or double offices, the

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noise generated by the discharge of the supply air may pose an inadvertent distraction to the occupant(s). Therefore, the supply diffuser, in addition to being aesthetically pleasing, must afford the least amount of noise. Another important consideration is the location of the discharge point. The discharge air velocity from a typical SAM system is comparable to that of a forced-air system. So to the best extent possible, the discharge needs to be in a location that would not appreciably increase the air velocity in the primary work areas.

1.7 RADON IN WATER MITIGATION

Radon can be removed from water by using one of two methods:

- aeration treatment —spraying water or mixing it with air and then venting the air from the water before use, or
- granular activated carbon (GAC) treatment—passing water through a GAC bed.

However, if GAC is used, disposing of the carbon may require special handling if it is used at a high radon level or if it has been used for a long time. In either treatment, it is important to treat the water where it enters the building (point-of-entry device) so that all the water will be treated. Point-of-use devices such as those installed on a tap or under the sink will only treat a small portion of your water and are not effective in reducing radon in water. It is also important to maintain the water treatment units properly because failure to do so can lead to other water contamination problems. In addition, EPA and the CDC recommend that the water be tested at least once a year after installing the treatment system.

1.8 OVERVIEW OF RADON-RESISTANT NEW CONSTRUCTION

Within the last 15 years, ASTM, DoD, and EPA have published standards and guidance documents to assist with incorporation of radon-resistant features into new construction. Examples of available radon-resistant new construction (RRNC) documents are listed here.

Residential

- *Building Radon Out: A Step-by-Step Guide on How to Build Radon-Resistant Homes* (EPA 402-K-01-002, April 2001).
- *Model Standards and Techniques for Control of Radon in New Residential Buildings* (EPA 402-R-94-009, March 1994).
- *Standard Practice for Radon Control Options for the Design and Construction of New Low-Rise Residential Buildings* (ASTM E1465-08a).

Nonresidential

- *Indoor Radon Prevention and Mitigation* (UFC 3-490-04A, May 2003).
- *Radon Prevention in the Design and Construction of Schools and Other Large Buildings* (EPA 625-R-92-016, June 1994).
- ASHRAE, *Indoor Air Quality Guide, Section 3.3, 2010.*

As for selecting the most appropriate standard or guideline to follow, each document has its own strengths and weakness. However, in most cases a blended approach (e.g., taking the most applicable parts of each) is best in drafting a nonresidential RRNC design. For example, in deciding the extent of RRNC techniques needed, UFC 3-490-04A recommends that the type of facility be taken into account along with the potential for elevated radon based upon the highest radon result collected in close proximity to the new facility, whereas ASTM simply details options that could be incorporated into the design. Another consideration is the fact that certain nonresidential construction techniques go counter to the requirements of what is needed to incorporate radon-resistant features. For example, when high ground-floor loads are expected or the ground floor is part of a structural support member, compaction of the subslab aggregate is required. Therefore, in this case a "to the best extent possible" approach for RRNC incorporation will have to be employed. The following sections provide an overview of some of the most common options available for RRNC integration.

1.8.1 Passive Sealing

A common theme in all RRNC approaches is the need to perform sealing in the floor/foundation system to prevent radon entry through openings in the slab (e.g., expansion and foundation joints, pipe penetrations). Presumably if these are sealed, the radon flux into the building can be greatly reduced. However, more recent additional benefits such as reduction of moisture and insect intrusion into the building have also been identified. Sealing also offers energy savings if SSD mitigation is needed in the future. Studies by DOE and EPA have shown that up to 75% of the exhaust air from an SSD system comes from the living area. Although the energy penalty associated with the loss of this small volume of air is small (typically 50–75 cfm costs about $50/year), the cumulative cost over the lifetime of the building can be significant. With respect to the cost of sealing, typical estimates range from $0.10 to $0.25 per gross ft^2 (cost will vary from region to region). Therefore, for a 10,000 ft^2 building, sealing would add an additional $1000 to $2500 to the construction cost. It is because of this low cost and the variety of resulting benefits that the authors of the various standards encourage this approach as a minimum for new construction.

1.8.2 Passive Stack

In addition to sealing, ASTM and EPA recommend what is called a passive stack approach. In addition to passive sealing, they recommend the installation of a 3 or 4 in. PVC vent pipe that runs from the aggregate bed [minimum 4 in. layer of clean coarse gravel (½–¾ in. mesh)] through the building and roof (Fig. 36). The idea is that the pipe would allow some radon to passively vent to the outside above the roof and not diffuse into the building. If this approach is used, they also recommend that an electrical

junction box be placed in the attic or outside near the pipe in case a fan is needed later to activate the system. EPA recommends at least one vent pipe for every 2000 ft^2 of slab area. Cost estimates for this method range from $200 to $400 per vent pipe, which also includes the electrical junction box. For a 10,000 ft^2 building, installing five passive vent pipes would add an additional $1000 to $2000 to the construction cost. Unlike sealing, other than the possibility of passive radon control, installing a passive vent pipe offers no other apparent benefits. However, if active mitigation is required, the cost of converting a passive vent pipe to an active SSD system is typically around 10% of the cost of installing a new system. Thus five passive vent stacks could be installed in new construction for approximately the cost of installing one from scratch for an active SSD system.

Although from a contractual point of view, it would be expedient to install the mitigation fan and go ahead and take the system active as part of the construction project, the long-term costs of maintaining a system that is not needed can be significant over the lifetime of the building. For example, over 30 years a 150 Watt radon fan would accrue $4500 in electrical cost (assume $0.08/kwh, will vary from region to region). Using industry averages, fan replacements would cost an additional $900 ($300/fan replaced on average every 10-years). Last but not least, active systems need periodic testing with inspections (every 2-years) to ensure that the system is operating properly requiring an additional $7500 (5 rooms/system at $100/room every 2-years). Therefore, over 30 years, the projected cost of operating an active system would be approximately $13,000. Not included in this estimate would be any institutional cost (e.g. periodic inspections and record keeping) associated with the active system. However, although the 30 year cost of active mitigation is significant, mitigating circumstances (location, historical test data, type of building etc.) may be an overriding factor in the decision to go active.

1.8.3 Soil Gas Collection System

Over the past 10 years, there has been a considerable increase in the number and type of soil gas collections systems available for incorporation in new construction. The oldest and perhaps simplest designs focused primarily on making the aggregate bed as permeable as possible. In this design, 6–8 in. of noncompacted, clean, ½–¾ in. mesh stone was used under the slab, grade beams, and interior footings. If radon mitigation was required later, an SSD system was installed. The key advantage of this approach was the low cost for initial installation and the additional and predictable subslab coverage (typically 2000 ft^2 for an active system) offered by the added aggregate. In cases where the additional aggregate was not available or not practical, later designs made use of trenches filled with aggregate or proprietary strip mats.

To enhance subslab coverage for both passive and active mitigation systems, later approaches used, in addition to the enhanced aggregate bed, a network of perforated pipe under the slab. This network consists of a perforated 4 in. PVC pipe (commonly called septic field line or slotted PVC well casing) in the aggregate bed which bisects the length of the slab and, as needed, branches to penetrate interior footings or foundations (Fig. 37). In lieu of using PVC pipe, 4 in. polyethylene slotted, flexible, corrugated drain

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pipe can be used, but care must be taken to ensure that the pipe is not crushed before the slab is poured. In this technique, the flexible pipe is looped around the perimeter of the subslab on top of a layer of aggregate (Fig. 38). At a convenient location, one side of the loop is connected (solid or flexible pipe) to the other side and a tee is inserted. Inside the tee, a section of solid PVC is installed which will extend at least 6 in. above the top of the slab. To successfully cover the perforated pipe, an additional 3–4 in. (½–¾ in. mesh) of aggregate (8 in. total) is applied in addition to a vapor barrier on top of the aggregate. In designing the soil gas collection system, it is imperative that the pipe extend into each and every compartment of the subslab. In addition, aggregate depth, size, and degree of compaction have a strong influence on the coverage. For example, if 8 in. of noncompacted, ½–¾ in. mesh stone is used, the vacuum field will extend up to 50 ft from each side of the branch in a non-subdivided subslab compartment. However, if the same aggregate is highly compacted, the coverage can drop to <10 ft. If the system is properly installed and if the correct aggregate is used, field extensions of 5000 ft^2 or more can be expected for active mitigation systems.

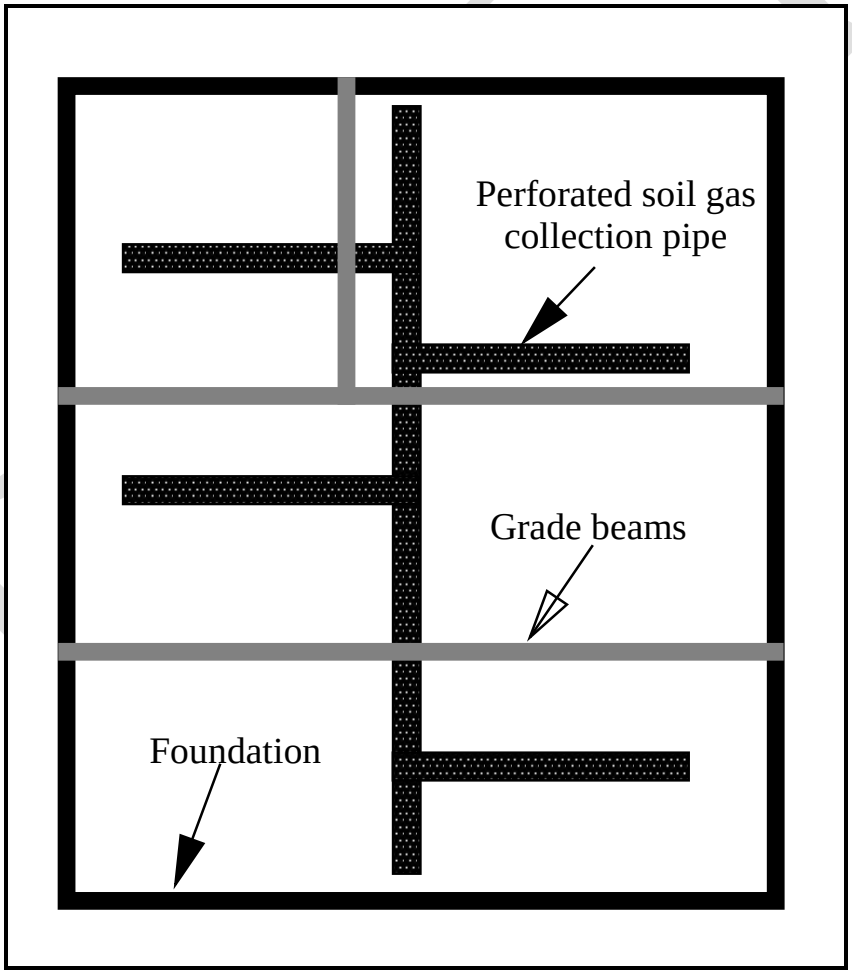

Fig. 16. Example of a rigid soil gas collection system.

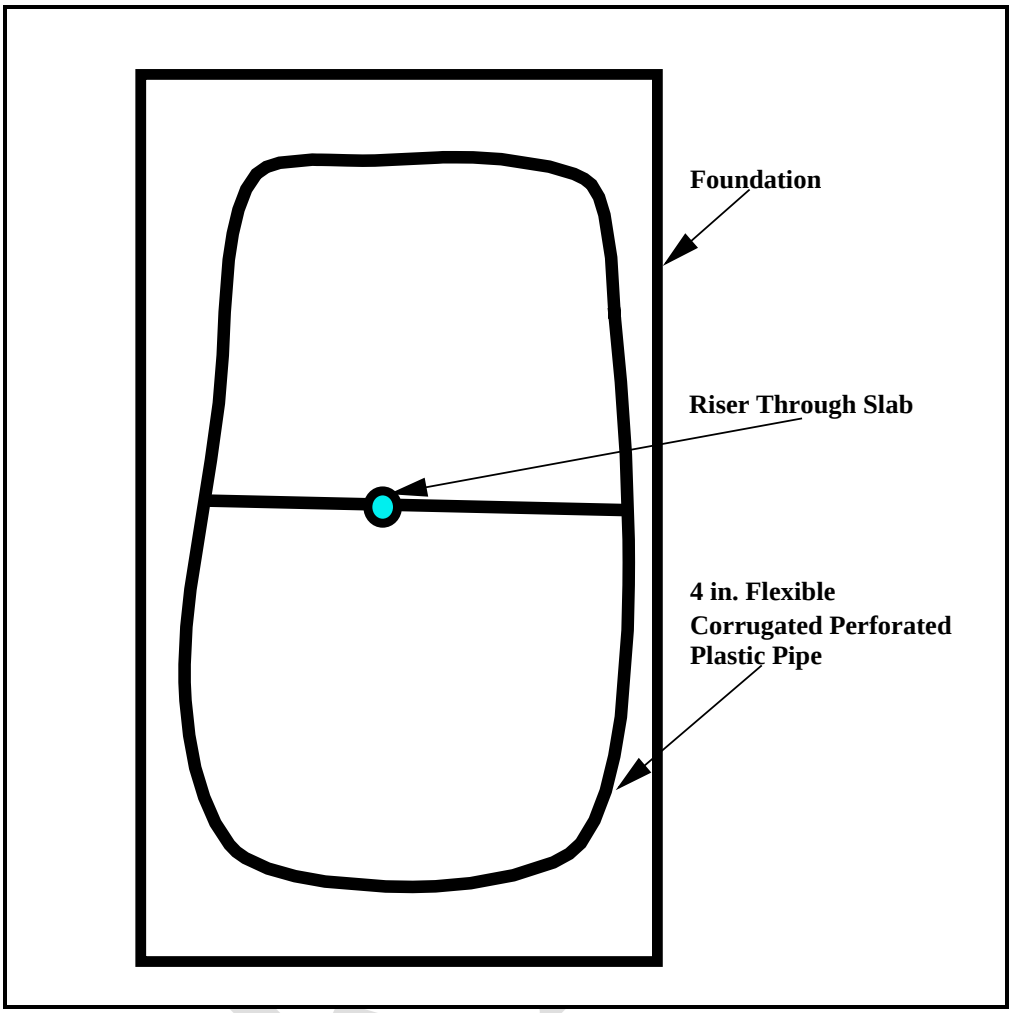

Fig. 17. Example of a flexible soil gas collection system

More recently, in 2008, ASTM conducted a review of all available soil gas system methods and consolidated its findings in *Standard Practice for Radon Control Options for the Design and Construction of New Low-Rise Residential Buildings (*ASTM E1465-08a). In the standard ASTM has categorized the most common soil gas collection systems into five general designs (Table 2, page 9) each with its own options (Table 4, page 10). Although this document was drafted for residential applications, the decision tree and specifications extrapolate readily to nonresidential applications.

1.8.3.1 Vent Pipe Options for Soil Gas Collection System

If a soil gas collection system is installed, the pipe network must be connected either to a passive stack vent or to a pipe that is stubbed out and capped either in the living area or attic or on the exterior of the building. The number of vent pipes, commonly referred to as risers, depends upon the aggregate depth, size, and degree of compaction. For example, if 8 in. of noncompacted, ½–¾ in. mesh stone is used, one riser would usually cover 3000–5000 ft^2 in a non-subdivided compartment. However, if the same aggregate is highly compacted, the coverage can drop to <1000 ft^2. Because of the possibility of

passive mitigation in noncompacted aggregate beds, EPA recommends that a passive stack be connected to the soil gas collection system with allowances for the installation of a fan if needed later.

Because not all building designs can accommodate a passive stack, another option is to extend a branch through the outside foundation to the outside of the building and install a capped riser (Fig. 39). If later testing determines that an active system is needed, the vent pipe and fan are installed.

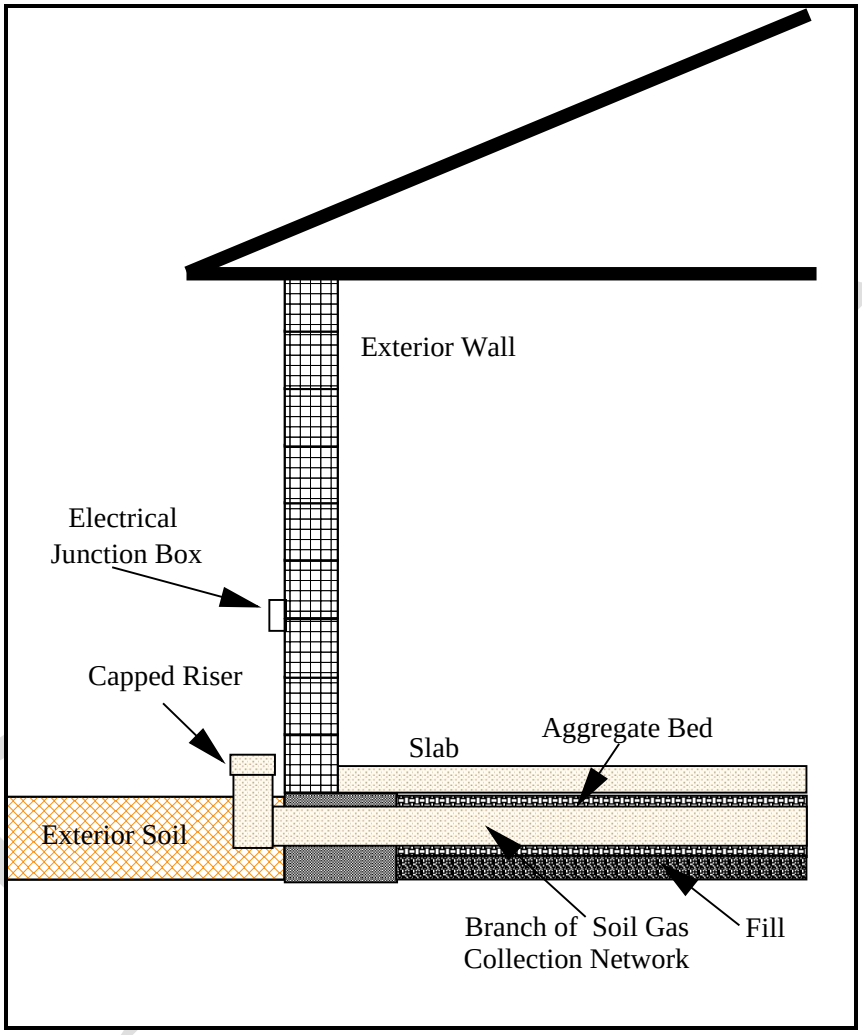

Fig. 18. Exterior riser on a soil gas collection network.

1.8.4 Role of Building's Mechanical Systems in RRNC

Another RRNC technique in nonresidential construction is to design the building mechanical systems so that all the rooms in ground contact are pressurized relative to the subslab (ASHRAE, *Indoor Air Quality Guide, Section 3.3, 2010).* Although no standard has been proposed for how much pressure is needed, studies by DOE have found 4 Pa

(0.016 WC) sufficient for consistent radon control. Another option is to allow for additional ventilation in the ground-contact rooms in the design. However, the inability to predict in advance what the radon levels might be within those rooms limits the application of this technique.

1.8.5 Considerations for RRNC in Nonresidential Buildings

Although EPA recommends that RRNC techniques be considered for all new construction, this statement is based primarily on successes in residential applications. For most residential applications, the average cost of an RRNC passive stack (Fig. 36) connected to a soil gas collection system (Figs. 37 and 38) is around $500. If post-construction testing finds elevated radon, then only a fan is needed to complete installation. If installed properly and with the right aggregate, one riser can typically handle up to 5000 ft^2 of subslab.

In nonresidential buildings, however, subslab construction usually contains grade beams, interior footings and foundations, pier supports, and enclosed utility chases. In addition, aggregate compaction is commonly used to prevent excessive slab settling or to support the slab in areas of high load potential. All of these features will have a significant impact on the efficiency of the soil gas collection network. To compensate, additional branches, multiple soil gas collection networks, and risers may be needed (Fig. 40). This added complexity increases the cost of nonresidential RRNC (additional materials and installation labor plus qualified designers and reviewers) and may bring into question its overall cost benefit. In areas of high radon potential (e.g., EPA Zone 1, Fig. 5) population studies have shown that RRNC is cost-effective. However in marginal and low-potential areas (e.g. EPA Zones 2 and 3 respectively), the potential savings is not as clear.

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1.9 RADON TESTING AND MITIGATION SUMMATION

As a known Class 1 human carcinogen, many studies have shown that exposure to radon is the second leading cause of lung cancer deaths in the United States. Although in the early 1980's it was hypothesized that indoor elevated radon would only be found in areas high in uranium or along geological faults, data collected over the last 30 years has found elevated radon in every state and almost every county in the United States. Although a precursor for having elevated radon is having some concentrations of uranium and thorium in the soil or rock formations under the building, structures with low ventilation have been found with elevated radon in areas where uranium and thorium are below the detection limits of most standard radiological assessment methods. Although analytical methods exist to measure the radon surface flux and radon soil gas concentrations at a building site, the uncertainties in estimating the radon infiltration rate through the soil/building interface and its retention within the building shell bring into question the overall reliability of these methods as a prognostication tool. It is for these reasons that EPA and USGS recommend that all buildings be tested for radon.

Although EPA protocols allow for radon measurements to be performed in as little as 48 h, it is a well established fact that the concentration can vary significantly because of season, episodic weather conditions and occupant lifestyle. It is for these reasons that EPA recommends that a single radon test be performed for as long as possible or use a multi-test strategy be employed (perform separate short-term tests doing different seasons). If the conclusion of the testing is that elevated radon is present (currently defined as radon $\geq$ 4 pCi/L), EPA recommends that the mitigation be performed as soon as possible. As for retesting, EPA recommends retesting after every renovation in which changes were made in the soil/building interface or to the shells ventilation rate. Also, in light of the fact that radon generation is permanent, and the fact that buildings change over time (use, settling, interior modifications, etc.) retesting should be performed every 5-years.

In nonresidential buildings, studies have shown significant variation in the room-to-room radon concentration. The causes for this are varied (type of forced air system, structural features, pressure imbalances etc.) but are considered too complex and unreliable to model. It is for these reasons that EPA recommends testing all routinely ground contact rooms in nonresidential buildings.

In selecting a mitigation method, techniques using active soil depressurization [subslab depressurization or SSD is a member of this group) have proven to be the most economical and reliable over time. However, other considerations (structural, ventilation, aesthetics etc.) may override these considerations. It is for these reasons, mitigation diagnostics (scientific tests which help with the selection of the most appropriate mitigation method) are recommended prior to selecting a mitigation method. Regardless of the mitigation method installed, retesting is recommended every 2-year to ensure that the system is still working in addition, periodic inspections of the system components.

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In new construction, in particular at sites with known elevated radon potential (EPA Zone 1, Fig. 5), EPA recommends that radon resistant features be incorporated into the building design. Although these features will not guarantee that elevated radon will not be present upon building completion or at some time in the future, they will (if installed properly) ensure that mitigation will be predictable, effective and at a cost less than installing a system from scratch. However, in marginal radon potential areas (EPA Zones 2 and 3) the potential savings is not as clear.

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2. REGULATION, POLICY AND GUIDELINES

2.1 REGULATORY OVERVIEW OF RADON

In recognition of the public health hazard presented by indoor radon, the U.S. Congress passed the *Indoor Radon Abatement Act of 1988* and the President signed it into law. IRAA, part of Title III of the *Toxic Substances Control Act of 1988*, declares the national goal to be "that the air within buildings in the United States should be as free of radon as the ambient air outside the buildings" (Public Law 100-551, TSCA Section 301 in Title III of the *Toxic Substances Control Act of 1988*). In addition, the law stipulates that the head of each federal agency that manages a building will design a study to assess the extent of radon contamination in buildings within its jurisdiction and submit that study to EPA. However, unlike the case for other indoor environmental hazards (e.g., lead-based paint, asbestos), IRAA did not require that any corrective action be taken. With respect to other federal laws, the Occupational Safety and Health Administration (OSHA) regulates radon only at privately owned and operated nuclear facilities. At the state level, many states (e.g., Illinois, Pennsylvania, and New Jersey) have strict laws requiring that homes be tested and that radon test results be disclosed to the prospective home buyer. Also, within some states, radon must be reduced to acceptable levels prior to closing.

2.1.1 Regulatory Overview of Radon in Water

The *Safe Drinking Water Act* as amended in 1996 directed EPA to make available a multimedia mitigation (MMM) program to address radon risks in indoor air and from drinking water. This option affords states the opportunity to develop enhanced state programs to address the health risks from radon in indoor air, while individual water systems reduce radon levels in drinking water to 4000 pCi/L or lower. Currently, EPA is encouraging states to adopt this option because it is the most cost-effective way to achieve the greatest radon risk reduction.

2.2 U.S. NAVY RADON POLICY

In response to IRAA, the U.S. Department of the Navy (DON) with concurrence from the Commandant of the Marine Corps tasked the Naval Facilities Engineering Command (NAVFACENGCOM), to identify activities worldwide with elevated radon potential and take corrective action. As a result, NAVFACENGCOM created the Navy Radon Assessment and Mitigation Program (NAVRAMP), the goal of which was to identify potential hazards to Navy and Marine Corps personnel from exposure to naturally occurring radon gas, to prioritize corrective actions, and to coordinate these actions with the major claimants. The DON Navy Message R 191631Z, dated January 1989, authorized the formation of NAVRAMP. The message also stated that buildings with confirmed elevated levels of radon are to be mitigated. Navy policy (*Radon Assessment and Mitigation*, OPNAVINST 5090.1B CH-1, Chapter 26, 1998) states that NAVRAMP

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is the Navy's program to identify, mitigate, and prevent radon levels in excess of 4 pCi/L in Navy-occupied structures. More recently, the Navy's requirements were included in OPNAVINST 5090.1C Chapter 30, 30 October 2007 (see below). Briefly, Chapter 30 instructs all Navy installations to implement NAVRAMP and incorporate radon-resistant designs in new construction as appropriate. Marine Corps policy is covered under Section 6206 of MCO P5090.2A, 21 May 2009. Briefly, the policy states that all Marine Corps installations must implement all phases of NAVRAMP and incorporate radon-resistant designs in new construction where required by historical elevated radon site data, geological conditions, or regulatory requirements.

Overseas Navy and Marine Corps installations may be required to meet the country-specific Final Governing Standards (FGS) prepared by the DoD Environmental Executive Agent based on the host nation's environmental requirements and the Overseas Environmental Baseline Guidance Document (OEBGD).

2.3 HISTORICAL NAVRAMP OVERVIEW

To address the requirements of the IRRA, NAVFACENGCOM-HQ in 1988 developed a phased, programmatic approach to identify installations with radon problems. The phases were

1. Facility Screening Phase: Statistically representative sampling to identify those Navy and Marine Corps installations with elevated radon levels.
2. Detailed Assessment Phase: Sampling of all occupiable, ground-contact rooms at an activity where the facility screening effort identified one housing unit or room with an elevated level of radon.
3. Mitigation Phase: Performing corrective actions (mitigation) in buildings with elevated radon levels to reduce those levels below the EPA guideline of 4 pCi/L.
4. Postmitigation Phase: Verifying, through periodic sampling, whether the corrective actions were effective in reducing the radon levels

From 1988 through 1993, NAVRAMP was a centrally funded and managed program under NAVFACENGCOM–HQ. To assist with the logistics and field-testing of the program, NAVFACENGCOM–HQ entered into an Interagency Agreement with DOE. DOE then assigned the project to its Hazardous Waste Remedial Actions Program (HAZWRAP). During this 5-year period, approximately 31,000 radon measurements were performed in family housing and 35,000 measurements performed within nonresidential buildings. However, in 1994, NAVRAMP ceased as a centrally funded and managed program and was implemented on a cost-recovery basis for the activities and major claimants through the Engineering Field Divisions (EFDs) or Engineering Field Activities (EFAs).

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2.4 NAVRAMP POLICIES

At the inception of the NAVRAMP in 1988, the stated overall objective was to screen all Navy installations worldwide using a sampling protocol that would ensure an overall 95% statistical confidence that no single building would have elevated radon potential. Since that time, NAVRAMP's focus has shifted from a worldwide screening program to more of an ongoing facility environmental program. Therefore, Phase I of NAVRAMP is now considered complete (Section 2.3). Pursuant with current EPA recommendations, statistical screening will no longer be recognized as a method to determine an activity's radon potential. However, conclusions reached by past NAVRAMP testing efforts may be used to set testing needs and priorities. The following policies reflect the requirements listed in OPNAVINST 5090.1C 30 October 2007 and include more recent EPA guidelines.

2.4.1 Subdividing Activities

Under specific conditions (differences in geology or building type, and area remoteness) an activity may be divided into sites for radon testing purposes. If this option is used, the sites and reason(s) shall be documented in the Activity Radon Management Plan (RMP). For radon testing purposes, sites can be assigned their own Radon Potential Categories.

2.4.2 Activity Radon Potential

Using current and/or historical NAVRAMP radon data, all Navy activities shall be classified into one of three of the following Radon Potential Categories:

1. activities or sites with known elevated radon potential (e.g., elevated radon has been confirmed in one or more rooms),
2. activities or sites with unknown radon potential, and
3. activities or sites with no radon potential.

All activities or sites determined to be Radon Potential Categories Site 1 or 2 shall meet all NAVRAMP testing requirements for all occupied buildings. However, activities or sites that are designated as Radon Potential Category 3 need only meet the new construction testing requirements for buildings constructed after CY 2003. All activity and site Radon Potential Categories shall be considered dynamic, meaning that they can change based upon the most recent test data. In addition, for purposes of this testing classification, elevated results from buildings considered to be atypical in construction or use (e.g., underground bunker or command center, etc.) may be ignored provided no other elevated radon is found at the site or activity.

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2.4.3 Radon Management Plan Policy

All activities regardless of radon potential shall have an RMP (Section 2.5). As a minimum, the plan shall establish control procedures for radon testing, data analysis, data management, the review process for incorporation of radon-resistant features into new construction, and, if applicable, the breakout of sites and the rationale for their creation and any atypical buildings with elevated radon which would alter the activity or sites Radon Potential Category. If applicable, the plan should also contain mitigation implementation procedures and maintenance of radon reduction systems at the Naval Activity. In addition the plan shall also contain distinct roles and responsibilities for the implementation of the plan and current staff names.

2.4.4 Buildings to Test Policy

For a building to be considered testable under NAVRAMP, it must first be enclosed, be in ground contact, be occupied (the noted exception being for a newly constructed building), and not be proposed for demolition within the next two calendar years.

2.4.5 Rooms to Test Policy

Under NAVRAMP, all enclosed, ground-contact rooms occupied for ≥4 h/day shall be tested for radon. Included under this testing requirement are occupied rooms over crawlspaces and rooms located directly over unoccupied basements that are not being tested. Other rooms that meet the above requirements for testing include spaces currently vacant but suitable for occupancy or readily occupiable, break rooms, classrooms, conference rooms, and other common areas. Additional rooms for testing at the discretion of the Navy may include ground-contact hallways, stairwells, and other types of common areas. Rooms that should not be tested (unless for diagnostic purposes) include but are not limited to bathrooms, utility closets, and dedicated storage rooms, elevator shafts, and entry lobbies.

2.4.6 Reserve Centers

All Navy Reserve Centers shall be tested for radon. Radon testing within testable buildings shall include, in addition to all currently occupied spaces, all potentially occupiable rooms as well. Retesting of Reserve Centers should be performed every 5 years at centers located in EPA Zone 1 or 2 areas (Section 1.2.1) and at Reserve Centers with known elevated radon potential regardless of EPA zone.

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2.4.7 Radon Detector Policy

For radon testing in Navy buildings, four types of detectors are approved for radon measurements: alpha-track, charcoal, electret, and CRMs. In addition, all detectors and continuous monitors used for radon testing must

- be EPA, National Environmental Health Association (NEHA), or National Radon Safety Board (NRSB) approved;
- be used in accordance with the manufacturer's, EPA, NEHA, and NRSB published specifications; and
- meet the minimum NAVRAMP data quality objectives (Section 3.6).

Although EPA, NEHA, and NRSB protocols allow for the measurement and reporting of radon results in either picocuries per liter or WL (working level), uncertainties in particulate concentrations (a key assumption in WL measurements) within Navy buildings make using WL measurements difficult. Although it is acknowledged that considerable risk comes from radon progeny attached to particles, there is still a great deal of uncertainty associated with the lung cancer risk from unattached progeny. However, what is known and acknowledged by EPA is that if the radon gas concentration is low, the lung cancer risk is low. For these reasons, WL measurements are not permitted under NAVRAMP.

With respect to the duration of radon testing, NAVRAMP radon testing policy requires that to the best extent possible, the initial radon test in a building or room should be long term (i.e., >90 days) and be a collocated duplicate measurement. For all other types of radon testing (e.g., renovation and follow-up retesting, postmitigation, and O&M testing), collocated, duplicate short-term testing (i.e., 2 to 90 days) is permitted (collocated duplicate measurements are not required if a CRM is used). In addition, the testing device must measure and report radon gas directly and not rely either directly or indirectly on the particulate concentration.

2.4.8 Confirmation Policy

Consistent with current EPA recommendations for follow-up testing, NAVRAMP requires that all rooms with a single reading (e.g., one detector) ≥4 pCi/L be confirmed by additional radon testing (short or long-term) or by other means (Section 3.8.3) prior to mitigation.

2.4.9 Retesting Policy

As recommended by EPA, radon testing shall be performed after every renovation (e.g., weatherization, whole building replacement, additions), or HVAC modification or replacement that would alter the building's ventilation rate or change its footprint. In addition, retesting is also recommended at an activity or site with known elevated radon potential every 5 years.

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2.4.10 Corrective Action Policy

Consistent with EPA guidelines, NAVRAMP requires that all occupied rooms (i.e., >4 h/day) with a confirmed radon concentration ≥4 pCi/L shall be mitigated. With respect to timeline, all mitigation should be performed as soon as practical as or within the timeframe listed in Table 6.

Table 5. NAVRAMP action levels and timeline[a]

Radon level (pCi/L)	Timeline for corrective action
<4	No action required
≥4 to < 20	Mitigate within 2 years
20 to < 200	Mitigate within 6 months
≥200	Mitigate within 3 weeks.

[a] OPNAVINST 5090.1C 30 October 2007, US Navy Bureau of Medicine, *Radon Assessment and Mitigation*, Memo 14 Feb 2000.

2.4.11 Radon Mitigation Policy

The only mitigation techniques allowed under NAVRAMP are those which prevent radon gas from entering the building or those which dilute the gas by use of supplemental ventilation (see EPA/625/5-88/024 August 1988, and EPA/625/R-93/011 October 1993 for a complete list of mitigation techniques). Mitigation methods using HEPA filtration or progeny removal are not allowed. All active soil depressurization (ASD) mitigation systems shall be in accordance with ASTM E2121-09 and UFGS-31-21-13 (April 2006) and shall be equipped with a performance indicator and contact information to report system failure. In addition, all mitigation shall be performed by qualified personnel (Section 4.2.6).

2.4.12 Operation and Maintenance of Radon Mitigation System Policy

Consistent with EPA guidelines and recommendations, all radon mitigation systems shall be maintained. This includes, but is not limited to, performing any required maintenance, conducting periodic inspections, and retesting the mitigated rooms every 2 years.

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2.4.13 Radon-Resistant New Construction Policy

For all construction of new buildings at sites with known radon potential or within EPA Zone 1 and 2, activities shall incorporate appropriate radon-reduction techniques into the design and construction phases. Incorporation of these features at all other sites (no known potential, unknown radon potential, and within EPA Zone 3) should be considered.

2.4.14 Radon Testing In New Construction Policy

For all new buildings, radon testing (short-term) shall be performed after the construction has been completed but prior to occupancy. Follow-up testing using long-term devices shall be performed 2–3 years after occupancy.

2.4.15 Radon Testing in Buildings Constructed after 2003

Beginning with UFC 3-400-01, July 2002, significant changes were made to building envelopes and ventilation systems to improve energy efficiency within new buildings. Studies performed by DOE have found that buildings constructed with this and subsequent standards published by ASHRAE significantly reduced the natural ventilation of the building compared with older buildings within the same locale. Consequently, radon data collected in older buildings may not be a good indicator of the radon potential for these more energy-efficient buildings. Therefore, under NAVRAMP, all pre-existing testable buildings constructed after 2003 regardless of location shall be assessed for radon.

2.4.16 Radon Testing Quality Assurance and Quality Control Policy

To ensure that all results are defensible, NAVRAMP requires that all radon testing be accompanied by quality assurance (QA) measurements (Section 3.6) using a prescribed number of collocated detectors (duplicates), unexposed detectors (blanks), and controlled exposure detectors (spikes). Testing quality control (QC) shall be ensured by the use of qualified personnel during the testing (Section 3.6.4), and approved testing devices (Section 3.5.7).

2.4.17 Health and Safety Policy

Before any testing or mitigation project begins, the subcontractor shall prepare a project health and safety plan (HASP). As a minimum, the plan shall list the expected potential hazards to the workers and building occupants and the measures to control them.

2.4.18 Policy on Use of Radon Data from Non-Navy Sources

Radon data from non-Navy sources can, under certain circumstances, be used to determine the radon potential of a building that has been recently acquired, provided it

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can be validated (Section 3.8.7). Examples of where this might occur are properties acquired from joint basing, other federal agencies, host governments, and private developers. As soon as practical, a review of the radon testing data set(s) will be performed (Section 3.8.7) and all acquired sites will be assigned a Radon Potential Category (Section 3.3) and appropriate actions taken.

Another source of radon data may be the current occupant of a building. Because of the availability and relatively low cost of "do-it-yourself" radon test kits, occupants may be tempted to perform the radon testing themselves. However, under no circumstances are these data to be used to draw any testing conclusions. In addition, other data sources in the form of summary reports, sometimes referred to as circumstantial data, cannot be used to reach a testing conclusion unless the individual measurement data are available and meet the minimum acceptance criteria (Section 3.8.7).

2.4.19 Public Awareness Policy

NAVRAMP policy is that all verified information be offered to the specific stakeholder(s) in a traceable fashion as soon as it becomes available. Examples of stakeholders are

- occupants of the buildings,
- command authorities,
- Department of Defense Dependent Schools (DODDS) and Department of Defense Education Activity (DoDEA) personnel, and
- activity medical support staff.

Release of general information or individual radon results to other potentially interested parties such as state, local, and federal officials; educational and research institutions; and news organizations must be cleared by the Public Affairs Office prior to release.

2.4.20 Use of In-House Personnel Policy

If required, Navy personnel (military or civilian employee) can perform radon testing, radon mitigation, or design of RRNC without having accreditation. However, training and appropriate certification is recommended.

2.5 ELEMENTS OF A RADON MANAGEMENT PLAN

The primary purpose of an activity RMP is to serve as the primary document of the oversight mechanism for the entire radon control program. In addition, the document also serves as a major item for maintaining the credibility of the radon program. As a minimum, the RMP should have requirements for the establishment of a Radon Control Team (RCT) and list the organizations at the activity that would be affiliated with the team, including their respective role and responsibilities. The intent of the RMP is not to

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establish a chain of command but to document how the radon control program team members may effectively function in relation to other organizations.

The introduction of the RMP should contain a brief overview of the radon testing/mitigation history of the activity, its RPC, and the last time the document was reviewed. If the activity has been subdivided into sites, then the individual sites should be listed in the introduction, along with a reason and its respective RPC.

As for staffing, the administrative head of the RCT, the Radon Management Control Officer (RMCO), would have the primary responsibilities of

1. Periodically ascertain the status of radon testing and mitigation at the activity and assign RPCs to sites (if applicable).
2. Set priorities to alleviate the deficiencies in the implementation of the RMP.
3. Program and budget for radon contractor services, training, and equipment to perform QA activities.
4. Provide radon awareness training and technical services to activity personnel and stakeholders as needed.
5. Perform QA activities as needed to ensure that contractors and in-house staff are following EPA and NAVRAMP testing, mitigation guidelines.
6. Review and provide comments for all renovations and energy upgrade projects for possible impact on radon levels within buildings. In addition, comments will be provided for all new construction with respect to the incorporation of passive mitigation measures into the design to significantly reduce the presence of elevated radon after the construction has been completed.
7. Review and revise as needed the activity RMP every 3 years.
8. Maintain a data management system (DMS) in electronic and written format that tracks and records in a retrievable manner all radon survey results and all mitigation and O&M activities.

Additional members of the RCT and possible responsibilities are

- activity maintenance (periodic inspections, maintenance and repair of mitigation systems),
- activity medical authority (to assist with health questions),
- engineering design (new construction),
- contracting (new construction),
- safety office, and
- public affairs (for release of historical radon data).

Stakeholders who also may want to participate would include

- family housing (government owned or privatized),
- DoDDS or DoDEA, and
- representatives of non-Navy tenants at the activity.

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The RMP should also contain these elements:

- the process for notification of radon results (current and historical occupants),
- any training requirements for RCT members,
- recordkeeping, and
- the activity or site testing requirements based on the RPC.

If applicable, the RMP should also contain a breakout of sites and the rationale for their creation and any atypical buildings with elevated radon which would alter the activity or sites Radon Potential Category.

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3. RADON TESTING PROCEDURES

3.1 CHANGES IN THE NAVRAMP

The objective of the centralized NAVRAMP from 1988 to 1993 was to identify activities worldwide that had significant radon problems so that additional testing and corrective measures could be taken. In 1994, after a review of all available data, NAVFACENGCOM-HQ assigned each activity into one of the following three categories with the following instructions:

1. Activities with known elevated radon potential (e.g. elevated radon has been confirmed in one or more rooms):
    - assess all testable buildings at the activity,
    - mitigate buildings with confirmed elevated radon,
    - maintain radon mitigation systems in accordance with EPA recommendations, and
    - assess all new buildings and retest after every renovation.
2. Activities with unknown radon potential:
    - perform statistical screening to determine radon potential and implement NAVRAMP as required by final radon potential category.
3. Activities with no radon potential:
    - assess all newly constructed buildings

However, since that time, new facilities have been acquired (e.g., joint basing), activities have merged, new buildings have been constructed, and renovations to existing buildings have occurred. In addition, changes in EPA guidelines, specifically regarding statistical screening and expiration dates of radon measurements have necessitated policy changes and updates for the NAVRAMP.

Although the 1988–1993 NAVRAMP was managed and implemented at the activity level, updates in NAVRAMP policy allow (i.e., not require) that the activity be administratively divided into small groups or sites based on geology, building types, and location (e.g., some distance away from the main activity). In addition, each of the identified sites can be assigned its own RPC so that sites that do not need to be assessed can be omitted in future surveys and those that might need additional testing can be more easily identified.

Because of the changes in the programmatic scope, changes in QA/QC were required as well. During the testing in 1998–1993, a significant portion of the measurements were used for screening purposes in order to model and then estimate an activities radon potential. Consequently, the data had to be of the best quality that the technology would provide. Because the focus of NAVRAMP has shifted to an ongoing activity

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environmental program in which the basic element is the building, or more precisely the room, the level of confidence in an individual measurement need not be as high. The current mix of blanks, spikes, and duplicates reflect this change and afford the confidence needed to reach a defensible testing conclusion.

With respect to statistical screening, current EPA recommendations do not support the use of limited radon sampling as a means of mapping radon potential. However, during the 1988–1993 NAVRAMP, all radon results—including those collected in family housing—were integrated into an activity-specific radon model which has demonstrated over time the ability to predict if elevated radon was indeed present. Because of this, the original recommendation for Category 3 activities (no additional testing required except for newly constructed buildings) or sites (no radon potential) will be kept. However, consistent with EPA current guidelines, all Category 2 activities or sites will need to be assessed in order to assign the proper RPC.

Reflecting the fact that to some extent radon from geology is everywhere, the 1994 requirement that all new testable buildings be tested for radon will remain. The rationale is that newer, more energy-efficient buildings are at higher risk of having elevated radon. However, if testing in new buildings at an RPC 3 activity or site finds confirmed elevated radon, all testable buildings at the activity or site will be tested consistent with the change to an RPC 1.

The radon testing time limit (roughly speaking the shelf-life of a particular radon measurement) is assumed to be set by the recent EPA requirement to retest after every 5 years. This 5-year retesting will be performed at all Category 1 activities or sites.

3.2 ACTIVITY VS SITES

Although the basic entity within the Navy for radon testing and mitigation is the activity, activities can consist of many sites separated by many miles. Although not required to implement NAVRAMP, in certain situations, it might be advantageous to split an activity into smaller sites for radon testing. The rationale for this is that geology can vary from location to location; hence the radon potential could be different, and the types of buildings at these sites might be different as well (e.g., ship yards usually have different types of buildings from Naval magazines). Therefore, it is possible that an activity may have some sites with a high frequency of elevated radon and some with none.

At most activities, traditional mission or command groupings separated by 10 or more miles may be sufficient to identify sites. However, under certain circumstances (geology or types of buildings) this may not be possible. In this case, use the following guidelines:

1. Using a scale map, identify the most centrally located geographical position at the activity.
2. Draw a circle of approximately 10 miles in radius.
3. All buildings that fall within this circle are considered part of the same site.

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4. For buildings that fall outside that circle, repeat steps 1 and 2 until all sites at the activity have been placed within a site grouping.
5. Working individually with each site identified above, verify that no site contains more than one geological surface. For non-geologists, this is usually indicated by color and/or symbol changes on the map. If a site is on two or more different geologic surface formations, and if desired, divide the site into smaller sites by grouping neighborhoods into similar geological features.
6. If needed, adjoining or overlapping sites on similar geology may also be combined into a single site.

If an activity is broken into sites for radon testing, the sites and the reasons should be documented in the activity RMP (Section 2.5).

3.3 NAVRAMP RADON POTENTIAL CATEGORIES

Based upon all historical radon testing data, activities and/ or sites are assigned by NAVFACENGCOM–HQ or its designee an RPC. These categories define the actions that must be taken in order to be in compliance with NAVRAMP.

- For RPC 1 activities and/or sites, all
    - testable building need to be assessed every 5 years,
    - new buildings are required to be tested before and after 2–3 years of occupancy,
    - renovated buildings need to be assessed prior to re-occupancy, and
    - mitigated rooms shall be tested every 2 years.

- For RPC-2 activities and/or sites,
    - all testable buildings need to be assessed and,
    - based upon the survey findings, assigned either an RPC-1 or RPC-3 designation.

- For RPC-3 activities and/or sites,
    - new buildings are required to be tested before and after 2–3 years of occupancy, and
    - buildings constructed after 2003 shall be assessed.

An overview of the current NAVRAMP testing requirements by RPC designation is illustrated in Flowcharts 1 to 3.

3.4 BASIS OF THE TESTING PROTOCOL

At the inception of NAVRAMP in 1988, the stated overall objective was to screen all activities worldwide using a sampling protocol that would ensure an overall 95%

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statistical confidence that no single facility would have elevated radon potential. Since that time the focus has shifted from an activity screening program to more of an ongoing environmental program in which the primary focus is the individual building. Because most radon testing in the United States is performed in single-family housing, EPA has focused considerable effort on the development of residential testing protocols. The underlying premise in these protocols is that the resident is genuinely motivated by either health concerns or the desire to sell a house and will do what is required to achieve a defensible testing conclusion. Consequently, the ability to perform a successful short-term radon measurement under the prescribed closed building conditions presumably is simplified. With respect to nonresidential buildings, the only available EPA guidance document, *Radon Measurement in Schools* (EPA 402-R-92-014, July 1993), does not adequately address the reality of testing a large population of buildings using its multiple measurement strategy. Consequently, in consultation with EPA and other subject matter experts, the Navy developed its own nonresidential sampling protocol which blends applicable portions of the following EPA documents into a testing protocol:

- *A Citizen's Guide to Radon* (EPA 402/K-09/001, January 2009);
- *Home Buyer's and Seller's Guide to Radon* (EPA 402-K-06-093, November 2006);
- *Radon Measurement in Schools Revised Edition* (EPA 402-R-92-014, July 1993);
- *Technical Support Document for the 1992 Citizen's Guide to Radon* (EPA 400-R-92-011, May 1992); and
- *Indoor Radon and Radon Decay Product Measurement Device Protocols* (EPA 402-R-92-004, July 1992).

3.5 APPLICATION OF NAVRAMP TESTING PROTOCOL

These testing procedures apply to all nonresidential radon testing within the U.S. Navy.

3.5.1 Radon Measurement Test Types

During the nominal lifetime of a building (30–50 years), it is possible to accumulate 20 or more data sets. Even with the best of records, over time it is possible that the reason or rationale for a particular set of measurement could be lost or misinterpreted. The long-term health risk posed by exposure to radon exacerbates this problem by raising the possibility of the need to perform future dose reconstruction. To assist current and future users of the data set with determining a particular building's testing history or status for stakeholders or other interested parties, all radon measurements performed under NAVRAMP are assigned a testing code (Table 7).

Table 6. NAVRAMP radon measurement testing codes

Type of radon measurement	Testing code	Preferred test type	Description of the test
Assessment	AS	Long-term	Testing was performed using the

			NAVRAMP testing protocol
Supplemental assessment	SA	Long-term	Measurement was repeated as a replacement for lost detectors
Assessment confirmation	AC	Short or long-term	Confirmation measurement performed on an elevated assessment radon result
Follow-up test	FT	Short or long-term	A requested retest of a room or building by a stakeholder
New Construction	NC	Short-term	A radon test performed in a new building prior to occupancy
Renovation retest	RR	Short-term	A retest of the room or building after renovation or HVAC replacement
Diagnostic Measurement	DM	Short-term	A radon test performed as part of a mitigation diagnostic
Postmitigation	PM	Short-term	Radon test after mitigation performed after radon mitigation
Operation and maintenance	OM	Short-term	A mitigation performance test

3.5.2 When to Test

For radon testing > 90 days but < 1 year, radon testing should be performed during a period when the building is the most closed (not required if the testing is approximately 1 year in duration). For radon testing of ≤ 90 days (short-term test), every attempt should be made to perform the test under closed building conditions (closed windows and doors except for normal entrances and exits) and during normal HVAC operation. Short-term radon testing should not be performed during periods of abnormal weather conditions or in buildings that can not meet the closed building conditions testing requirements. In addition, no radon testing should occur if building renovations or HVAC replacements are proposed during the test period.

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3.5.3 Testing Duration

Under NAVRAMP, if 1-year tests are not practical, long-term measurements (≥ 90 days) would be preferred for assessment and supplemental assessment measurements. However, short-term measurements of these types can be used provided that the closed building conditions testing requirements (Section 4.1.2) can be met. For all other measurements (Table 7), short- or long-term devices can be used as circumstances warrant. Under NAVRAMP, all short-term testing should be for at least 72 h (3 days) with 96 h (4 days) preferred.

3.5.4 Building Testing Requirement

For a building to be considered testable, it must first be enclosed, in ground contact, occupied, and not proposed for demolition within the next 2 calendar years. Exceptions to these requirements are

- new buildings which are tested (short-term devices) after construction has been completed and just prior to occupancy,
- buildings currently under or proposed for renovation or HVAC replacement which are tested after the work has been completed, and
- Buildings that are normally occupied but are currently vacant because of unit deployment, training, or mission reasons.

3.5.5 Room Testing Requirements

For a room to be considered for radon testing, it must be in ground contact (wall, floor, or ceiling), over a crawlspace, or directly over a basement space that is not being tested. To be considered testable, the room should be occupied for ≥ 4 h/day or readily occupiable (e.g., vacant bachelor quarter room, vacant office, or space that could easily be converted into occupied space). In addition, conference rooms, classrooms, and break areas should be included. Occupied service bays (e.g., motor transport buildings) should be tested only if the bay doors are closed for ≥ 4 h/day. Additional rooms for testing at the discretion of the Navy may include ground-contact hallways, stairwells, and other types of common areas. Rooms that should not be tested (unless for diagnostic purposes) include but are not limited to bathrooms, gear lockers, utility closets, dedicated storage rooms, elevator shafts, and unoccupied mechanical rooms.

3.5.6 Testing Location Intervals

All radon testing using passive detectors shall be performed using collocated duplicate detectors (e.g., two detectors placed side-by-side at the same location). (This is not a requirement for CRMs.) Within the room, testing shall be performed at a frequency of one testing location per 2,000 ft^2. In rooms ≥ 10,000 ft^2 (e.g., warehouse bays, commissary or exchange sales rooms, gymnasiums,), testing locations shall be at an interval of one per 5,000 ft^2 up to a maximum of 50 sampling locations per room.

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3.5.7 Radon Detector Selection

The selection of the most appropriate radon detector for a particular application is dependent on many factors, such as the type of radon test, the cost of the device, and the logistics of getting the detector analyzed. For testing in Navy buildings, three types of detectors are approved for short-term measurements (charcoal, electret, and CRM) and two types of detectors for long-term measurements (ATD and electrets). It is important to note that NAVRAMP policy does not specify a particular detector manufacturer but does require that the following technical specifications be met:

- The detectors and analysis laboratory must be EPA, NEHA, or NRSB approved.
- The CRM must be EPA, NEHA, or NRSB listed.
- The detectors or CRM must be used in accordance with the manufacturer's, EPA, NEHA, and NRSB published specifications.
- The data collected must meet minimum NAVRAMP data quality objectives.

Another consideration in the selection of the detectors is overall suitability. Most radon detectors are designed for typical indoor environments and have published lower and upper temperature and humidity limits. Testing outside these limits will result in poor data quality and in some cases be invalidated by the manufacturer (Note: not all manufacturers do this). Maximum testing duration is another consideration as well. Some detectors have extremely short exposure periods (e.g., 2–3 days) which, if exceeded, invalidate the radon measurements. In addition, some detectors also have short holding times (the time elapsed between when the detectors are retrieved and when they must be analyzed) which, if exceeded, would invalidate the radon measurement. Therefore, manufacturer information and return logistics should always be consulted prior to selecting measurement devices.

Although EPA, NEHA, and NRSB protocols allow for the reporting of radon results in either picocuries per liter or working level months (WLM), uncertainties in particulate concentrations (a key assumption in WLM measurements) within Navy buildings make using WLM difficult. Therefore, only testing methods that measure radon gas concentration directly in picocuries per liter are permitted.

3.5.8 Selecting a Testing Location

After the rooms for radon testing have been selected, to the best extent possible, the detectors should be placed in accordance with applicable portions of *Indoor Radon and Radon Decay Product Measurement Device Protocols* (EPA 402-R-92-004, July 1992) and *Protocols for Radon and Radon Decay Product Measurements in Homes* (EPA 402-R-92-003, May 1993). Specifically, the following guidelines should be observed.

- Select a testing location that reduces the probability that the device will be disturbed.
- Do not place the devices within 3 ft of drafts caused by fans or heating, air-conditioning, or other ventilation systems.

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- Do not place or hang the detectors on light or fire sprinkler fixtures.
- Do not put the detectors inside drawers or cabinets.
- Place the devices between 2 and 8 ft from the floor, 4 in. from other objects, at least 3 ft from exterior doors and windows, and 1 ft from an outside wall.
- Place collocated duplicate detectors (i.e., two detectors per test location), within 4 to 6 in. of each other.

In addition to the above requirements, all recommendations provided by the device manufacturer should be followed (e.g., do not use in direct sunlight or in areas of high humidity or temperature) .

After the detectors are placed, a sticker bearing the following information should be attached either to the detectors or adjacent to them on the wall:

DO NOT DISTURB
RADON TESTING IN PROGRESS
CALL: (contact phone number)

At the time of detector placement, a handout containing information about radon, the testing device, etc., should be left with the occupant.

3.5.9 Testing Documentation

After the radon detectors have been placed, specific information needs to be recorded on a data sheet. At a minimum, the following information should be collected:

- placement technician,
- building number,
- building name,
- detector numbers,
- types of radon detectors (e.g., ATD, electret, CRM),
- type of radon test (Section 3.5.1),
- date placed,
- time placed (if applicable),
- room placed,
- location placed in the room, and
- comments.

In addition to the above information, rooms that require radon testing but that, for a valid reason, could not be accessed during detector placement should be recorded and the reason documented.

During detector retrieval, the following information should be collected or verified and recorded on the data form:

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- date retrieved,
- time retrieved (if applicable),
- detector number,
- room and location,
- any evidence of tampering,
- any evidence of renovation or modifications to the building that could have an impact on the radon level, and
- whether closed building conditions were maintained during the test period (short-term only).

After the detectors have been retrieved, they should be returned to the manufacturer for analysis and reporting. Because different devices have different field holding times (the time between detector retrieval and analysis), manufacturer recommendations shall be strictly adhered to at all times. In addition, the QA detectors (blanks and spikes) should be returned at the same time as the field detectors. In surveys in which more than one shipment is required, the QA detectors should be distributed proportionally with each shipment.

3.5.10 Detector Losses and Missed Rooms

For planning purposes, in nonresidential radon surveys, one can usually anticipate losses of about 0.5 to 1% per month of the total number of rooms tested. Therefore, during a 6 month, 1000-room survey, one would expect to lose detectors in between 30 and 60 rooms. Studies have identified the following three major reasons these losses occur:

1. The occupant threw the detector away for various reasons (15%).
2. Uniformed painters and cleanup crews threw the detector away (75%).
3. The detector fell and was disposed of (10%).

To counter these causes for detector loss, the following precautions should be taken.

1. Affix warning stickers with a local number to call for additional information to the detectors and provide information handouts during detector placement.
2. Inform contractors and base personnel working in the buildings that radon testing is in progress and the testing devices are not to be disturbed.
3. Place detectors in out-of-the-way locations to ensure that they will not be bumped during the test period, and instruct occupants during placement to reattach the detectors if they accidentally fall.

If warranted, rooms in which detectors are lost and rooms that could not be accessed during detector placement can be retested using either long-term (preferred) or short-term measurement devices. However, short-term testing can be performed only if the test can be performed during nominal closed building conditions. It is recommended that all rooms without radon results be retested within 1 calendar year of the previous survey's retrieval date. The noted exception is for buildings in which one or more rooms had radon results ≥4 pCi/L. In this case, testing shall be completed as soon as possible so that

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mitigation planning and implementation can proceed in a timely manner. For all other buildings in which the highest result was < 4 pCi/L, retesting in the rooms with missing data should be considered only if losses exceed 20% of the total testable rooms.

3.5.11 Testing Errors

During the test period, things may happen which would have an impact on the validity of the radon measurement. Certain types of these events would result in the test's being classified as invalid or not reportable (commonly referred to as a "catastrophic error"). For example, EPA recommends, as does NAVRAMP, that short-term test data be invalidated in the case of abnormal weather events or if building mechanical problems occur during the test period. Other examples of catastrophic errors include relocation of the detectors to other rooms, damage to detectors (e.g., vandalism, water, smoke, paint), building renovation or HVAC replacement, not meeting the manufacturer's recommended minimum or maximum exposure time, and testing not being performed during closed building conditions. For these types of errors, the result is not reported (the attempted measurement is documented without the radon result and with the error description listed under comments) and retesting is recommended. However, other types of errors need only be recorded and reviewed to see if the resulting error is significant. Examples of these types of conditional errors are

- One or both the detectors fell down:
  —not significant if both results are < 2 pCi/L.
- Placement and/or retrieval dates are missing.
  —not significant if substituting the last placement date and/or the first retrieval date for the project yields results < 2 pCi/L.

If the above qualifying conditions for the conditional error are true, then the result accompanied with the error may be reported. However, if the qualifying conditions for the error are not met, then retesting is required if one or more rooms in the building has elevated radon or if problems were encountered with > 20% of the testable rooms.

3.6 TESTING QUALITY ASSURANCE AND QUALITY CONTROL

The objective of radon measurement QA is to ensure that data are scientifically sound and of known precision and accuracy. To determine these values, QC is performed using blanks, duplicates, and controlled exposures (spikes). In addition, contractors who are performing radon measurements should establish and maintain QA programs. In these QA programs, procedures for attaining the defined QA objectives and a system for recording and monitoring should be established. In performing the validation and analysis of a data set (a data set being defined as a group of measurements performed at the same time using the same devices), all exceptions must be noted and reported and their impact noted in the data report. In addition, the QC measurements shall be permanently linked with the data set to afford independent analysis in the future.

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Because in most Navy surveys large number of measurements are performed within a short period of time, plotting daily control charts (Section 1.5.4) would be of only minimal benefit. Instead, the Navy has established an individual measurement tripwire using the EPA control limits (see duplicates below).

Under NAVRAMP the QC requirements for all passive radon measurements are the following.

- Blanks: Blanks should be at or below the manufacturer's published lower level of detection (LLD).
- Duplicates: Collocated detectors in which both measurements are >4 pCi/L should have a relative percent difference (RPD) of <36% (see Eq. 4). For collocated detectors, > 2 pCi/L and <4 pCi/L, an RPD of <67% is considered acceptable.
- Spikes: Spike results should be within ±25% of the known value.

To the best extent possible, the blanks and spikes should be returned to the laboratory at the same time with the field detectors. In addition, they should be intermingled with and undistinguishable from the field detectors.

3.6.1 Passive Measurement Quality Assurance and Quality Control

Before a data set can be reported, it must first be validated to ensure that it meets specific QA requirements. Failure to meet any of the minimum QA requirements will require specific reporting actions and, depending on the severity of the failure, possibly retesting. The following sections detail the requirements, analysis procedures, and corrective actions to be taken if needed. Under NAVRAMP, the level of QC for passive detectors (ATDs, charcoal canisters, and electrets) is dependent upon the number of locations (e.g., rooms) being tested at a given time. The minimum levels of QC follow.

- <10 locations:
  - one blank detector and
  - 100% collocated duplicates.
- 10 to <33 locations
  - three blank detectors,
  - 100% collocated duplicates, and
  - three spike detectors at 4 times the number of days of the projected exposure (e.g., for a 120 day exposure, the spike should be 480 pCi/L-days).
- ≥33 locations
  - blank detectors: 3% of the total number of locations tested, or up to 30 blanks (2/3 of the total should be field blanks, 1/3 should be laboratory), whichever quantity is less;
  - 100% collocated duplicates; and
  - spike detectors: 5% of the total number of locations tested or up to 50 spikes, whichever quantity is less; spike concentration should be 4 times the number

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of days of the projected exposure (e.g., for a 120 day exposure, the spike should be 480 pCi/L-days).

For blank ATDs, an acceptable blank measurement would be any reported measurement ≤60 pCi/L-day (1 pCi/L-day is the dose a detector receives if it is exposed to 1 pCi/L for 1 day). For charcoal canisters, an acceptable blank measurement would be any reported measurement ≤1 pCi/L-day. For electret-based detectors, an acceptable blank measurement would be any measurement ±3 V from the original measurement.

Under NAVRAMP, all spikes must be performed in a NEHA or NRSB accredited chamber or within a U.S. governmental calibration chamber. With respect to analysis of spike results, NAVRAMP requirements are that the mean spike result (the average of all spike results at a given concentration) be ±25% of the known concentration (Eq. [4]).

$$\textbf{Individual relative error} = \frac{\textbf{(Average pCi/L)} \times \textbf{100\%}}{\textbf{(Known pCi/L)}}$$

Equation 4. Individual relative error.

In all cases where one or more of the above QC requirements are not met, the testing contactor shall first inform the laboratory of the problem(s). If the laboratory can correct the problem, then the corrected results for the data set shall be resubmitted by the laboratory. However, if the laboratory is unwilling or unable to correct the QC problem(s), then the contractor shall perform an in-depth analysis of the impact of the QC failure on the radon measurements. At a minimum, the impact analysis shall address the overall measurement uncertainty at 4 pCi/L and the likelihood of false positive and/or negative measurements. Using these measurement uncertainties, a review of the individual field measurements should be performed and all measurements in which the conclusion (e.g., the need to perform mitigation) is in question should be identified. For these individual measurements, retesting would be required. With respect to the individual measurements that fall outside the range of interest, the errors should be documented, and retesting would be at the discretion of the Navy.

3.6.2 Precision Calculations for Passive Detectors

All radon testing currently performed under NAVRAMP using passive radon detectors is performed using 100% collocated duplicates. To determine if a data set meets overall precision requirements, the RPD for each measurement is calculated (Eq. [2]) and then the results are sorted into two ranges based upon the average radon concentration of the measurement (> 2 pCi/L and <4 pCi/L, and ≥4 pCi/L). No RPD requirement is needed for radon measurements for which both collocated results are < 2 pCi/L.

The arithmetic average of the RPDs of each range is then calculated, and a data set (i.e., a group of radon measurements performed at approximately the same time using identical detectors, the same QC, etc.) is considered to have acceptable precision if both of the following requirements are met:

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- an average RPD of <67% is achieved for all average radon results > 2 pCi/L and <4 pCi/L, and
- an average RPD of <36% is achieved for all average radon results ≥4 pCi/L.

However, if one or both of the RPD precision requirements are not met, then further analysis is required using the following steps:

Average Radon Measurements > 2 pCi/L and <4 pCi/L with RPD ≥67%

- Using the Student T test or other appropriate statistical method, eliminate all statistical outliers and recalculate the average RPD.
    - If the average RPD without the statistical outliers is <67%, then the abbreviated data set is considered to have acceptable precision in the lower range.
        - Retesting of the rooms that failed the RPD test is not required.
    - If after the exclusion of the statistical outliers, the average RPD is >67%, then the laboratory should be consulted to see if the problem can be corrected.
        - If the problem cannot be corrected then retesting should be considered for all rooms with RPDs ≥67%.

Average Radon Measurements ≥4 pCi/L with RPD ≥36%

- Using the Student T test or other appropriate statistical method, eliminate all statistical outliers and recalculate the average RPD.
    - If the average RPD without the statistical outliers is <36%, then the abbreviated data set is considered to have an acceptable precision in the upper range.
        - For the statistical outliers excluded from the RPD analysis, retesting is recommended for results with an arithmetic average ≥4 pCi/L to <20 pCi/L, and not recommended for statistical outliers where both measurements are ≥20 pCi/L.
- If after the exclusion of the statistical outliers, the average RPD is >36%, then the RPD should be recalculated excluding all outliers and measurements in which both radon results are ≥10 pCi/L.
    - If the average RPD is <36%, then the abbreviated data set is considered to have an acceptable precision in the upper range.
        - For the results excluded from the RPD analysis, retesting is recommended for those in which both results are <10 pCi/L, and not recommended for those in which both results are ≥10 pCi/L.

If both methods using the abbreviated data set fail to achieve a <36% RPD using the abbreviated data sets, then the rooms should be confirmed prior to mitigation.

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3.6.3 Continuous Radon Monitor Quality Assurance and Quality Control

At a minimum, all CRMs used under NAVRAMP must have ±10% resolution at 2 pCi/L and be able to record the levels hourly. The device used in the field must have a current manufacturer's calibration certificate and shall be maintained in accordance with manufacturer specifications. For every tenth radon measurement performed, a duplicate measurement performed with another CRM or an approved electret or charcoal canister shall be performed. The acceptance criterion for the CRM is that the result be within ±25% of the collocated duplicate measurement.

If this condition is not met, then the test should be repeated using either collocated duplicate passive detectors or collocated duplicate CRMs. If the CRM is found to be in error, then all rooms previously tested by the CRM since the last performance check should be retested.

3.6.4 Radon Testing Provider Qualifications

For all field placement and retrieval activities, the radon team must be under the supervision of an on-site field supervisor. Qualifications of the field supervisor follow.

- Training: Radon testing training certified by EPA, NEHA, or NRSB.
- Experience: 3 years of documentable radon testing experience.
- Certification: Current NEHA or NRSB certification.

Personnel other than the on-site field supervisor who are placing and retrieving radon detectors are called field technicians. Qualifications for the field technician follow.

- Training: Radon testing training certified by EPA, NEHA, or NRSB.
- Experience: 1 year of documentable radon testing experience.
- Certification: Current NEHA or NRSB certification.

Personnel who perform data analysis, validation, and certification of the radon testing results are called radon testing analysts. Qualifications for the radon testing analyst follow.

- Training: Radon testing training certified by EPA, NEHA, or NRSB.
- Experience: 5 years of documentable radon testing experience.
- Certification: Current NEHA or NRSB certification.

Under EPA guidelines for implementation of the IRAA, government employees may perform the radon testing at their facilities without accreditation. Therefore, for small testing projects and routine O&M testing, radon testing may employ Navy staff as a cost savings measure. However, the remaining requirements for the testing (EPA, NEHA, or

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NRSB listed devices and laboratories shall be used, testing locations, documentation, etc.) remain unchanged.

3.7 RADON MEASUREMENT REPORTING REQUIREMENTS

For all radon testing conducted, a report shall be generated and submitted to the designated Navy point of contact and shall contain at a minimum the following information:

Contractor Information

- contractor name,
- address and phone number,
- contract number, and
- NEHA or NRSB testing certification number.

Device Information

- manufacturer's name, address, and phone number;
- device type and model number; and
- manufacturer's NEHA and/or NRSB certification number.

The following information should be submitted by building and room tested:

- report date,
- building name,
- sample room and location,
- type of detector,
- type test (short-term or long-term),
- detector identification number,
- duplicate identification number,
- date placed and retrieved,
- measured radon concentration in pCi/L,
- duplicate radon concentration in pCi/L,
- average radon concentration in pCi/L,
- occupied rooms that could not be tested, and
- testing exceptions and losses and comments

For each building tested, a summary listing should include the following:

- number of measurements completed,
- number of detectors lost,
- list of rooms in which testing was unsuccessful,
- number of rooms 0 to <4 pCi/L,

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- number of rooms 4 to <8 pCi/L,
- number of rooms 8 to <20 pCi/L,
- number of rooms 20 to <200 pCi/L,
- number of rooms ≥200 pCi/L or greater,
- highest measurement in picocuries per liter,
- rooms requiring radon mitigation, and
- recommendations for future actions.

Depending on the size, complexity, and needs of the project, additional deliverables (e.g., electronic format, maps, and local geological conditions) may also be requested.

3.8 DATA ANALYSIS

3.8.1 Data Set Validation

When a radon measurement data set is received, the data must be validated before any conclusions are drawn. All deficiencies in the data set need to be documented and corrective actions taken, if warranted. For QA detectors, the following acceptance criteria should be verified:

- The appropriate number of blanks were used (Section 3.6.1) and all blanks are at or below the reported manufacturer lower level of detection (LLD).
- RPD calculations (a measure of precision) should be performed for all duplicate measurements and meet the requirements listed in Section 3.6.2.
- The appropriate number of spikes were used and were exposed at the correct concentration (Section 3.6.1) and are within ± 25% of the known concentration.

Data sets that meet these QA criteria are considered validated and are suitable for further processing. However for data sets with QA deficiencies further analysis is required.

For all QA deficiencies, the manufacturer of the testing devices should be consulted to determine if corrections can be performed. In cases where corrections cannot be performed, or where the corrections still do not meet the NAVRAMP QA requirements, two options exist: redo the radon survey or perform an error impact analysis. For small radon surveys, retesting would probably be the option of choice. However, for larger surveys, time, funding, and logistics may preclude retesting. The objective of error impact analysis is to determine if a defensible conclusion can be reached for measurements at or near the action level using conservative assumptions. The conclusions reached using these methods can be reported provided that the appropriate disclaimer is provided. For example, in cases where the blanks are above the LLD but all radon test results < 4 pCi/L, the impact is minimal. The overall conclusion, no elevated radon is present, can be reached and results reported. Conversely, in cases of significantly elevated results, a conclusion can also be reached (e.g., elevated radon is present) provided the difference between the reported measurement and the background

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is ≥ 4 pCi/L. However, in cases where the background correction yields a result between 3 and 5 pCi/L, those rooms should be retested.

With respect to accuracy, conclusions can be reached provided that the data set has acceptable precision (Section 3.6.2). For example, if the bias is ± 2 pCi/L and the highest measured result is 1.0 pCi/L, the overall conclusion that no elevated radon is present can be reached. However, in cases in which the bias could result in some individual results being ≥ 4 pCi/L, or some marginally elevated results being < 4 pCi/L, retesting should be performed. The same is also true for significantly elevated radon results for which subtracting the bias still provides a result ≥ 4 pCi/L and the conclusion that radon is elevated is evident.

However, poor precision is much more difficult to work around within the area of interest. For example if the average RPD for results for all survey data < 4 pCi/L is twice the NAVRAMP limit (e.g., 134%), any result over 1.7 pCi/L could potentially be above the action level. Therefore, redoing the survey is warranted. Conversely, an elevated result of 5.6 pCi/L would also be potentially suspect if its RPD were twice the NAVRAMP > 4 pCi/L limit (e.g., 72%). Therefore, confirmation measurements would be needed. At higher radon concentrations (e.g., > 10 pCi/L), poor precision does not alter the conclusion that elevated radon is present; therefore, confirmation testing would not be needed.

3.8.2 Data Set Completeness

The overall objective of NAVRAMP testing is to test all routinely occupied ground-contact rooms. However, detector losses, inaccessible areas, and other errors will inevitably result in some rooms not having radon data. The necessity of retesting these rooms depends upon many factors, such as the total number of rooms in which data are available, the potential for elevated radon at the site, and the highest result in the building. Within each building tested, a check should also be performed to ensure that all occupied areas required to be tested under NAVRAMP actually were tested (Section 3.5.5). Any areas or rooms that were missed should be documented and reasons provided. Under NAVRAMP, retesting of testable rooms with missing data (not the entire building) shall be performed for any building in which a confirmed elevated measurement was found. For all other buildings in which the highest result was <4 pCi/L, retesting in the rooms with missing data should be considered only if losses exceed 20% of the total testable rooms.

3.8.3 Elevated Radon Results

The objective of this section is to reach a defensible testing conclusion for each room tested using a validated data set following standardized procedures. Because EPA and NAVRAMP guidelines require that any measurement ≥4 pCi/L be confirmed before corrective action is taken, the measurements need to be segregated by room into two types of measurements, those performed individually and those performed using collocated duplicates.

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For rooms tested with a single measurement, results ≥4 pCi/L are considered confirmed if one or more of the following is true:

- One or more rooms in the building are ≥4 pCi/L.
- Prior testing in the room has been ≥4 pCi/L.
- The average of sequential measurements employing similar test devices for a similar duration in the room is ≥4 pCi/L.

For all other rooms, a single measurement of ≥4 pCi/L will need to be confirmed by independent measurement using either long-term or short-term devices before taking corrective action.

For measurements performed using collocated duplicates, results in which the arithmetic average is ≥4 pCi/L are individually reviewed to determine if confirmation is required. The measurement is considered confirmed if one or more of the following is true:

- The RPD is <36%.
- One or more rooms in the building are confirmed ≥4 pCi/L.
- Prior testing in the room has been ≥4 pCi/L.
- The average sequential measurements employing similar test devices at a similar duration in the room is ≥4 pCi/L.

For the remaining cases, the ≥4 pCi/L measurement will need to be confirmed by independent measurement using either long-term or short-term devices before taking corrective action.

The only exception to these rules is in cases in which both radon results are >30 pCi/L. For both technical and business reasons, all commercially available radon measurement devices have upper limits for radon exposure. After they are exceeded, both precision and accuracy tend to widen and drift, respectively. In these cases, the device manufacturer should be consulted. In cases of high radon, obtaining a measurement within the NAVRAMP control limits is a secondary concern to mitigation

3.8.4 Averaging Sequential Radon Measurements

For any radon measurements < 1 year in duration, questions may arise as to what the annual average concentration would be (the annual concentration is the result upon which most mitigation decisions are made). Within the EPA guidance, one recommendation is that mitigation should be considered for any result ≥ 8 pCi/L. The rationale is that another follow-up test, even if it were 0.0 pCi/L (a physical impossibility), would nonetheless average to 4.0 pCi/L.

When sequential measurements (sometimes referred to as sequential duplicates) are performed, in accordance with EPA guidelines, averaging of long-term and short-term measurements cannot be performed. Averaging can be performed only between similar

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types of radon measurements with acceptable NAVRAMP RPDs. When similar types of radon measurements are averaged, the average of each measurement event is calculated first and then the average of these results is calculated. In the example shown in Table 8, over a 1-year period, a room had three short-term testing events, each performed with collocated duplicate detectors. The average result and RPD of each measurement event were calculated. Because all of the RPDs were within acceptable limits, the overall average of all three measurement events was then calculated. The result, 3.5 pCi/L, would indicate that mitigation would not be required in this room. However, if one of the three measurement events had an unacceptable RPD, it would be discarded, the average of the two remaining results would be taken, and a conclusion would be drawn from the result.

Table 7. Sequential testing averaging example

Measurement	Detector 1 (pCi/L)	Detector 2 (pCi/L)	Average (pCi/L)	RPD (%)
1	3.9	4.5	4.2	14.3
2	2.0	2.4	2.2	18.2
3	3.8	4.3	4.1	12.3
Average			**3.5**	

However, in some buildings, seasonal HVAC settings may have a direct impact on the radon concentration. Examples of this include variation in the volume of make-up air, physically turning the HVAC off during transient seasons, and changes in the supply air volume, to name a few. In these cases, a time-weighted average method can be employed to determine if mitigation is required. For this determination, detailed HVAC operational information is required—specifically, when the changes occur and for what duration—in addition to representative, good-quality radon measurement data collected during these periods. To perform the time-weighted average, the number of days is first estimated for each specific HVAC condition found throughout the year. The individual estimated days are then multiplied by their respective radon results (pCi/L) for this period. The pCi/L-days are then summed and then divided by the total number of days (ideally, 360 to 365 days). The result in pCi/L would be an estimate of the annual average for the building (see Table 9 for examples).

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Table 8. Examples of time weighted averaging

Example 1	**Winter (HVAC On)**	**Spring (HVAC Off)**	**Summer (HVAC On)**	**Fall (HVAC Off)**	**Total**
Number of days	120	60	120	60	360
Radon level (pCi/L)	8.0	1.0	4.0	0.5	N/A
pCi-L-days	960	60	480	30	1530
Average radon level	4.3				
Conclusion	**Mitigate**				
Example 2	**Winter (HVAC On)**	**Spring (HVAC Off)**	**Summer (HVAC On)**	**Fall (HVAC Off)**	**Total**
Number of days	180	N/A	180	N/A	360
Radon level (pCi/L)	8.0	N/A	0.1	N/A	N/A
pCi-L-days	1440	N/A	18	N/A	1458
Average radon level	4.1				
Conclusion	**Mitigate**				
Example 3	**Winter (HVAC On)**	**Spring (HVAC Off)**	**Summer (HVAC On)**	**Fall (HVAC Off)**	**Total**
Number of days	90	90	90	90	360
Radon level (pCi/L)	6.0	0.5	0.8	0.5	N/A
pCi-L-days	540	45	72	45	702
Average radon level	2.0				
Conclusion	**Mitigation is not required, but 1-year testing should be considered**				

In cases where the estimated annual average is ≤2 pCi/L, mitigation would not be recommended; however, retesting using a 1-year measurement should be considered. For an annual average ≥4 pCi/L, mitigation should be performed in accordance with the NAVRAMP time line (Table 6). However, for estimated results >2 and <4 pCi/L, retesting using a 1-year measurement should be performed.

3.8.5 Confirmation Measurements

As was mentioned earlier, the objective of all NAVRAMP testing is to reach a defensible testing conclusion. If NAVRAMP QA/QC has been followed and the data set validated (Section 3.8.1), then the likelihood of an erroneous radon measurement is very small. In cases in which seasonal weather patterns or cyclic HVAC operation is known or suspected to have caused an error, testing should be performed using sequential measurements (Section 3.8.4).

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In all other cases using a valid data set, the only reasons to confirm an elevated measurement would be

- if the measurement in question failed to meet the RPD requirements (Section 3.6.2),
- if the measurement was not performed using collocated duplicates, or
- if a specific event occurred during the testing that might have resulted in an elevated radon reading.

The perception of "testing until I find a result that I like" should be avoided at all times.

For a single, valid, elevated radon measurement (e.g., no collocated detector), retesting must be performed if there are no other results in the building ≥4pCi/L. If the initial measurement was short-term, then another short-term measurement can be used if similar test conditions (e.g., during the same season) can be obtained. If not, then a long-term measurement will be required. If the retest of a short-term measurement is performed using short-term devices, under similar conditions, the initial measurement is considered confirmed if

- the average of the test and the retest is ≥4 pCi/L,
- the average w the retest is <4 pCi/L but ≤ 50% of the initial measurement (e.g., a retest of 2.0 pCi/L confirms a 4.0 pCi/L).

If the measurement is not confirmed, then a third test is employed using the same criteria as above. If the elevated measurement cannot be confirmed, it should be error coded and not used.

Ideally, to confirm a long-term measurement, another long-term measurement would be performed during the same season. Unfortunately, time and/or financial considerations may require a follow-up test using a shorter measurement interval in a different season. Extrapolating from EPA guidance and programmatic lessons learned, a few general rules have been developed to assist in interpreting independently measured long-term tests and short-term data. The following is a summary of the confirmation algorithm:

1. If both the short-term and long-term measurements are ≥4 pCi/L, then the long-term result is considered confirmed (e.g., initial long-term = 4.0 pCi/L and average short-term confirmation = 30 pCi/L).

2. If the short-term measurement result is <4 pCi/L but >50% of the long-term result, then the long-term result is confirmed (e.g., initial long-term = 4.0 pCi/L and short-term confirmation = 2.0 pCi/L).

In cases of disagreement, a second confirmation measurement should be performed using either a short-term or long-term (preferred) confirmation during similar long-term test conditions. If the second follow-up measurement is >4 pCi/L, then the initial conclusion is kept (e.g., elevated radon is present). If the second follow-up agrees with the first

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follow-up measurement, then a new conclusion is reached based on the most recent short-term measurements. In addition, consideration should be given to any changes (usage, structural, or mechanical) that may have occurred since the initial long-term test was performed. The occurrence of any one of these events can cause significant increases or decreases in the radon levels. The confirmation algorithm is shown in Flowchart 4.

3.8.6 Postmitigation and O&M Measurements

For postmitigation testing, EPA requires only that the measurement be performed using an approved device/method and be conducted within 30 days of the mitigation installation (EPA 402-R-93-078, 1994). A successful mitigation is evident if the measurement is <4 pCi/L. Similar guidance is provided for O&M testing with the exception that the test is to be performed every 2 years after mitigation. Under NAVRAMP, these measurements are performed using collocated duplicates (duplicates are not required for CRMs) and the results validated by calculating the RPD (Eq. [2]). The measurement is considered valid if

- an average RPD of <67% is achieved for average radon results >2 pCi/L and <4 pCi/L, or
- an average RPD of <36% is achieved for average radon results ≥4 pCi/L.

RPD validation is not required if both results are < 2 pCi/L.

3.8.7 Analysis of Radon Test Data from Other Sources

Recently, as a cost savings measure, DoD has combined separate DoD facilities into a common administrative entity to save on both administration and maintenance costs. At Naval activities where joint basing has occurred and the Navy has been designated as the administrative lead, a data review of all available radon data for the acquired buildings will be required. The objective of this review is to assign the appropriate RPC (Section 3.3). However, before category assignment, the data set must first be validated by meeting the following requirements:

1. The testing method, procedures, and QA/QC meet the EPA requirements listed in *Protocols for Radon and Radon Decay Product Measurements in Homes*, EPA 402-R-92-003, 1992, or the EPA testing requirements for federal agencies (Section 1.5.4).
2. The testing devices used meet the NAVRAMP testing device policy (Section 3.5.7).
    a. WL or progeny measurements cannot be accepted.
3. The radon results are submitted with the following information:
    a. type and manufacturer of testing device (i.e., ATD, charcoal canister, E-Perm, etc.),
    b. name of the organization that performed the testing, and

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c. individual radon results for each room tested, including the detector number, date placed, and date retrieved.

If all of these are not met, then the newly acquired property is assigned an RPC-2 designation (Section 3.3) and required testing is performed.

If the data set is validated, then a review is required to determine if any radon results are ≥4 pCi/L. If yes, then NAVRAMP Confirmation Algorithm (Flowchart 4) should be applied to determine if additional follow-up testing is needed. If the results are confirmed (existing or by confirmation measurements), the site is assigned an RPC- 1 designation (Section 3.3) and required testing performed.

If the data set is validated but the highest radon result is <4 pCi/L, a determination needs to be made whether sufficient testing has been performed. If at least 1/4 of the ground-contact occupied rooms at the site were tested, then an RPC-3 designation (Section 3.3) is assigned and any required testing is performed. If <1/4 of the rooms were tested, then an RPC-2 designation (Section 3.3) is assigned and any required testing is performed.

If no data are available, then an RPC-2 designation (Section 3.3) is assigned and testing should be initiated.

3.9 RELEASE OF RADON TEST DATA

Simply stated, the NAVRAMP policy is full disclosure of radon results to current, past, and future occupants of a building. For current occupants of the building, radon results are provided to the building manager once they have become finalized. However, data summaries and results will be provided to current and past occupants if requested in writing.

As a minimum, the radon information packet should contain

- the period during which radon testing was performed,
- the building number and/or room (as applicable),
- a brief description of what radon is,
- the radon result,
- applicable action, and
- a local contact for additional information about radon.

For buildings with multiple data sets, the most recent radon results should be provided, unless a particular time period was requested. However, if applicable, reference should be made in the packet that additional test data may be available if requested. A record of this correspondence should be kept on file.

For past occupants, radon results can be provided in the letter format shown above, provided that

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1. the request is made in writing to the activity environmental director and
2. the requestor's occupancy can be verified.

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3.9.1 Radon Testing Records Management

All radon testing data forms shall be kept in active files for a period of 10 years. After that time, they should be scanned into Adobe Portable Document Format (PDF) or a similar electronic format for indefinite long-term storage. All individual test results shall be stored electronically in a database file to facilitate data retrieval for occupant requests.

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4. RADON MITIGATION

4.1 NAVRAMP RADON MITIGATION SYSTEM REQUIREMENTS

All radon mitigation shall meet the following requirements:

- The installed mitigation system shall consistently maintain radon levels at <4 pCi/L when operating.
- Only mitigation methods that either (1) prevent radon gas from entering the building or (2) dilute the gas by use of supplemental ventilation can be used within Navy buildings (EPA/625/5-88/024 August 1988, and EPA/625/R-93/011 October 1993).
- All mitigation systems shall be equipped with a performance indicator and contact information to report system failure.
- All mitigation shall be performed by qualified personnel (Section 4.2.6).

4.2 RADON MITIGATION SPECIFICATIONS AND REQUIREMENTS

EPA divides radon mitigation into two basic categories: passive and active. Passive mitigation is defined as a nonmechanical means of radon abatement or control by the use of sealing cracks, balancing an existing mechanical system, installing a passive stack vent pipe during construction, or increasing the natural ventilation rate of the building substructure (i.e., crawl space). On the other hand, active mitigation entails the use of mechanical means, such as a fan or blower, to either dilute or control the entry of radon into the living area. Examples of active mitigation include, but are not limited to, SP, ERV, SSD, and SAM.

Because of the diversity in style and construction of Navy buildings, a single mitigation approach for all buildings at an activity is not possible. Therefore, building-specific mitigation diagnostics (measurements that assist in the selection of a mitigation system) should be conducted to ensure that a proper mitigation system selection is made. As mitigation method selection criteria, in general the costs (installation and O&M), probability of success, and direct impact on the buildings occupants are always considered. Other considerations might include

- energy consumption,
- security concerns,
- aesthetics,
- noise generation,
- loss of indoor functional space,
- proposed and pending renovations,
- projected remaining lifetime of the building, and

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- understanding of the occupants' concerns.

As a general rule, because of their long-term cost-effectiveness, passive, SSD, and SAM mitigation should always be considered first. If these methods are not viable, then other mitigation methods (e.g., ERV, SP) should be considered. However, under no circumstances, because of uncertainties in risk reduction, should HEPA systems or other methods that alter the radon decay product equilibrium be used.

Upon completion of a mitigation system installation, postmitigation radon testing shall be performed by the mitigation contractor to ensure that radon levels are <4 pCi/L. All postmitigation testing shall be short term and in accordance with NAVRAMP testing policies, guidelines, and procedures and EPA 402-R-92-004 (July 1992). Postmitigation testing shall be performed no sooner than 24 h and no later than 30 days after system activation or, in the case of passive mitigation, completion. Within 30 days of the reporting of the postmitigation test results and at the discretion of the Navy, an independent postmitigation test may be performed to verify that radon mitigation has indeed occurred. The extent and frequency of this follow-up postmitigation testing are at the sole discretion of the Navy.

4.2.1 Passive Mitigation Specifications and QA

For use in existing construction, passive mitigation is divided into two categories: sealing and mechanical balance and repair. Although it is simple in concept (e.g., no moving parts), it can in the long term be difficult to inspect passive mitigation and ascertain current system performance. With respect to O&M, EPA applies the same inspection and testing criteria as with active systems (e.g., periodic inspection, retest every 2 years).

In passive sealing, various sealants are applied to cracks, crevasses, expansion joints, and other potential radon soil gas entry points in a effort to reduce or, ideally, eliminate radon entry entirely. Passive sealing should be attempted as a mitigation means only if the repair would potentially last for >20 years. Therefore, the selection of the most appropriate sealant is critical. According to the American Adhesive and Sealant Council, the choice of a sealant should be based on the type and size of the opening, the opening substrate, the environment in which the sealant would be used, and the potential for deterioration, among other criteria. For most sealants on the market, specification and instruction sheets provided by the manufacturer are a good source of this type of information. In addition, the Material Safety Data Sheet should be consulted to see if any precautions need to be taken during installation and post-application curing.

With respect to post-installation QA, passive sealing is highly application-specific and thus does not fit easily into a standard checklist. Therefore, a customized QA checklist must be developed for each post-installation inspection and for future O&M checks. Questions that should always be included on the post-installation checklist are

- Was the use of this particular sealant appropriate for this application?
- Was the sealant applied per manufacturer's instructions?

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In mechanical balance and repair, the building's mechanical systems (e.g., supply and exhaust) are modified or restored to the original design specifications. This includes, but is not limited to, the replacement of makeup air and exhaust components, adjustments to supply and return air, adjustments to the fresh-air and exhaust dampers, and modifications to duct components that are in ground contact (e.g., subslab return or supply ducts). As with passive sealing, this technique is very much application-specific and does not easily fit into a standardized QA checklist. Therefore, a customized form will have to be developed for the post-installation check and future O&M inspections. Questions that should always be included on the post-installation check list are

- Did the adjustment, modification, or repair keep the building's temperature and humidity within the design specifications?
- Did the adjustment, modification, or repair have any significant impact on the occupants' comfort?

Within 30 days of the passive mitigation installation, the activity or its designee should perform independent inspections on the passive mitigation installation to verify that the system meets the design requirements and was installed properly.

4.2.2 Shell Pressurization Specifications and QA

SP, although the oldest and best understood of all radon mitigation methods, should be considered the mitigation method of last resort. To be brief, SP mitigation compared with other forms of radon mitigation has higher maintenance and energy costs and, depending upon the type of SP system installed, may have higher installation costs. SP systems consist of two basic types differentiated by how the required volume of outdoor air is supplied.

A Type 1 SP system uses either an existing or an installed fresh-air damper to supply the fresh air. In this design, the air is conditioned by the building's existing mechanical system prior to discharge into the building. Therefore, before the SP system is installed, the building's current mechanical system would need to be evaluated and load calculations performed to determine if it could condition the added volume of air (e.g., heat, cool, and dehumidify). If the existing mechanical system lacks the capacity for conditioning the required makeup air, then a Type 2 SP system (an independent mechanical system to condition the outdoor air prior to its entry into the structure) will be required. As before, load calculations must be performed to ensure that the unit will adequately condition the supply air year round.

Specifications for SP mitigation systems are building- and application-specific, meaning that the design for one building will not be readily interchangeable with another. Many considerations go into the design of an SP system to ensure that the current mechanical system(s) can handle the added conditioning load and that the possible increase in humidity would not place the building within the range for inducing mold growth ($\geq$ 60% RH). Therefore, if SP is selected as the mitigation method, the design will need to be

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reviewed and approved by a qualified mechanical engineer before the mitigation system is installed. From this final design, a QA checklist can be generated for possible inspection. Examples of typical features and conditions to check after installation are

1. The quarters, room(s), or building is between (+) 4 and 8 Pa relative to the outdoors.
2. Installed filters are MERV 8 or greater rating (ASHRAE 52.2-2007) and are accessible.
3. The relative humidity in the room(s) or building is ≤60% or whatever the building's requirements are.
4. Wall penetrations to the exterior are sealed.
5. To the best extent possible, the system should meet fresh-air intake requirements of *DoD Minimum Antiterrorism Standards for Buildings* (UFC 4-010-01, October 2003, updated 22 January 2007).

Within 30 days of the mitigation installation, an independent inspection should be performed on the SP system to verify that the system meets the design requirements and was installed properly. In addition, pressure, temperature, and humidity measurements should be made in the supply air and in the rooms or building to verify that the tolerances listed in the design were met.

4.2.3 Energy Recovery Ventilation Specifications and QA

ERV is a post-entry mitigation technique that reduces the indoor radon concentration by increasing the air exchange in the building or room(s). An ERV unit typically consists of two fans, one exhausting a known volume of indoor air and the second bringing in an equal volume. During operation, the two air streams (in separate compartments of the unit) pass over an inter-compartmental heat exchanger (for energy recovery) and a desiccant wheel (for humidity control). Although heat recovery is high for most units (ranging from 60 to 80%), the units are not well suited for use as dehumidifiers in particular climates with hot, humid summers. Consequently, as part of the mitigation design, the existing building's mechanical system needs to be evaluated to determine if it can handle the added cooling and heating load and the increase in humidity. If that capability is in question, optional features (available on most commercial units) for conditioning the incoming outdoor air should be included.

The design specifications of all ERV systems for use within Navy buildings must have been evaluated using either ASHRAE Standard 84-2008 or AHRI Standard 1060-2005.

The proposed ERV unit should have a rated capacity of at least 10% above the required CFM to allow for some performance degradation between air filter changeouts. Also, the supply air volume should be at least 5% greater than the exhaust volume to prevent possible room depressurization. In addition, on average the unit should recover at least 70% of the conditioned temperatures year round (as determined by either ASHRAE Standard 84-2008 or AHRI Standard 1060-2005). The unit should be equipped with an insect screen and MERV 8 filters (ASHRAE 52.2-2007). In addition, the operation of the

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unit should not cause room(s), or building to exceed 60% RH or whatever the building's requirements are for any extended period of time. Also, to the best extent possible, the system should meet fresh-air intake requirements *of DoD Minimum Antiterrorism Standards for Buildings* (UFC 4-010-01, October 2003, updated 22 January 2007).

Within 30 days of the ERV installation, an independent inspection of the installation should be performed to verify that the system meets the proposed contract design requirements and was installed properly. In addition, temperature and humidity measurements should be made in the supply air and in the room(s) or building to verify that the tolerances listed in the design are met.

4.2.4 Supplemental Air Makeup Specifications and QA

SAM is used to correct elevated radon problems in a single nonresidential room by providing additional forced-air ventilation. Although relatively easy to install and maintain (a typical SAM system consists of a blower, ductwork, and a switch), the technique is not widely employed because of its limited application. For example, the criteria for the room to be mitigated by SAM are that it must

- have radon levels <20 pCi/L,
- be no larger than 3500 ft^3,
- have an ACH rate of <0.2 air changes per hour, and
- be located near a large room or common area from which the desired volume of low-radon conditioned air can be withdrawn without a significant risk of depressurization.

In addition to these criteria, particular attention must be paid to noise and occupant comfort. Because these systems are usually used in single or double offices, the noise generated by the discharge of the supply air may pose an inadvertent distraction to the occupant(s). Therefore, the supply diffuser, in addition to being aesthetically pleasing, must produce as little noise as possible. Another important consideration is the location of the discharge point. The discharge air velocity from a typical SAM system is comparable to that of a forced air system. So to the best extent possible, the discharge needs to be in a location that would not appreciably increase the air velocity in the primary work area.

Within 30 days of the SAM installation, an independent inspection should be performed to verify that the system meets the proposed contract design requirements and was installed properly.

4.2.5 Subslab Depressurization Specifications and QA

For SSD mitigation systems, minimum specifications are that the systems comply with

- *Standard Practice for Installing Radon Mitigation Systems in Existing Low-Rise Residential Buildings*, ASTM E2121-09.

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- *Radon Mitigation*, UFGS-31-21-13, April 2006.

In addition, the following requirements must be met:

1. All electrical work shall meet or exceed the most current National Electrical Code and shall use solid 12 AWG wire.
2. The electrical circuit for the radon fan shall be clearly labeled in the breaker panel.
3. All mitigation fans shall be hard-wired unless in an attic where corded fans (<6 ft) will be allowed.
4. A wet location–rated electrical switch shall be located within 6 ft of the fan unless it is an attic installation where corded fans are permitted.
5. All vent pipes and fittings shall be white 4 in. PVC Schedule 40.
6. All metal components of the system (e.g., fasteners, pipe straps, channel) shall be stainless steel or be corrosion resistant.
7. All fans shall be rated for exterior use and be designated by the manufacturer for use as radon mitigation fans.
8. Every vent stack shall be covered with a vent cap.
9. All systems shall have a performance indicator located within 6 ft of the primary slab penetration point. Instructions on how to read the indicator and a contact phone number shall be posted adjacent to the indicator.
10. Where applicable, all radon fans shall be covered by a fan cover attached to a fan cover base plate.
11. All exterior clamps and fasters shall be stainless steel, galvanized, or corrosion resistant.

Contractor-requested exceptions to these standards shall be submitted to the Navy in writing for consideration at least 2 weeks prior to the mitigation installation.

Within 30 days of the mitigation installation project, an independent inspection should be performed on a randomly selected section of the radon system to verify that the system meets the proposed design specifications. The frequency of the random checks and the number of systems to verify are at the sole discretion of the Navy. An example data form for SSD inspection is included in Appendix A.

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4.2.6 Radon Mitigation Subcontractor Qualifications

For all field mitigation diagnostics and installation activities, the radon team must be under the direct supervision of an on-site field supervisor. Qualifications for the field supervisor follow.

- Training: Radon mitigation training certified by EPA, NEHA, or NRSB.
- Experience: 3 years of documentable radon mitigation experience.
- Certification: Current NEHA or NRSB certification.

Personnel other than the on-site field supervisor who are involved in mitigation diagnostics or installation are called field technicians. Qualifications for the field technician follow.

- Training: Radon mitigation training certified by EPA, NEHA, or NRSB.
- Experience: 1 year of documentable radon mitigation experience.
- Certification: Current NEHA or NRSB certification.

Personnel who perform mitigation design are called radon mitigation analysts. Qualifications for the radon mitigation analyst follow.

- Training: Radon mitigation training certified by EPA, NEHA, or NRSB.
- Experience: 5 years of documentable radon mitigation experience.
- Certification: Current NEHA or NRSB certification.

4.3 RADON-RESISTANT NEW CONSTRUCTION REQUIREMENTS

The basic design considerations for buildings that will incorporate radon-resistant features in new construction are as follows:

- if possible, the aggregate bed under the slab not be compacted,
- one riser should be installed for every 3000–5000 ft^2 of slab (see also ASTM E1465-08a),
- there should be provision for 3–4 ft of clearance in the attic to allow for easy access to install and maintain the fan, and
- the electrical outlet should be located within 6 ft of the radon vent riser in the attic.

In addition to the requirements listed, the passive sealing portions of Unified Facilities Criteria (UFC) 3-490-04A (May 2003) and the subslab gas collector specifications from ASTM E1465-08a should be incorporated as well.

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4.3.1 RRNC Design Overview

For all new construction incorporating radon–resistant features, all gaps/joints and slab penetrations should be sealed. However, the installation of other RRNC features and components will depend upon the design of the building. It is recommended that to the best extent possible, one of the following three RRNC methods be incorporated into the building design:

- Method 1 uses a preinstalled vent pipe to route radon from under the slab to above the roof. This method is commonly referred to as passive stack.
- Method 2 uses a subslab soil gas collection piping network that is connected to a vent pipe that penetrates the roof. This technique is commonly referred to as mitigation-ready passive stack.
- Method 3 uses an identical subslab soil gas collection piping network, but the vent piping is stubbed out and capped in either the living area or attic or on the exterior of the building. This technique is commonly referred to as "mitigation ready."

4.3.1.1 Slab Sealing Specifications

All gaps/joints and all floor slab penetrations must be sealed in accordance with ASTM E1465-08a, UFC 3-490-04A, and UFC 3-190-01FA to prevent air leakage into the building. Gaps can be filled with polyethylene backer rod or comparable filler material as required and sealed with polyurethane caulk or other elastomeric sealant. Caulks and sealants shall be applied according to the manufacturer's instructions. All penetrations into the building exterior should be inspected to ensure they are watertight. All work should be coordinated with the contracting officer.

4.3.1.2 Method 1: Passive Stack (Option)

Operational Principle

This design utilizes a radon-resistant technique to potentially retard radon entry into the building by passively redirecting the radon soil gas from under the slab to a vent pipe.

Specifications

Just before the slab is poured, at an interval of one pipe for every 2000 ft^2 of slab, a 4 in. Schedule 40 PVC vent pipe equipped with a Tee will be inserted into a noncompacted aggregate bed [minimum 4 in. layer of clean coarse gravel (½–¾ in. mesh)]. After the concrete has been poured, the gap around the pipe will be sealed with polyurethane caulk or other elastomeric sealant. The vent pipe will then be routed vertically through the building and through the roof in a manner that would not interfere with the daily operations and functions of the building occupants. The exhaust end of the pipe shall be left uncapped, and the vent stack pipe discharge location shall be as specified in ASTM E1465-08a.

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Within 6 ft of the location of a proposed fan (fan cannot be mounted in or directly under living space), an electrical outlet on a dedicated circuit shall be installed. If needed, multiple fans can be wired to the same dedicated circuit. All components of radon system piping shall drain their condensed water vapor and collected rain completely to the ground beneath the slab. If the intent is to mount the proposed fan in the attic, then a minimum of 3–4 ft of vertical clearance will be required to allow for easy access to install and maintain the fan. To the best extent possible, the visibility of the system should be kept to a minimum, and all operating components should be accessible for maintenance and repair.

4.3.1.3 Method 2: Mitigation-Ready Passive Stack (Option)

Operational Principle

This design uses a radon-resistant technique to potentially retard radon entry into the building by passively redirecting the radon soil gas through a network of underground pipes to a vent pipe.

Specifications

A network of Schedule 40 perforated PVC pipes (Type 1 soil gas collector; flexible corrugated drain tile may be substituted) will be buried in the gas-permeable layer of crushed stone [minimum 8 in. layer of clean coarse gravel (½–¾ in. mesh)] and manifolded to effect coverage under all rooms. A Tee assembly shall be positioned so that the suction point pipe that attaches to it penetrates the slab in an unobtrusive place and where the suction point can be attached to the vent stack (one riser for every 3000–5000 ft^2 of slab). Perforated, corrugated drain tile can be substituted for the Schedule 40 PVC provided it is inspected for deformations (e.g., crushing) and repaired just prior to pouring the slab. The radon system's vent piping (4 in. Schedule 40; corrugated drain tile **cannot** be substituted) shall be routed so as not to interfere with the daily operations and functions of the building occupants. The exhaust end of the pipe shall be left uncapped, and the vent stack pipe discharge location shall be as specified in ASTM E1465-08a.

Within 6 ft of the location of a proposed fan (fan cannot be mounted in or directly under living space), an electrical outlet on a dedicated circuit shall be installed. If needed, multiple fans can be wired to the same dedicated circuit. If the intent is to mount the proposed fan in the attic, then a minimum of 3–4 ft of vertical clearance will be required to allow for easy access to install and maintain the fan. All components of radon system piping shall drain their condensed water vapor and collected rain completely to the ground beneath the slab. To the best extent possible, the visibility of the system should be kept to a minimum, and all operating components should be accessible for maintenance and repair.

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4.3.1.4 Method 3: Mitigation-Ready (Option)

Operational Principle

This design uses a mitigation-ready approach to ensure that if elevated radon is found, mitigation can be successfully performed at a lower cost.

Specifications

A network of Schedule 40 perforated PVC pipes (Type 1 soil gas collector; flexible corrugated drain tile may be substituted) will be buried in the gas-permeable layer of crushed stone [minimum 8 in. layer of clean coarse gravel (½–¾ in mesh)] and manifolded to effect coverage under all rooms. In the design, allowances should be made for one riser of either type (see below) for every 3000–5000 ft^2 of slab. If perforated, corrugated drain tile must be substituted for the Schedule 40 PVC soil gas collection network, it must be inspected for deformations (e.g., crushing) and repaired just prior to pouring the slab.

For interior risers, a Tee assembly shall be positioned so that the suction point pipe that attaches to the soil gas collection network penetrates the slab in an unobtrusive place and where the suction point can be attached to the vent stack. The capped riser should extend at minimum 6 in. above the floor (proposed route of the optional vent pipe should be included in the building plans) and should be located in an area that is readily accessible (e.g., the capped end of the riser cannot be enclosed inside a wall).

For exterior-mounted risers, a branch of the soil gas collection network should extend through the foundation using 4 in. Schedule 40 pipe and should have a 90 degree elbow attached. From the top of the elbow, a minimum of a 6 in. section of 4 in. Schedule 40 pipe shall be attached and a cap installed on the end. The riser should be located in an area that is readily accessible, and the building plans should contain the proposed route of the optional vent pipe. In addition, the location of the riser and optional vent pipe should not interfere with the daily operations and functions of the building occupants.

Within 6 ft of the location (either type of riser) of a proposed fan (fan cannot be mounted in or directly under living space), an electrical outlet on a dedicated circuit shall be installed. If needed, multiple fans can be wired to the same dedicated circuit. If the intent is to mount the proposed fan in the attic, then a minimum of 3–4 ft of vertical clearance will be required to allow for easy access to install and maintain the fan. All components of radon system piping shall drain their condensed water vapor and collected rain completely to the ground beneath the slab. To the best extent possible, the visibility of the system should be kept to a minimum, and all operating components should be accessible for maintenance and repair.

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4.3.1.5 Design Specification for Radon Fan Assembly

For all passive stack and mitigation-ready options, designs and specifications shall be provided for the installation of the radon fan. In addition, the proposed fan shall be installed in a vertical section of the vent stack pipe and in a vertical orientation to prevent condensed water and precipitation from accumulating in the fan. As a minimum, the design shall contain the

- proposed fan location and type of fan,
- proposed electrical hook-up and wiring specification,
- location and type of the system performance indicator, and
- any additional hardware needed for fan activation.

4.3.1.6 Labeling of System

Labeling of system components as specified in ASTM E1465-08a shall be performed for all passive stack and mitigation ready options.

4.3.1.7 Radon Testing

Upon building completion, an initial radon gas test shall be performed as specified in accordance with the NAVRAMP testing protocol. The building should be tested under closed building conditions (e.g., all windows and doors should be closed). In addition, all mechanical equipment (normally, exhaust blowers and central air-conditioning system typically operating) that will be operating during normal human occupancy should be operating at least 24 h prior to performing an initial radon test.

4.3.1.8 Activation of Radon Mitigation System (Option)

If the initial radon test results are ≥4.0 pCi/L, then the mitigation fan and any remaining vent pipe should be installed per design and activated by a certified radon mitigator under the supervision of the responsible system designer. Upon completion of fan installation and activation, postmitigation testing shall be performed no sooner than 24 h after fan activation to ensure that radon levels in occupiable spaces are <4.0 pCi/L. All testing should be performed under closed building conditions (i.e., all windows and doors should be closed). In addition, all mechanical equipment (normally, exhaust blowers and central air-conditioning system typically operating) that will be operating during normal human occupancy should be operating at least 24 h prior to performing an initial radon test. If elevated radon is still present, the contract officer should be consulted for further instruction.

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4.3.2 Radon-Resistant New Construction Designer Subcontractor Qualifications

For all RRNC designs, the designer shall have as a minimum

- Training: Radon mitigation training certified by EPA, NEHA, or NRSB,
- Experience: 5 years of documentable radon mitigation experience,
- Certification: Current NEHA or NRSB certification.

Personnel responsible for the installation, oversight, or activation of the RRNC system shall have as a minimum

- Training: Radon mitigation training certified by EPA, NEHA, or NRSB,
- Experience: 1 year of documentable radon mitigation experience,
- Certification: Current NEHA or NRSB certification.

4.4 O&M OF RADON MITIGATION SYSTEMS

To maintain effective long-term radon control, radon systems will require periodic maintenance and retesting. Therefore, EPA recommends (EPA 402-R-93-078, 1994) that in addition to periodic performance checks, a detailed system inspection be performed every 2 years, followed by radon testing of the mitigated rooms. The following sections outline recommended O&M by type.

4.4.1 O&M of Passive Mitigation Systems

With respect to O&M, passive sealing is very much application-specific and thus does not fit easily into a standard checklist. Therefore, a customized O&M checklist will have to be developed. For passive mitigation involving mechanical balance and repair, the building's mechanical system (e.g., supply and exhaust) is modified or restored to the original design specifications. This includes, but is not limited to, the replacement of makeup air and exhaust components, adjustments to supply and return air, adjustments to the fresh-air and exhaust dampers, and modifications to duct components that are in ground contact (e.g., subslab return or supply ducts). Therefore, the O&M checklist should include those items. In addition, in cases where the repairs or adjustments involved bring in more fresh air, the building's temperature and humidity should be included as well. In cases where sealing was involved, all joints should be inspected to verify that the caulk is still adhering to the substrate.

4.4.2 O&M of Shell Pressurization Systems

An SP system retards radon entry by mechanically introducing sufficient outdoor air to induce a positive pressure across the slab (typically 4 to 6 Pa) and into the soil. By applying pressure across the building shell, the natural flow of radon from the soil into

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the living area is reversed. Therefore, the air flows from the living area into the subslab, preventing radon entry. The downside of an SP system is that all windows and doors must be kept closed to maintain mitigation. Small openings, such as leaving an entry door ajar or leaving a window cracked, will result in the radon levels reverting to their unmitigated levels. Also, as door and window seals deteriorate over time, additional fresh air must be drawn to maintain mitigation.

With respect to routine maintenance of an air intake SP system, the following maintenance is recommended on a quarterly basis or as required by the manufacturer:

1. Clean or replace as needed the air intake grill air filter.
2. Clean in-house return air filter.
3. After cleaning both filters, verify that shell pressure (indoor to outside) is between 4 to 6 Pa with the aid of a digital micromanometer.

Table 10 lists troubleshooting techniques for air-intake SP mitigation systems if, in the future, mitigation failure occurs or the unit can no longer be pressurized to 4 Pa.

Table 9. Troubleshooting SP mitigation systems

Problem	Possible solutions
Unit is <4 Pa shell pressure (indoor to outside)	1. Verify that the mechanical blower is running continuously and properly. 2. Inspect intake grill for blockage. 3. Clean intake grill air filter. 4. Adjust air intake damper to increase outdoor airflow. 5. Inspect the mechanical collar for leakage. Repair leak as needed. 6. Inspect shell for any significant leaks around windows and exterior doors. As appropriate, replace door seals or caulk any cracks around windows and doors.
Unit is >6 Pa pressure (indoor to outside)	1. Adjust air intake damper to decrease outdoor airflow. 2. Clean central mechanical return air filter. 3. Inspect mechanical collar for leakage. Repair leak as needed.
Unit is >4 pCi/L	1. Verify that the blower is running continuously and properly. 2. Check shell pressure with digital micromanometer. 3. Verify that residents are not leaving windows and doors open for extended periods of time.
Unit is >4 pCi/L and shell pressure is between 4 and 6 Pa	1. Repeat differential pressure diagnostic for all major air exhaust systems. Discuss with residents the frequency of usage of the exhaust systems. Increase airflow accordingly to compensate for largest and/or most frequently used air exhaust system.

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4.4.3 O&M of Energy Recovery Ventilation Mitigation Systems

ERV systems are commercially available package systems that reduce radon levels by increasing the natural ventilation rate in the building or room(s). Because of differences in design, installation, and materials, no two manufacturers' O&M requirements are exactly the same. Therefore, it is important to review the owner's manual and draft a system-specific O&M plan. Common O&M elements to address are

1. the frequency of changing the air filters and drive belts,
2. lubrication of the drive and blow motors,
3. maintenance of the desiccant wheel, and
4. the recommended frequency to check the pressure balance of the system.

It is important to note the following: for ERV systems, O&M is not just a good idea; it is mandatory. For example, if the system filters are not changed, the unit may become depressurized (ERV is exhausting more air than it is bringing in), resulting in an increase in the unit's radon levels. In addition, on some ERV models, lack of maintenance of the desiccant wheel could result in a sudden uncontrollable increase in humidity of the supply air. This condition could result in catastrophic condensation release followed by the onset of mold.

4.4.4 O&M of Supplemental Air Makeup Mitigation Systems

In general, SAM systems are easy to operate and maintain. The system consists of two basic parts: the electric fan and the duct, neither of which requires any scheduled maintenance. However, periodically, the intake (Pictures 2 and 3) should be inspected and cleaned and it should be confirmed that the unit is exhausting (e.g., smoke test, strip of paper). To determine if a SAM is working, an illuminated light box (Picture 4) can be installed. Fan operation is indicated by the green LED light (Picture 4).

Every 2 years, it is recommended that the exhaust rate of the blower be checked using a pitot tube, face velocity probe, or other suitable measuring device to confirm a minimum of 150 cfm of makeup air or as specified by the installer. If the air volume is found to be less, the blower should be replaced.

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4.4.5 O&M of Subslab Depressurization Mitigation Systems

SSD mitigation uses a pipe that is inserted through the slab and connected to a fan (Fig. 41, Pictures 5 to 7). When the fan is activated, the area beneath the slab (subslab) is depressurized. The resulting depressurization prevents radon entry into the living area by redirecting the subslab radon into the pipe for discharge into the atmosphere, where it is harmlessly diluted. Generally speaking, an SSD system consists of two major components: the exhaust pipe and the mitigation fan. Of these two components, only the fan will need to be replaced during the remaining lifetime of the building. To determine if the fan is working properly, it is recommended that the occupant perform a monthly visual inspection of the U-tube. If the oil level reads between 0.3 and 4.0 on the scale, then the fan is operating properly (Fig. 42). If the oil level is reading 0, then the occupant should contact the phone number on the decal. A decal placed next to the U-tube provides detailed instructions and contact phone numbers. The only required maintenance of the U-tube is the infrequent addition of oil. If oil is needed, common cooking oil (e.g., Mazola® oil or the equivalent) may be used or the U-tube can be replaced. Petroleum-based oils or fluids should not be used because of the potential for poisoning small children. Before oil is added to the U-tube, the fan should be turned off either at the exterior switch or by tripping the circuit breaker labeled "radon mitigation system" in the unit's main breaker panel. Using an eyedropper or plastic drinking straw, oil can then be added a drop at a time until the level equals 0 or it can simply be replaced. Pictures 8 and 9 show typical U tube installations. The illuminated light box (Picture 10) relies on an electrical pressure sensor to trigger one of two LED lights (red indicating fan is off, and green indicating fan is on). Maintenance for an illuminated light box is limited to infrequent replacement of the 10-year LED bulbs and pressure sensor.

Depending upon the orientation of the building and the type of system installed, the U-tube can be mounted on the exterior of the building inside a manometer box (Picture 8) or mounted on the pipe near the floor penetration (Picture 9). An illuminated light box (Picture 10), on the other hand, can be located near the system or at a convenient location some distance from the system for remote viewing. In the private sector, routine maintenance of the mitigation system is the responsibility of the individual homeowner or building owner, and maintenance is usually performed by qualified personnel after system failure. Evaluation of the SSD systems installed at other military facilities identified several critical parts and components that should be checked on a regular interval. This maintenance is recommended to prevent water leakage into the unit and loss of exterior components during high winds. With these considerations in mind, it is recommended that each component and part listed in Table 11 be inspected in accordance with the proposed schedule. To assist with the identification of the components, a "typical" SSD system has been broken into three assemblies (pipe, fan, and roof flashing) and is illustrated in Figs. 43, 44, and 45).

With respect to trouble-shooting an SSD mitigation system, problems generally are caused by failure of the mitigation fan or the loss of vacuum under the slab. Table 12 summarizes the most common problems and proposed corrective actions for SSD mitigation systems.

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Table 10. SSD components requiring routine inspection

Component	Check for	Corrective action	Recommended frequency of inspection
U-tube (Fig. 42)			
U-tube	Fan operation	Call Trouble Desk if fan is not operational	Monthly by occupant
U-tube	Oil level	Add oil	2 years
Pipe assembly (Fig. 43)			
Pipe/slab seal	Leakage	Apply additional polyurethane caulk	2 years
Interior wall/pipe seal	Leakage	Apply additional polyurethane caulk	2 years
Exterior wall/pipe seal	Leakage	Apply additional polyurethane caulk	2 years
Clamp nut	Tightness	Tighten nut	2 years
Pipe-mounted fan assembly (Fig. 44)			
Rubber boot	Cracking or sagging, fan seated level	Replace boot	2 years
Fan operation	Excessive noise, vibration, or not operating	Replace fan	2 years
Rubber boot/pipe seal	Leakage	Replace boot	2 years
Flex conduit electrical condition	Cracking of conduit and deterioration of liquid-tight connectors	Replace conduit and liquid-tight connectors	2 years
Switch and switch and switch cover gasket	Functional switch and seal of box gasket	Replace switch and gasket	2 years
Conduit C clamp	Tightness and corrosion	Tighten or replace C clamp	2 years
Hose clamp	Tightness	Tighten	2 years
Roof flashing (Fig. 45)			
Flashing	Water leaks and cracking	Replace flashing	2 years

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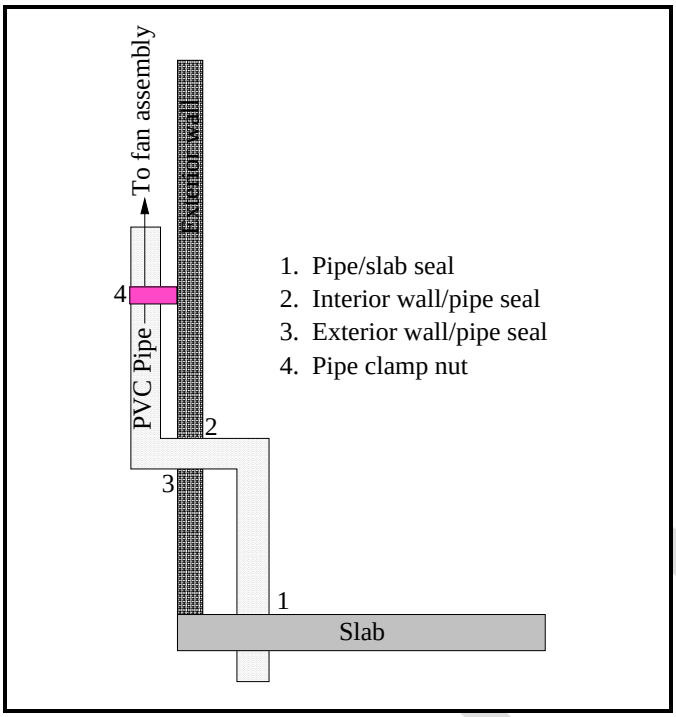

Fig. 19. Components to inspect in an SSD system pipe assembly.

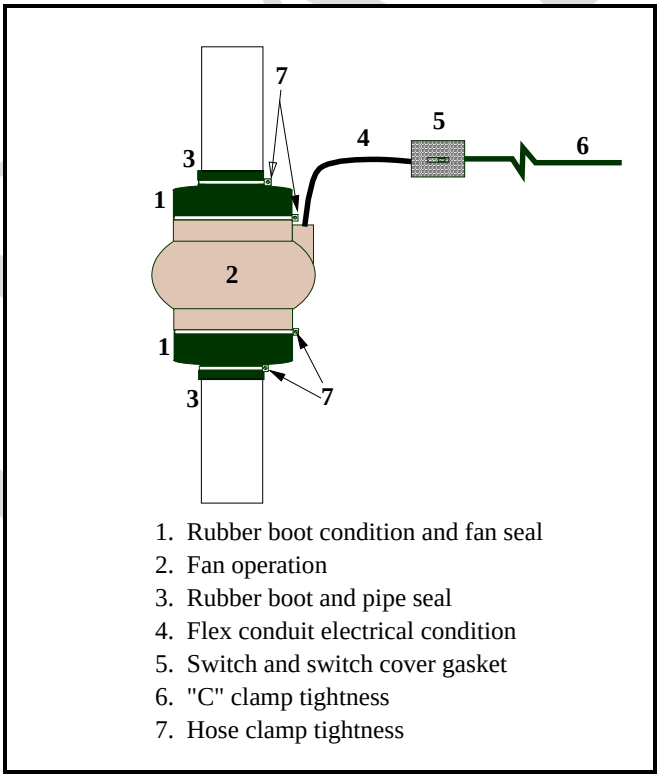

Fig. 20. Components to inspect in an SSD system pipe-mounted fan assembly.

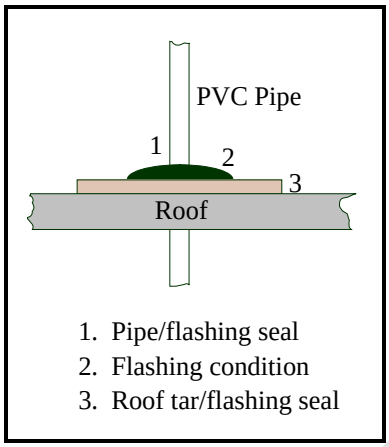

Fig. 21. Components to inspect in an SSD system roof flashing assembly.

Table 11. Common problems associated with SSD mitigation systems

Problem	Possible solution
Fan is not operating	1. Verify that the switch is on and the circuit breaker has not tripped 2. Check electrical connections from the switch box to the fan 3. Replace mitigation fan
Pipe has a noticeable vibration sound	1. Make sure that the fan is level 2. Verify that the base of the fan is not in contact with the pipe. If boot is sagging, replace boot 3. Replace fan
Fan is vibrating	1. Make sure that the fan is level 2. Replace fan
Fan is operating, but U-tube reads <1.5	1. Verify that additional oil is not needed in the U-tube 2. Inspect the U-tube and verify that it is connected to the pipe and that the tubing has not been crimped 3. Verify that no obstructions are present in the system exhaust 4. Inspect the boot/fan seals for air leaks 5. Check floor/pipe seals for air leakage 6. Inspect PVC pipe for holes 7. Replace mitigation fan

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Table 12 (cont.)

Problem	Possible solution
Fan appears to be operating within normal parameters, but unit is no longer <4 pCi/L	1. Verify that U-tube has sufficient oil 2. Verify that no obstructions are present in the system exhaust 3. Inspect the boot/fan seals for air leaks 4. Check floor/pipe seals for air leakage 5. Inspect PVC pipe for holes 6. Repeat radon test 7. Replace fan 8. Review repair and renovation history of unit since the system was last verified to be functioning properly. Have renovations occurred that may have reduced the air change rate? Has a new air exhaust system been added? If the answer is yes to either question, a supplemental suction point may be required 9. Perform lateral field extension measurements to determine if vacuum gradient has changed. Install new suction point in area without vacuum
System has audible whistling sound while operating	1. Inspect pipe for holes 2. Inspect PVC joints for leakage 3. Inspect pipe/slab seal for leakage
During heavy rains, water leaks around pipe	1. Inspect wall/pipe seal for leakage 2. Inspect pipe/floor seal for leakage 3. Inspect flashing assembly for cracks or holes

Appendix A contains an example of a data form used for O&M inspection.

4.4.6 Qualifications of O&M Subcontractor

4.4.6.1 Subcontractor Qualifications for O&M Testing

For all field placement and retrieval activities, the radon team must be under the supervision of an on-site field supervisor. Qualifications of the field supervisor follow.

- Training: Radon testing training certified by EPA, NEHA or NRSB.
- Experience: 3 years of documentable radon testing experience.
- Certification: Current NEHA or NRSB certification.

Personnel other than the on-site field supervisor who are placing and retrieving radon detectors are called field technicians. Qualifications for the field technician follow.

- Training: Radon testing training certified by EPA, NEHA or NRSB.

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- Experience: 1 year of documentable radon testing experience.
- Certification: Current NEHA or NRSB certification.

Personnel who perform data analysis, validation, and certification of the radon testing results are called radon testing analysts. Qualifications for the radon testing analyst follow.

- Training: Radon testing training certified by EPA, NEHA, or NRSB.
- Experience: 5 years of documentable radon testing experience.
- Certification: Current NEHA or NRSB certification.

4.4.6.2 Subcontractor Qualifications for O&M Inspection

For all O&M activities, the radon team must be under the direct supervision of an on-site field supervisor. Qualifications of the field supervisor follow.

- Training: Radon mitigation training certified by EPA, NEHA, or NRSB.
- Experience: 5 years of documentable radon mitigation experience.
- Certification: Current NEHA or NRSB certification.

Personnel other than the on-site field supervisor who are involved in mitigation diagnostics or installation are called field technicians. Qualifications for the field technician follow.

- Training: Radon mitigation training certified by EPA, NEHA, or NRSB.
- Experience: 1 year of documentable radon mitigation experience.
- Certification: Current NEHA or NRSB certification.

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APPENDIX A: EXAMPLE DATA FORMS

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New Subslab Depressurization System Inspection Form (Pg 1 of 2)

Building Number: _____ **Building Name: _____**

Date: _____ **Inspectors: _____**

General System Description

System Number: Number Suction Points:	Suction Point Locations	Room(s) system fixes
Fan Make and Model	Fan Location Interior_____ Exterior_____ Attic_____ Roof_____	System Design Ext. (Type 1) ___ Int. w egress (Type 2) ___ Int. w/o egress (Type 3) ___
Performance Indicator Type	Performance Indicator Location	Performance Indicator Reading
Breaker/Panel Number	Switch Location	Electrical Tap Location
Comments		

Drawings/Notes

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New Subslab Depressurization System Inspection Form (Pg 2 of 2)

Component	Specification	Findings	Comments
Vent Pipe	4 in, PVC, SCH 40, White	**Pass Fail**	
	Fittings and connections appear to be air tight, properly joined/sealed	**Pass Fail**	
	10 ft above grade, at least 12 in. above eave/roof and at least 10 ft from any opening to conditioned space	**Pass Fail**	
	Vent exhaust cap present	**Pass Fail**	
	Fire collar/damper present if fire rated wall is penetrated	**Pass Fail** **Not Applicable**	
	Sealing around vent pipe penetrations through slab, wall and floor is intact	**Pass Fail**	
	Pipe is strapped at least every 6 ft on horizontal runs and every 8 ft on vertical runs	**Pass Fail**	
	All exterior fasteners are stainless steel, galvanized, or corrosion resistant	**Pass Fail**	
Performance Indicator	A performance indicator is present, visible, operating and accessible.	**Pass Fail**	
	Pressure tubing is sealed and intact	**Pass Fail**	
	Instructions on how to use the indicator are present and a contact phone number is provided	**Pass Fail**	
Mitigation Fan	Mounted in a vertical section of pipe and level	**Pass Fail**	
	Fan is **not** located in or below conditioned space	**True False**	
	Vacuum within manufacturers performance range	**Pass Fail**	
	Fan not vibrating	**Pass Fail**	
Does System Meet EPA/ASTM/FTC Standards	Any negative findings above circle No	**Yes No**	
Additional Comments			

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O&M Subslab Depressurization System Inspection Form

Building Number: _____ **Building Name: _____**

Date: _____ **Inspectors: _____**

System Number: _____ **Fan Make/Model: _____**

Item	P	F	NA	Comments	Corrected
Fan Cover					
Cover Screws					
Fan Operation				Replacement Fan: _____	
Fan Boots					
Fan Mounting					
System Decals					
Vacuum Indicator				Reading: _____	
Vacuum Tubing					
Pipe					
Pipe/Wall/Slab Seals					
Pipe Clamps					
Clamp Anchors					
Roof Cap					
Flex					
Flex Connectors					
Switch Operation					
Conduit					
Conduit Clamps					
Electrical Tap Seal					
Roof Seal					

Comments:

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CONTRACTOR SCREENING POLICY – MARINE CORPS BASE ORDER

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UNITED STATES MARINE CORPS
MARINE CORPS BASE
QUANTICO, VIRGINIA 22134-5001

MCBO 4200.3
B033
28 Jul 10

MARINE CORPS BASE ORDER 4200.3

From: Commander
To: Distribution List

Subj: CONTRACTOR SCREENING POLICY

Ref: (a) MARADMIN 533/08 Installation Access Control
(b) DTM 09-012 Interim Policy Guidance for DoD Physical Access Control

1. Purpose. To establish policy for contractor screening aboard Marine Corps Base, Quantico (MCBQ).

2. Applicability. This policy applies to all commands, organizations and tenant activities that employ contractors on MCBQ. Implementation will commence upon issuance of this Order (applied prospectively to any new contracts commencing on or after 1 October 2010), in which contract employees require physical access to MCBQ. Duration of contract, contract source, or length of time that employees will perform services/work on MCBQ does not diminish or effect applicability of this policy. This policy does not apply to contracted Role Players or Commissary Baggers, which fall under separate screening policies.

3. Definitions

a. Contractor: Any individual gaining access to MCBQ for the purpose of performing services under a government contract or subcontract who is not a member of the Armed Forces or a direct employee of the U.S. Government.

b. Identity Proofing: The process of reviewing federally authorized acceptable documentation to ensure authenticity of an individual.

c. Vetting: An evaluation of an individual’s character and conduct, for approval, acceptance or denial onto the installation as a contractor employee.

4. Background. Pursuant to reference (a) and (b), contractor screening of employees is a part of the overall installation access control and security program and requires that contractors doing business aboard MCBQ are screened to determine:

a. Identity.

b. Citizenship or legal alien status.

c. Eligibility for access.

5. Policy

a. All contractor employees performing services on MCBQ requiring physical access to the installation shall be properly screened in accordance with the standards set forth in this policy.

b. Contracting Officers shall provide notice of this policy in all contract solicitations and awards for all contracts to be performed on MCBQ.

c. Contractor screening consists of identity proofing and vetting.

(1) Identity Proofing. The following are acceptable source documents to establish the identity of a contract employee. The source documents must not show evidence of tampering, counterfeiting, or other alteration or appear questionable (e.g. having damaged laminates):

(a) U.S. passport or U.S. passport card.

(b) Permanent resident card or Alien Registration card (Form I-551).

(c) Foreign passport with a temporary (I-551) stamp or temporary (I-551) printed notation on a machine readable immigrant visa.

(d) Foreign passport with a current Arrival - Departure Record (Form I-94) bearing the same names as the passport and containing an endorsement of the alien’s nonimmigrant status, if that status authorizes the alien to work for the employer.

(e) Employment authorization document that contains a photograph (Form I-766).

(f) In the case of a nonimmigrant alien authorized to work for a specific employer, a foreign passport with Form I-94 or Form I-94A bearing the same name as the passport and containing an endorsement of the alien's nonimmigrant status, as long as the endorsement has not yet expired and the proposed employment is not in conflict with any restriction or limitation identified on the form.

(g) Driver's license or identification card issued by a State or outlying possession of the United States, provided it contains a photograph and biographic information such as name, date of birth, gender, height, eye color, and address.

(h) Identification card issued by Federal, state or local government agencies, provided it contains a photograph and biographic information such as name, date of birth, gender, height, eye color, and address.

(i) School identification card with a photograph.

(j) U.S. Coast Guard Merchant Mariner card or Transportation Workers Identification Card.

(2) Vetting. Vetting is an evaluation of a contractor employee that includes verifying employment eligibility (citizenship or legal alien status) and conducting a background check to determine fitness for employment on MCBQ.

(a) Employment Eligibility. Federal contractors are required to use the E-verify program (www.dhs.gov/e-verify) to instantaneously verify employment eligibility of both U.S. citizens and non-citizens. Executive Order 13465, the Immigration and Nationality Act, and Federal Acquisition Regulation (FAR) Subpart 22.18 require Federal contractors to abide by the immigration laws of the United States and to employ only individuals who are eligible to work in the United States.

(b) Criminal Records Check. Contractors shall, upon request of the contracting officer or MCBQ security officials, provide a list of all employees requiring physical access to MCBQ. Installation government representatives shall then query authoritative data sources to vet the claimed identity and to determine fitness using biographical information including, but not limited to, name, social security number and date of birth.

6. Denial of Access. Contractor employees will be prohibited from performing services on MCBQ, if the employee:

a. Is on the National Terrorist Watch List.

b. Is illegally present in the United States.

c. Is subject to an outstanding warrant.

d. Knowingly submitted an employment questionnaire with false or fraudulent information.

e. Has been issued a debarment order and is currently banned from any military installation.

f. Is on a prisoner work-release program, or currently on parole.

g. Is a registered sexual offender.

h. Has been convicted of a felony offense within the past 2 years.

7. Appeals

a. A contractor that wants to employ an individual that cannot meet the vetting process in paragraphs 5 and 6 above may submit an appeal to the Commander, MCBQ for special consideration. Appeals will be in writing and processed through the contracting officer.

b. An individual that cannot meet the vetting process in paragraphs 5 and 6 above may submit an appeal to the Commander, MCBQ for special consideration. Individual appeals will be in writing and processed through the MCBQ Inspector General.

8. Enforcement

a. Contractors with employees performing services on MCBQ shall, upon request, provide a list of employees requiring base access to the contracting officer or MCBQ security officials. Government officials will validate the employee list to ensure individuals meet access control standards. Contractors shall provide immediate updates to employee lists upon change (i.e. adding a new or additional employee that requires base access).

b. Contractors and their employees are subject to the Random Antiterrorism Measures being employed at Installation Access Control Points to include identification verification and screening against law enforcement and other databases.

c. Contractors and their employees are subject to random security sweeps of work sites to verify contractor identification and eligibility.

d. Contracting officers shall provide notice of this policy in all contract solicitations and awards for all services to be performed on MCBQ commencing on or after 1 October 2010. Contracting officers should consider modifying existing contracts as appropriate to ensure contractors understand this policy.

e. Contractors may be subject to a wide range of contract and administrative actions for failure to comply with this policy to include termination of their contract and suspension or debarment from doing future business with the Federal Government. Contractors are responsible to ensure subcontractors are notified of and comply with this policy.

9. The Regional Contracting Office-National Capital Region, Marine Corps Systems Command contracting officers, and the MCBQ Resident Officer in Charge of construction shall include a copy of this policy in their contracts and provide a copy to other contracting offices/officers in other Federal agencies that are soliciting and awarding contracts that may be performed on MCBQ in an effort to ensure maximum compliance.

/s/
D. J. CHOIKE

DISTRIBUTION: A

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SPECIFICATIONS FOR DIGITAL DATA

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SPECIFICATIONS FOR DIGITAL DATA. Any maps, drawings, figures, sketches, geospatial data, spreadsheets, or text files prepared for this contract shall be provided in both hard copy and digital form. The hard copy deliverables are defined in another section of this SOW.

A. Text, Spreadsheet, and Database Files: The Marine Corps standard computing software is Microsoft Office 2007. Final Reports and other text documents shall be provided in Microsoft Word 2007 format **AND** Adobe Portable Document Format (PDF). Spreadsheet files shall be provided in Microsoft Excel 2007 format. Databases shall be provided in Microsoft Access format, unless specified otherwise, as approved by the Government. **Prior to database development, the contractor shall provide the Government with a Technical Approach Document** for approval, which describes the contractor's technical approach to designing and developing the database. All text, spreadsheet, and database files shall be delivered on a Compact Disc read-only memory (CD-ROM) or Digital Versatile Disc read-only memory (DVD-ROM).

B. Maps, Drawings, and Sketches (Digital Geospatial Data):

1. **Geospatial Data Software Format**: Geographic data **must** be provided in a form that does **not** require translation, preprocessing, or post processing before being loaded to the installation's regionally hosted geodatabase. The Contractor shall validate any deviation from this specification in writing with the Government (Installation Geospatial Information & Services (IGI&S) Manager via the Project Manager). Digital geographic maps and the related data sets shall be delivered in the following software format:

   a. GIS: *File or Personal geodatabase format (Access database file) using ArcGIS 9.xx or later. The file or personal geodatabase must be importable to a multi-user geodatabase using ArcSDE 9.xx or later.*

   -AND / OR-

   b. CADD: *The Government may approve the use of AutoCAD when it is determined that the format will not compromise the spatial accuracy or structure of the delivered data and that the data will easily integrate with the enterprise GIS system. All CADD data shall be provided in AutoCAD 10.xx or later and shall be in the same projection and use the same coordinate system, datum, and units as stated below in the paragraph titled Geospatial Data Projection. Drawing files shall be full files, uncompressed, unzipped, and georeferenced.*

2. **Geospatial Data Structure:**

   a. GIS Data Sets *– When developing/delivering geospatial data, the Contractor shall develop the initial structure consistent with the most current version of the GEOFidelis Data Model. The GEOFidelis Data Model shall be followed for geospatial database table structure, nomenclature, and attributes. If the GEOFidelis Data Model does not adequately address subject datasets, the Contractor shall consult with the Government (IGI&S Manager) for direction and approval for proposed data structures. The Government may approve such modifications if they comply with the GEOFidelis-SDSFIE adaptation process. Copies of the GEOFidelis Data Model may be obtained from the GEOFidelis Portal or the IGI&S Manager via the Project Manager.*

When delivering updates to existing feature classes, the Contractor shall obtain a copy of the subject data in a personal geodatabase to use as a template for all subsequent data collection processes. If further modifications to structure are required as a result of this Scope, the Contractor will consult with the Government (IGI&S Manager) for direction and approval for proposed data structures. The Government may approve such modifications if they comply with the GEOFidelis-SDSFIE adaptation process.

-AND / OR-

b. CAD Drawings/Data *– The Contractor shall develop all CADD data in conformance with the latest version of the following standards and policies:*

- U. S. National CAD Standards (NCS)
- CAD/BIM Technology Center's AEC CADD Standards (https://cadbim.usace.army.mil/)
- NAVFACINST 4250.1, Electronic Bid Solicitation

3. **Geospatial Data Projection**: Geographic data (regardless of format) shall be provided in {insert unit of measure here, such as meters} and **projected** into the WGS 84, NAD 83 or *Universal Transverse Mercator (UTM) Zone 18* meters projection system. This projection requirement applies to all CADD drawings such as as-designed and as-built project plans, as well as GIS data layer deliverables. Each data set shall have a projection file if appropriate based on format. Map or drawing **scales** will be determined by the Project Manager, if applicable. Mapping **accuracy** for the agreed scales will conform to the American Society for Photogrammetry and Remote Sensing (ASPRS) "Accuracy Standards for Large-Scale Maps", "Interim Accuracy Standards for Large-Scale Maps", and "Geospatial Positioning Accuracy Standards". Copies of these standards can be obtained on the Internet at http://www.asprs.org, and/or at http://www.fgdc.gov, or by contacting:

American Society for Photogrammetry and Remote Sensing
5410 Grosvenor Lane, Suite 210
Bethesda, MD 20814-2160

4. Geospatial Data Collection:

a. Mapping grade Global Positioning System *(GPS) data collection (sub-foot, sub-meter, and sub-5 meter) shall be performed when specified in the statement of work and shall be completed in accordance with state and local guidelines and standards including Federal Geographic Data Committee Standards. Horizontal accuracy for mapping grade GPS data collection efforts shall meet a sub-meter threshold unless otherwise specified to be survey grade, sub-foot or sub-5 meter in the statement of work. GPS data collection. Spatial accuracy requirements are as follows:*

- Sub foot: 95% of all points are within ± 12 inches
-OR-
- Sub meter: 95% of points are within ± 1 Meter
*-OR_*
- Sub 5 meter: 95% of points are within ± 5 Meter

-AND / OR-

b. Survey grade GPS *data collection shall be performed when specified in the statement of work. As survey processes are highly regulated by federal, state, and/or local technical and licensing requirements, they are in general beyond the scope of this document. However, survey grade GPS data collection shall at a minimum use the Geoid2003 CONUS epoch (or a more current epoch if available at the time of this project) and spatial accuracy requirements for survey grade are 95% of GPS points are within ± 1 centimeter. Every effort shall be made to capture feature locations without using offsets unless obstructions are present. Any offsets used shall be annotated in the "user flag" field.*

NOTE: None of the GPS collection information is to be included in the table structure of the delivery, unless it is specifically part of the SDSFIE or established installation feature format.

5. **Media for Geospatial Data Deliverables**: Geographic data shall be delivered on a separate Compact Disc read-only memory (CD-ROM) –or-, Digital Versatile Disc read-only memory (DVD-ROM), or other digital media such as external hard drives if approved by the government. This media shall **contain only the value-added data sets** as designated in the Task sections of the statement of work. Do not include the Contractor's working files or original installation data sets that may have been used by the Contractor to develop the deliverables. "READ ME" files may be included on the geographic data media if such files provide explanation of the delivered data sets. However, these "READ ME" files should not be delivered in lieu of standard metadata.

6. **Geographic Data Documentation (METADATA)**: For each digital file delivered containing geographic information (regardless of format), **the Contractor shall provide documentation** consistent with the Federal Geographic Data Committee (FGDC) Content Standards for Digital Geospatial Metadata (CSDGM). Both 'Mandatory' and 'Mandatory as Applicable' fields shall be completed for each geographic data set. The documentation shall include, but not be limited to, the following:

   - The name, description, abstract, and purpose of the data set/data layer
   - The source of the data and any related data quality information such as accuracy and time period of content
   - Descriptions of the receiver and other equipment used during collection and processing, base stations used for differential corrections, software used for performing differential corrections, estimated horizontal and vertical accuracies obtained, and conversion routines used to translate the data into final geographic data delivery format.
   - Type of data layer (point, line, polygon, etc.)
   - Field names of all attribute data and a description of each field name
   - Definition of all codes used in the data fields
   - Ranges of numeric fields and the meaning of these numeric ranges
   - The creation date of the map layer and the name of the person who created it
   - A point of contact shall be provided to answer technical questions

   Metadata generation tools included in the ArcGIS suite of software (or equivalent technology) shall be used in the production of the required metadata in XML format. Regardless of the tools used for metadata creation, the Contractor must ensure that the metadata is delivered in XML format and can be easily imported to the

installation's enterprise geodatabase. Copies of the FGDC metadata standard can be obtained on the Internet at http://www.fgdc.gov or by contacting:

FGDC Secretariat
c/o U.S. Geological Survey
590 National Center
Reston, Virginia 22092
(703) 648-5514

NOTE: The metadata should be formatted from the installation database perspective, not the Contractor project perspective. Therefore such items as Point of Contact should be the installation POC currently associated with the data and NOT the Contractor's Project Manager. The Contractor shall use language and format consistent with existing installation metadata.

7. **Geographic Data Review**: The digital geographic maps, related data, and text documents shall be included for review in the draft and final contract submittals. The data will be analyzed for discrepancies in subject content, correct format in accordance with these specifications, and compatibility with the existing GIS system. The Contractor shall incorporate review comments to data and text prior to approval of the final submittal. For each review of digital geospatial data deliverables, the Contractor shall provide a technical consultant to meet on-site at the installation with the IGI&S Manager and functional area subject matter experts to visually review the data deliverables on a Windows XP compatible system unless otherwise approved by the government.

C. **Ownership**: All digital files, final hard-copy products, source data acquired for this project, and related materials, including that furnished by the Government, shall become the property of the installation and will not be issued, distributed, or published by the Contractor.

LID APPLICATION AND DESIGN GUIDANCE

Erosion & Sediment Control, Storm Water Pollution Prevention and Low Impact Development (LID) on MCB Quantico

Application & Design Guidance

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Guide To Requirements For Land Disturbances On MCB Quantico:

This guidance package is designed to help direct and assist applicants through the entire process for Land Disturbances on MCB Quantico. The following information will help the applicant determine what permit fees are required as well as what plans (i.e. Erosion & Sediment Control [E&SC] and/or Storm Water Pollution Prevention Plan [SWP3]) are required. In addition to what is required, there are many diagrams and visual aids to help in the design of your plans. In the very back is a Supplementary Forms section that contains all application forms talked about in this guide, as well as the applicable checklists that are used by NREA to review application submissions. The checklists can be used as a guide to ensure all components of your application are included prior to submittal to NREA. This will help to ensure a faster and smoother application process for you.
The first step in the land disturbance process is to determine how much land area will be disturbed during your project. To determine which application fees apply, and if a E&SC and/or SWP3 plan will be required, please use the following guidelines:

IF <2500 SQ FT (232 SQ.M., 0.057 ACRES):

No required permit, however applicable state and federal erosion and sediment control regulations still apply.

PROJECTS ≥ 2500 SQ FT:

THE FOLLOWING ARE REQUIRED FOR ALL PROJECTS ≥ 2500 SQ FT UNLESS OTHERWISE SPECIFIED:

Storm Water Construction Permit for DCR (Original Check and Signatures to be submitted through NREA)
Storm Water Pollution Prevention Plan (narrative and plans)
Erosion and Sediment Control (narrative and plans)
NREA Online Storm Water Construction Training
Onsite Responsible Land Disturber (Virginia State Certified)

a) Sites ≥2500 sq ft (232 sq.m., 0.057 acres) and within 100 feet from open water or drainage lines:

If the site is ≥2500 square feet and lies within a **resource protection area** (RPA), or an area determined by NREA to be in a sensitive area, the following is required:
This applies to all applicable size site locations East of I-95 and may include sensitive areas West of I-95 as determined by NREA at time of project review. Sensitive areas are designated as:

1. Tidal wetlands;
2. Nontidal wetlands connected by surface flow and contiguous to tidal wetlands or water bodies with perennial flow;
3. Tidal shores;
4. Such other lands considered by the local government to meet the provisions of this section and to be necessary to protect the quality of the state waters; (ex: county delineated RPAs) and
5. A buffer area not less than 100 feet in width located adjacent to and landward of the components listed above, and along both sides of any water body with perennial flow." (9VAC 10-20-10 et seq.).

b) For sites ≥10,000 square feet but <1 acre:

Located anywhere on Base, and more than 100ft from open water, sensitive areas, or drainage lines, the following is required:
Note: Erosion and Sediment Control (narrative and plans)- Short Form applies

c) If ≥ 43,560 sq.ft. (4,047 sq.m., 1.00 acre):

All other sites on installation

DCR Application Fees: **$200 (sites <1 acre but greater than 2500sq ft)**
$300 (1 acre but less than 5 acres)
$500 (5 acres and over)

Steps For Obtaining A Construction VPDES General Permit For Storm Water Discharges:

After you have determined your application fees and your requirements for E&SC/SWP3 you should refer to the following sequence:

It is recommended that all required submittals be provided to NREA AT LEAST 45 DAYS from anticipated date of the proposed land disturbing activity.

STEP ONE:

The following materials need to be obtained (you can find and print this information at http://www.dcr.virginia.gov/soil_and_water/vsmp.shtml or via the NREA Water Programs website at **http://www.quantico.usmc.mil/activities/display.aspx?PID=1786&Section=NREA**, there are also hard copies of this information located in the back of this pamphlet)

- VSMP general permit application form for construction activities:
- General permit notice of termination (NOT) for storm water discharges from construction activities
- Permit application fee form

STEP TWO:

Develop an Erosion and Sediment Control (E&SC) Plan *and* a Storm Water Pollution Prevention Plan (SWP3) for the project site. There is a generic SWP3 Plan that you can use (just fill in the highlighted areas with all pertinent information and attach the maps) located on the NREA Water Programs website and in the back of this pamphlet. The SWP3 and E&SC plans must be reviewed and approved by NREA prior to any land disturbance activities.

STEP THREE:

Provide NREA with a name of the Responsible Land Disturber (RLD) for the construction site. The RLD must fall under one of the following criteria to be acceptable:

- He/she must have a state RLD certificate (see http://www.dcr.state.va.us/sw/es_rld.htm for more information.), **OR**:
- Must be a certified P.E. in the state of Virginia, **OR**
- Must be enrolled in the state Erosion and Sediment Control Certification Program (see http://www.dcr.state.va.us/sw/estr&crt.htm for more info) or have obtained a state certificate through this program.

NEW TRAINING REQUIREMENT: At a minimum, all contractor RLD's are required to complete the online module of Storm Water Training at the following site:
http://nreabweb.emainc.com/MCBQ_SW_Training/SWPP%20Training/index.asp

STEP FOUR:

Provide a Storm Water Management Plan (SWMP) for review and approval.

STEP FIVE:

Fully fill out the permit registration statement and permit application fee forms.

STEP SIX:

Provide the original permit application fee form, the original check (made out to "Treasurer of Virginia") and the original registration statement to the Environmental Compliance Section, NREA Branch, who will review the forms, prepare the transmittal letter and submit the package to the Department of Conservation and Recreation (DCR).

NO LAND DISTURBING ACTIVITY CAN BEGIN UNTIL THE PERMIT HAS BEEN ISSUED BY DCR OR AFTER 15 BUSINESS DAYS FROM THE POSTMARK DATE WHEN NREA SUBMITS YOUR PERMIT TO DCR, WHICHEVER OCCURS FIRST.

STEP SEVEN:

When total stabilization of the site has occurred, NREA will provide the contractor a close-out memo. Once this memo has been received, the contractor is to fill out the Notice Of Termination (NOT) for the project and send it to the Virginia DCR. A copy of the NOT must be sent to NREA. If you have any questions about filling out these forms, please call NREA at (703) 432-0528.

Energy Independence And Security Act:

In December 2007, Congress enacted Energy Independence and Security Act (EISA). Section 438 of that legislation establishes strict storm water runoff requirements for Federal development and redevelopment projects. The provision reads as follows:

"Storm water runoff requirements for federal development projects**.** The sponsor of any development or redevelopment project involving a Federal facility with a footprint that exceeds 5,000 square feet shall use site planning, design, construction, and maintenance strategies for the property to maintain or restore, to the maximum extent technically feasible, the predevelopment hydrology of the property with regard to the temperature, rate, volume, and duration of flow."

INTENT OF SECTION 438 OF EISA:

The intent of Section 438 of EISA is to require federal agencies to develop and redevelop facilities in a manner that reduces storm water runoff and pollutants in order to protect or restore the waters of the U.S. A new way of thinking about storm water has evolved, and new approaches have been developed to eliminate or reduce the amount of water and pollutants that run off a site and ultimately discharged into adjacent water bodies. The new approach has a fundamental notion to employ systems and practices that use or mimic natural processes to 1) infiltrate and recharge, 2) evapotranspire, and/or 3) harvest and reuse precipitation near to where it falls to earth.

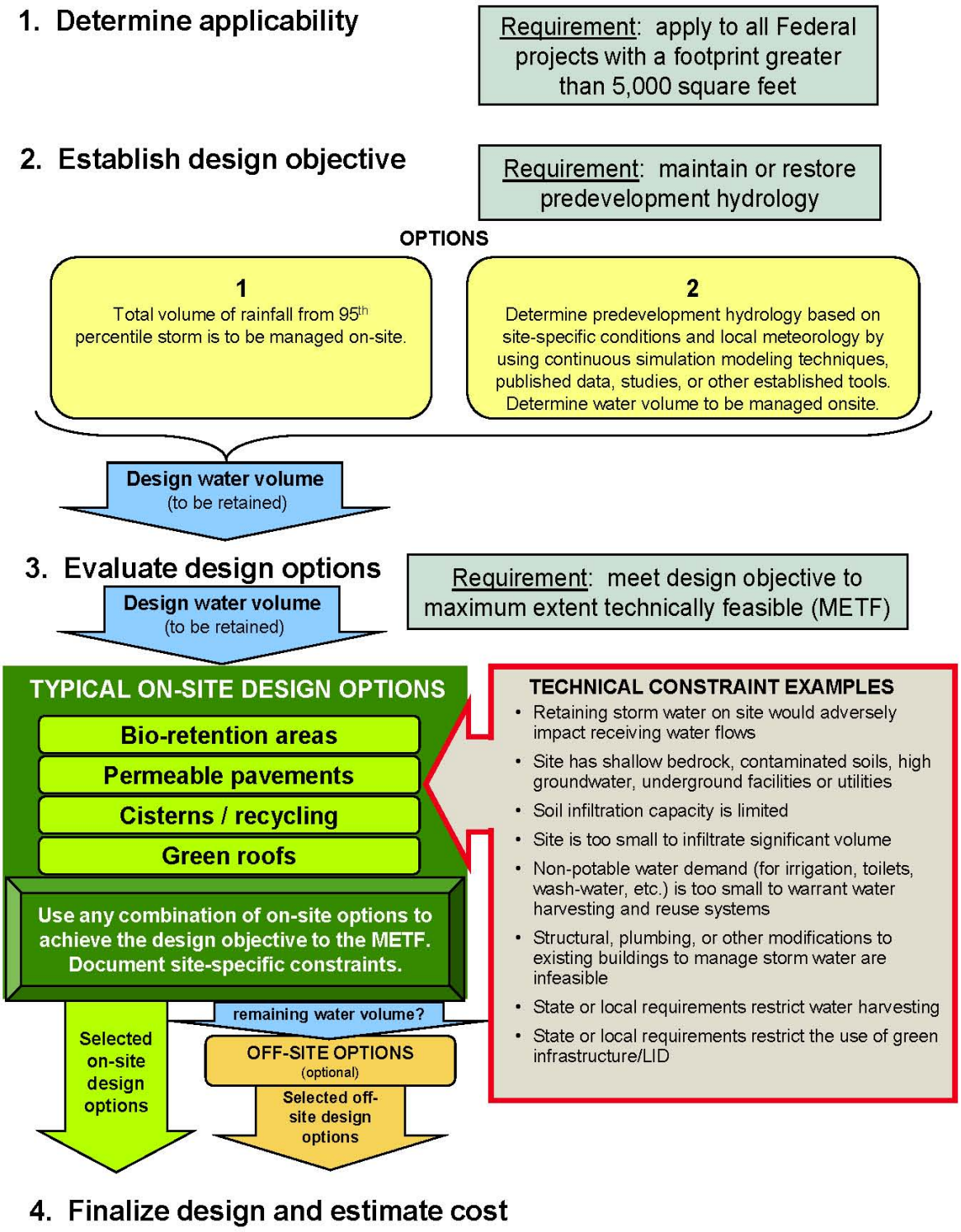
COMPLIANCE WITH SECTION 438:

Compliance with Section 438 requires that storm water management measures are implemented to the maximum extent technically feasible (METF) to maintain or restore the pre-development hydrology conditions, specifically with respect to temperature, rate, volume, and duration of flow. To meet these performance requirements, storm water control practices that are effective in reducing the volume of storm water discharge must be used. To meet the intent of the statute, the Federal facility must use all known, available and reasonable methods of storm water retention, and/or reuse to prevent the offsite discharge of storm water runoff.

Navy policy, dated 20 December 2010, Engineering and Construction Bulletin, Issue No. 2011-01, states that all new construction projects costing over Seven Hundred Fifty Thousand Dollars ($750,000.00) and/or disturbing 5,000 sq. ft. or more shall comply with EISA. The 2010 Navy Policy further states that Low Impact Development (LID) shall be used in these same projects. LID is to be tracked and reported as to the Navy's progress on storm water management.

IMPLEMENTATION OF SECTION 438:

Flowchart for EISA §438 Implementation



Low Impact Development (LID), What Is It And Do I Need It In My Project:

LOW IMPACT DEVELOPMENT (LID):

According to the Under Secretary of Defense memorandum dated January 19, 2010, Low Impact Development (LID) is to be utilized to the "most practicable extent possible" beginning FY2011. This offers a new innovative approach to urban storm water management. LID uniformly or strategically integrates storm water controls throughout the urban landscape. It does not rely on the conventional end-of-pipe or in-the–pipe structural methods. The primary goal of LID is to mimic the predevelopment site hydrology by using site design techniques that store, infiltrate, evaporate, and detain runoff.
The Department of Navy policy sets a goal of no net increase in storm water volume and sediment or nutrient loading from all construction sites.

WHAT IS LID:

LID is a storm water management strategy concerned with maintaining or restoring the natural hydrologic functions of a site to achieve natural resource protection objectives and fulfill environmental regulatory requirements. LID employs a variety of natural and engineered features that reduce the rate of runoff, filter out pollutants, and facilitate the infiltration of water into the ground. By reducing water pollution and increasing groundwater recharge, LID helps to improve the quality of receiving surface waters and stabilize the flow rates of nearby streams. LID incorporates a set of overall site design strategies as well as highly localized, small-scale, decentralized source control techniques known as Integrated Management Practices (IMPs). IMPs may be integrated into buildings, infrastructure, or landscape design. Rather than collecting runoff in piped or channelized networks and controlling the flow downstream in a large storm water management facility, LID takes a decentralized approach that disperses flows and manages runoff closer to where it originates. Because LID embraces a variety of useful techniques for controlling runoff, designs can be customized according to local regulatory and resource protection requirements, as well as site constraints. Figures located in Appendix D provide illustrations of key elements in LID. New projects, redevelopment projects, and capital improvement projects can all be viewed as candidates for implementation of LID.

LID employs a variety of different techniques. The following is a list of basic IMPs that are available.

- Bioretention: Vegetated depressions that collect runoff and facilitate its infiltration into the ground.
- Dry Wells: Gravel-or stoned-filled pits that are located to catch water from roof downspouts or paved areas.
- Filter Strips: Bands of dense vegetation planted immediately downstream of a runoff source designed to filter runoff before entering a receiving structure or water body.
- Grassed Swales: Shallow channels lined with grass and used to convey and store runoff.
- Infiltration Trenches: Trenches filled with porous media such as bioretention material, sand, or aggregate that collect runoff and infiltrate it into the ground.
- Inlet Pollution Removal Devices: Small storm water treatment systems that are installed below grade at the edge of paved areas and trap or filter pollutants in runoff before it enters the storm drain.
- Permeable Pavement: Asphalt or concrete rendered porous by the aggregate structure.
- Permeable Pavers: Manufactured paving stones containing spaces where water can penetrate into the porous media placed underneath.
- Rain Barrels and Cisterns: Containers of various sizes that store the runoff delivered through building downspouts. Rain barrels are generally smaller structures, located above ground. Cisterns are larger, are often buried underground, and may be connected to the building's plumbing or irrigation system.

- Soil Amendments: Minerals and organic material added to soil to increase its capacity for absorbing moisture and sustaining vegetation.
- Tree Box Filters: Curbside containers placed below grade, covered with a grate, filled with filter media and planted with a tree in the center.
- Vegetated Buffers: Natural or man-made vegetated areas adjacent to a water body, providing erosion control, filtering capability, and habitat.
- Vegetated Roofs: Impermeable roof membranes overlaid with a lightweight planting mix with a high infiltration rate and vegetated with plants tolerant of heat, drought, and periodic inundation.

WILL NREA REQUIRE LID FOR MY PROJECT:

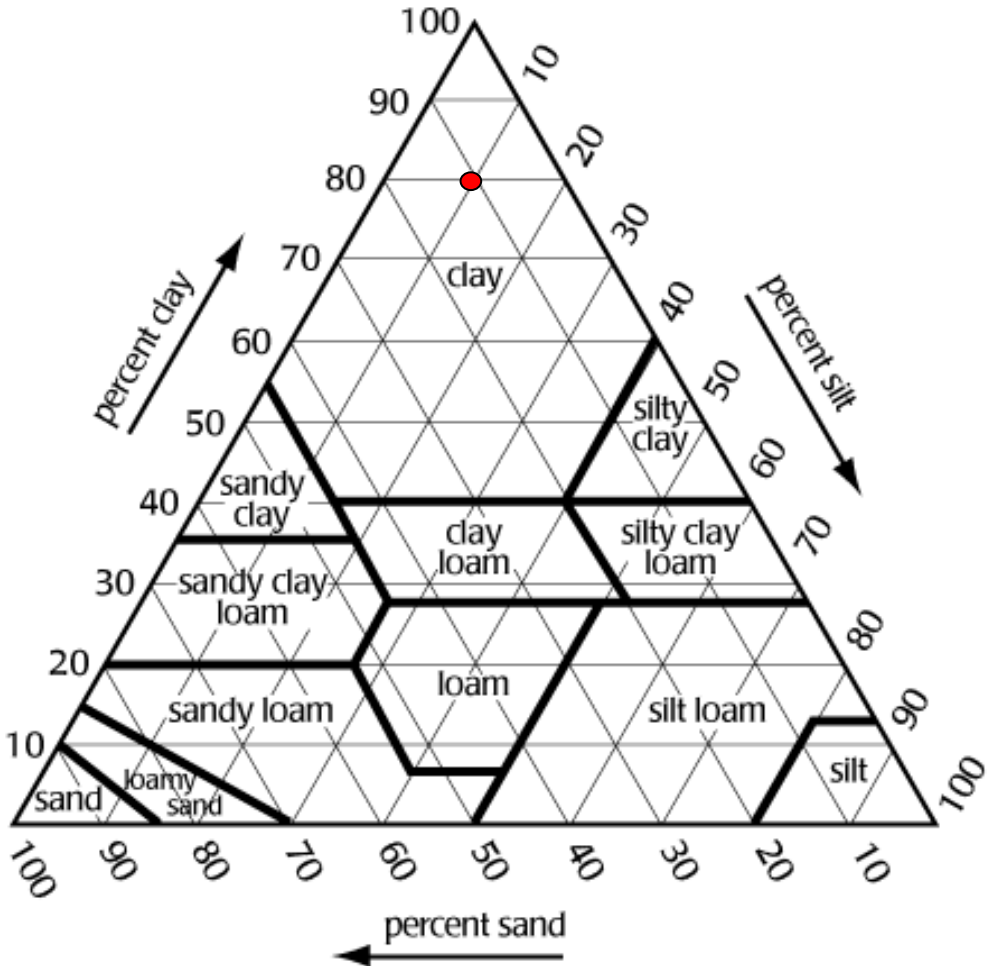
MCB Quantico began reviewing construction plans for adherence to the UFC in 2009 and will require LID integration into each land disturbing project with a Storm Water Management element in FY2011 and beyond. When designing your SWP3 plans, remember, Department of Navy (DON) policy states that all new and/or major construction projects beginning in FY2011 shall incorporate Low Impact Development (LID) features in the design. With this in mind, included is a simple guide with step-by-step instructions to help you in the process of determining where to start when designing LID devices for your project, including which devices may be most effective in different situations. The diagram below shows the most important aspects of LID that you should keep in mind when designing your LID features.

Determining What LID Features Are Best Suited For Your Project Site:

The following 4-step process will assist the designer/developer in identifying the LID practices best suited for their site.

STEP ONE:

Determine what type of soil, in general, your site consists of (i.e. sand, clay, etc.). You can use the Texture Triangle below to determine the general percentages of sand, silt, and clay on your site. For example, if it is determined that you have a heavy Clay texture on your site, you can look at the texture triangle and see that a heavy Clay (red dot on texture triangle) is approximately 80% Clay, 10% Sand and 10% Silt.



STEP TWO:

Once you have a general idea of the soil makeup, use the Soils and Particle Size Conversion Cheat below to determine the size of particle you are dealing with.

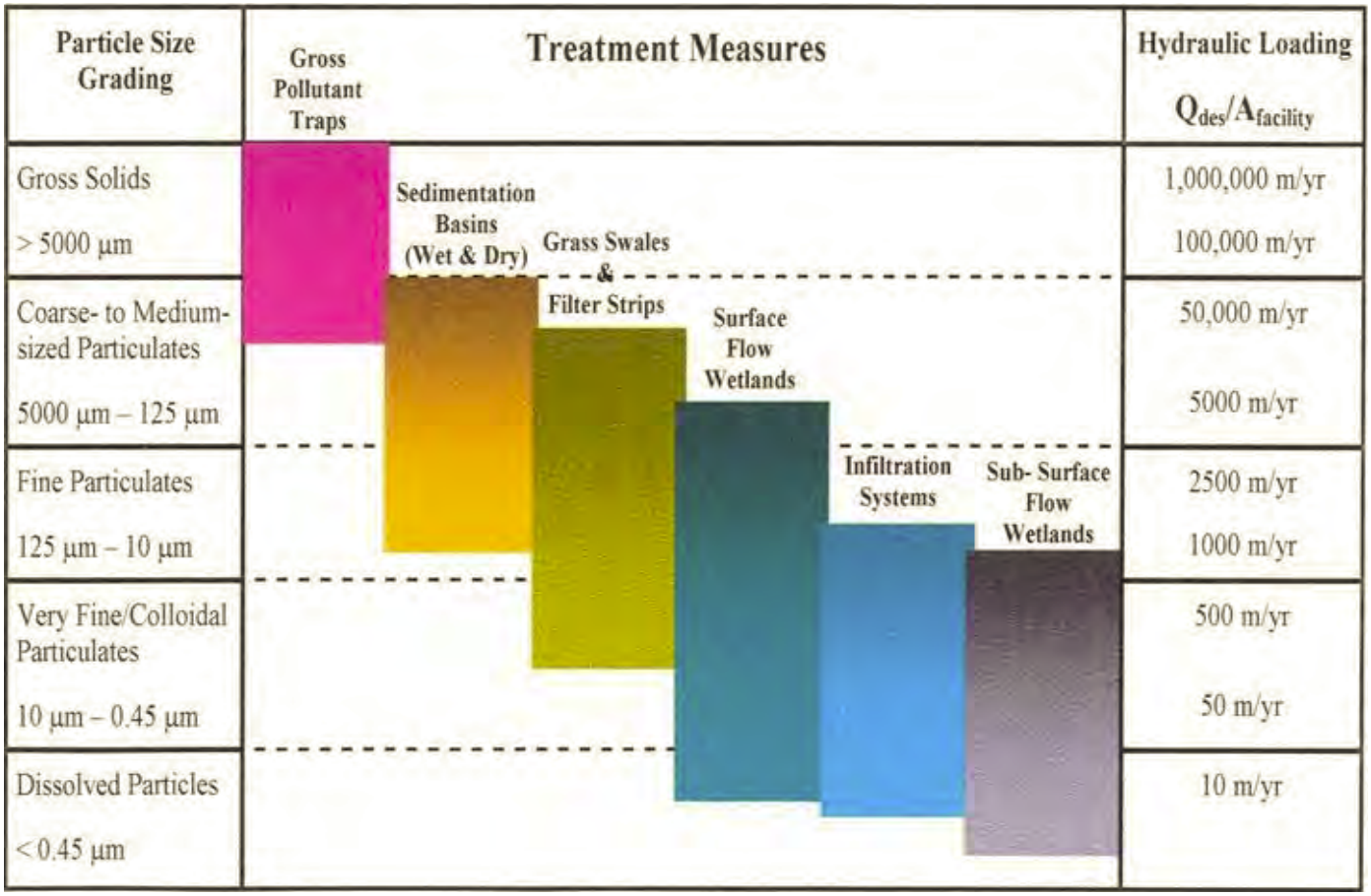
Soils and Particle Size Conversion Cheat Sheet		
Particle	**Diameter**	**Conversion**
clay	less than 0.002 mm	less than 2 µm
silt	0.002 mm - 0.05 mm	2µm - 50 µm
sand	0.05 mm - 2.00 mm	50 µm - 2000 µm
fine pebbles	2.00 mm - 5.00 mm	2000 µm - 5000 µm
medium pebbles	5.00mm - 20.00 mm	5000 µm - 20000 µm
coarse pebbles	20.00 mm - 75.00 mm	20000 µm - 75000µm

Looking at the chart, a general Clay material consists of particles 0.002 mm or less than 2 µm.

STEP THREE:

With this knowledge, you can refer to Removal Effectiveness of LID Features Chart (see below) to determine which type of LID feature(s) would work best on your site.

Removal Effectiveness of LID Features Chart



Using this chart, you can figure that on your site, the most effective LID Features would be some sort of Surface Flow Wetland, Infiltration System, and/or a Sub-surface Flow Wetland.

STEP FOUR:

You can then refer to the following charts (Functions of LID Features and LID Uses and Other Info.) to determine if the LID feature you have selected will accomplish your goal(s) for the site.

Functions of LID Features

Feature	Effect or Function				
	SlowerRunoff	Infiltration	Retention	Detention	WaterQualityControl
Soil Amendments		X			
Bioretention		X	X	X	X
Dry Wells		X	X		X
Filter Strips	X				X
Vegetated Buffers	X				X
Grassed Swales	X				X
Infiltration Trenches		X			X
Inlet Devices					X
Rain Barrels			X		
Cisterns			X		
Tree Box Filters					X
Vegetated Roofs	X			X	X
Permeable Pavers		X			X
Permeable Pavement	X	X			X

LID Uses and Other Information

LID Feature	Appropriate Uses	Estimated Cost	Maint. Issues	Corrective Actions
Soil Amendments	- increase soil's infiltration capacity - help reduce runoff from the site - soils become more effective at maintaining water quality	Increased upfront costs, may be partially offset by reductions in the required volume of stormwater ponds and other detention or retention practices	- may be inspected as part of the E&SC plan, usually at completion. -routine soil infiltration rate analysis of amended soils in potential problem areas is recommended.	- extensive mechanical aeration and/or disking of organic amendments to depth of several inches and site restabilization
Bioretention	Median Strips Parking lot islands Swales	$107 and $430 per square meter ($10 and $40 per square foot)	biannual evaluation of the trees and shrubs, subsequent removal of any dead/diseased vegetation	replace dead vegetation, soil pH regulation, erosion repair, mulch replenishment, unclogging the underdrain, and repairing overflow structures
Dry Wells	Small impervious areas Runoff from driveways Runoff from downspouts	Site Specific (i.e. cost of excavation, price of gravel, depth of well)	Clear debris from inlet, drain, gutter that could clog downspout.	Clogging of gravel over long period of time if extensive loading fine grained sediment is present
Filter Strips	Treating runoff from roads and highways Roof Downspouts Very small parking lots or pervious surfaces Fringe of stream buffers Pretreatment for structural purposes	Approximately 30¢ per square foot for seed or 70¢ per square foot for sod	Mowing, irrigation, and weeding. Inspection of filter strips at least twice annually for erosion or damage to vegetation and additional inspection after periods of heavy runoff.	The need for litter removal should be determined through periodic inspection, but litter should always be removed prior to mowing

LID Feature	Appropriate Uses	Estimated Cost	Maint. Issues	Corrective Actions
Vegetated Buffers	Along creeks, streams, rivers and other waterways	- Forest buffer costs range between $218 and $729 per acre to plant and maintain. - Grass buffers costs between $168 to $400 per acre to plant and maintain	Inspect annually, and after heavy rain events for evidence of sediment deposition, erosion, and flow channel development.	Self maintaning if sized and constructed properly
Grassed Swales	manage runoff from drainage areas that are less than 10 acres in size, with slopes no greater than 5 percent.	approximately $0.50 per square foot (includes design costs)	periodic mowing, weed control, watering during drought conditions, reseeding of bare areas, and clearing of debris and blockages.	Remove cuttings from the channel; Accumulated sediment removed to avoid concentrated flows; The grass should be thick and reseeded as necessary.
Infiltration Trenches	used in conjunction with another stormwater management device, such as a detention pond pretreated with other devices such as grit chambers, water quality inlets, sediment traps, swales, and vegetated filter strips	site and design specific	Prevent clogging; A thorough annual inspection should include monitoring of the observation well to confirm that the trench is draining properly	Remove stone and sediment that has clogged the system
Inlet Devices (Hydrodynamic Separators)	Areas with limited land availability	Capital costs can range from $2,300 to $40,000 per precast unit	Inspections can be scheduled according to observed rates of sediment accumulation, remove sediment by pump or vac truck	Removal or replacement of failed device

LID Feature	Appropriate Uses	Estimated Cost	Maint. Issues	Corrective Actions
Rain Barrels	Stores rooftop runoff from downspouts in barrels for later re-use	approx. $120/barrel	minimal maintenance; inspect screens for clogging	repair/replace sceens as needed; replace barrel as needed
Cisterns	Stores rooftop runoff from downspouts in larger volumes than barrels in underground tanks for later re-use	vary by size	minimal maintenance; inspect screens for clogging	repair/replace sceens as needed; replace tank as needed
Tree Box Filters	Satisfy regulatory requirements for new development protect and restore streams retrofit existing urban areas protect reservoir watersheds	site and design specific	Regular Removal of trash Watering of plants during severe drought	Plants may be replaced because they have overgrown the filter or because of environmental stress
Vegetated Roofs	help control nitrogen pollution in stormwater runoff	avg between $161-$215/sq m ($15-$20/sq ft)	minimal maintenance; tend to plants and shrubs as normal	Repair localized problems
Permeable Pavers	Used in place of conventional asphalt or concrete	$54-$108/sq m ($5.00-$10.00/sq ft.); may eliminate need for underground stormwater systems	sweeping, vacuuming or low pressure washing, adding aggregate as needed. DO NOT PLOW	Replace individual blocks as needed
Permeable Pavement	Used in place of conventional asphalt or concrete	Permeable Asphalt - $5-$11/sq m ($0.50 to $1.00 per square foot Permeable Concrete - $22-$70/sq m($2.00-$6.50/sq ft.)	sweeping, vacuuming or low pressure washing, adding aggregate as needed.	With Proper maintenance, no additional actions needed other than normal wear & tear repairs.

LID Definitions And Diagrams:

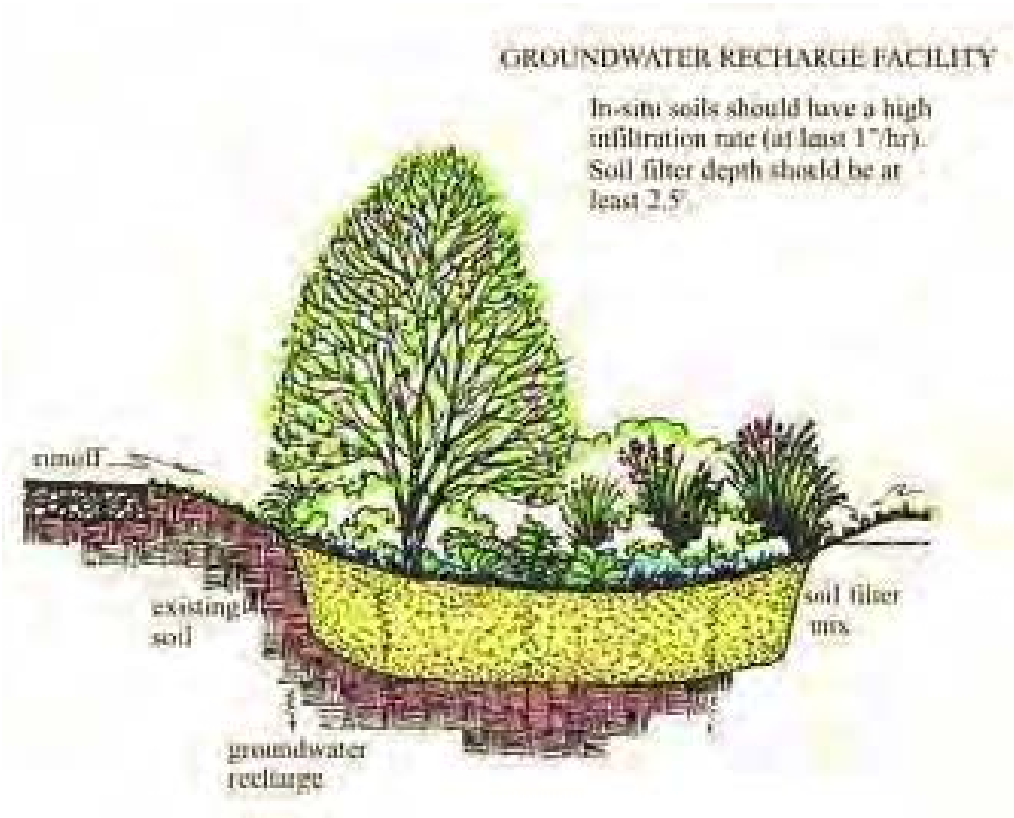
For additional reference and visual aide, see below for definitions of the basic LID features and diagrams to illustrate the basic concept/design of each feature. Remember, the following diagrams are not the only way possible to design the features. The guide is designed to be a tool to illustrate the feature, not be the design guide.

SOIL AMENDMENTS:

Soil amendments, which include both soil conditioners and fertilizers, make the soil more suitable for the growth of plants and increase water retention capabilities. The use of soil amendments is conditional on their compatibility with existing vegetation, particularly native plants.

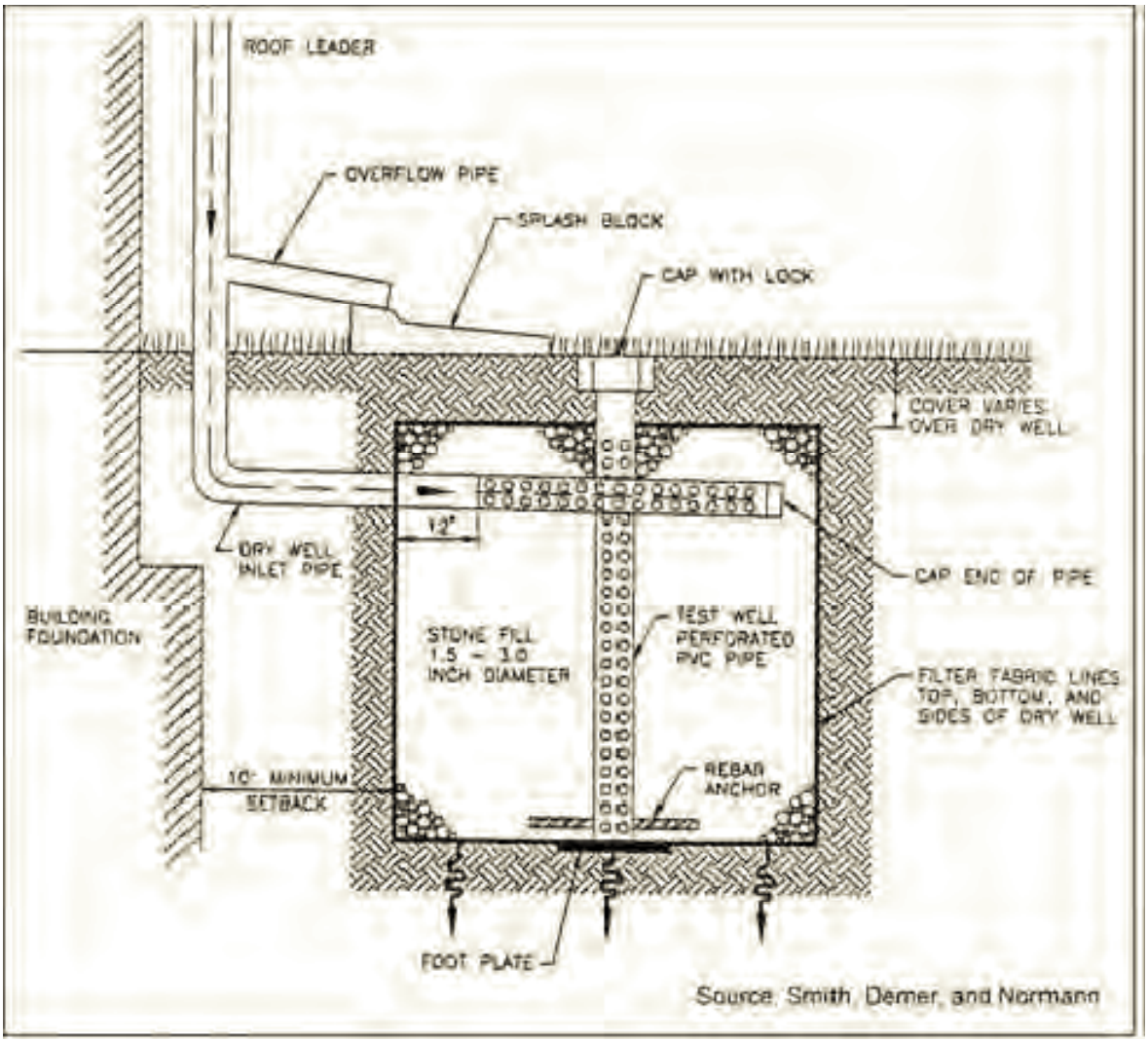
BIORENTION:

Bioretention areas typically have porous backfill under the vegetated surface, and an under drain that encourages infiltration and water quality filtering while avoiding extended ponding.



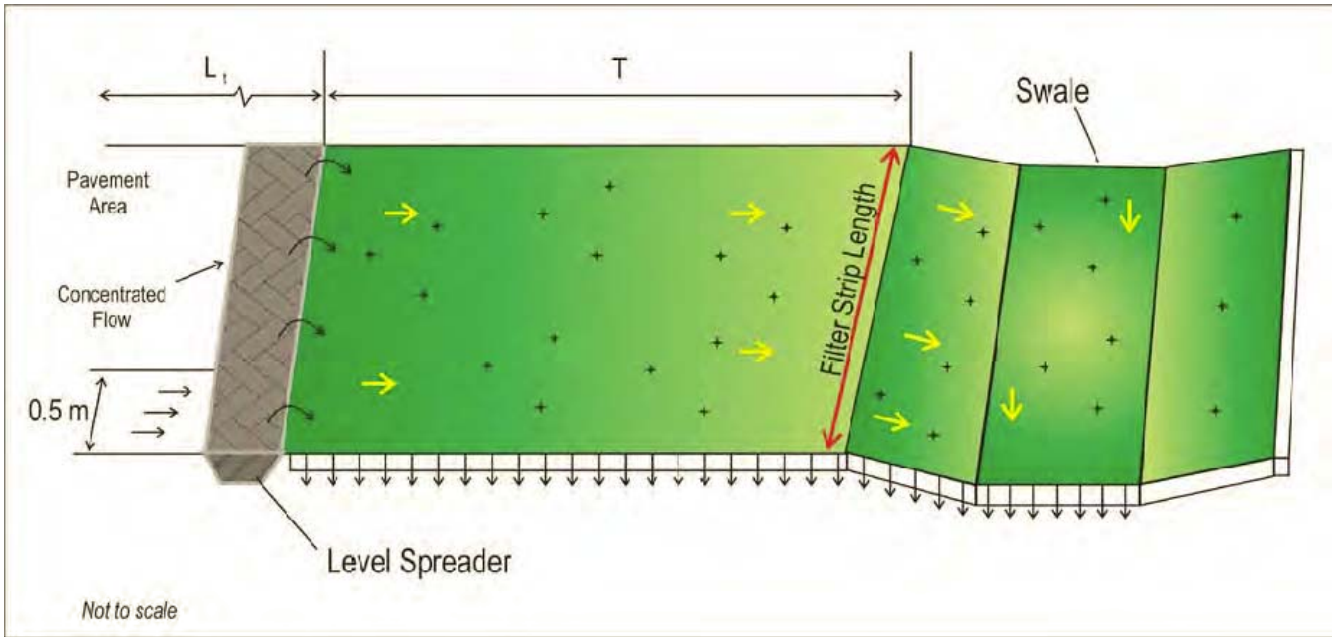
DRY WELLS:

A dry well typically consists of a pit filled with aggregate such as gravel or stone and is located to catch water from roof downspouts or paved areas.



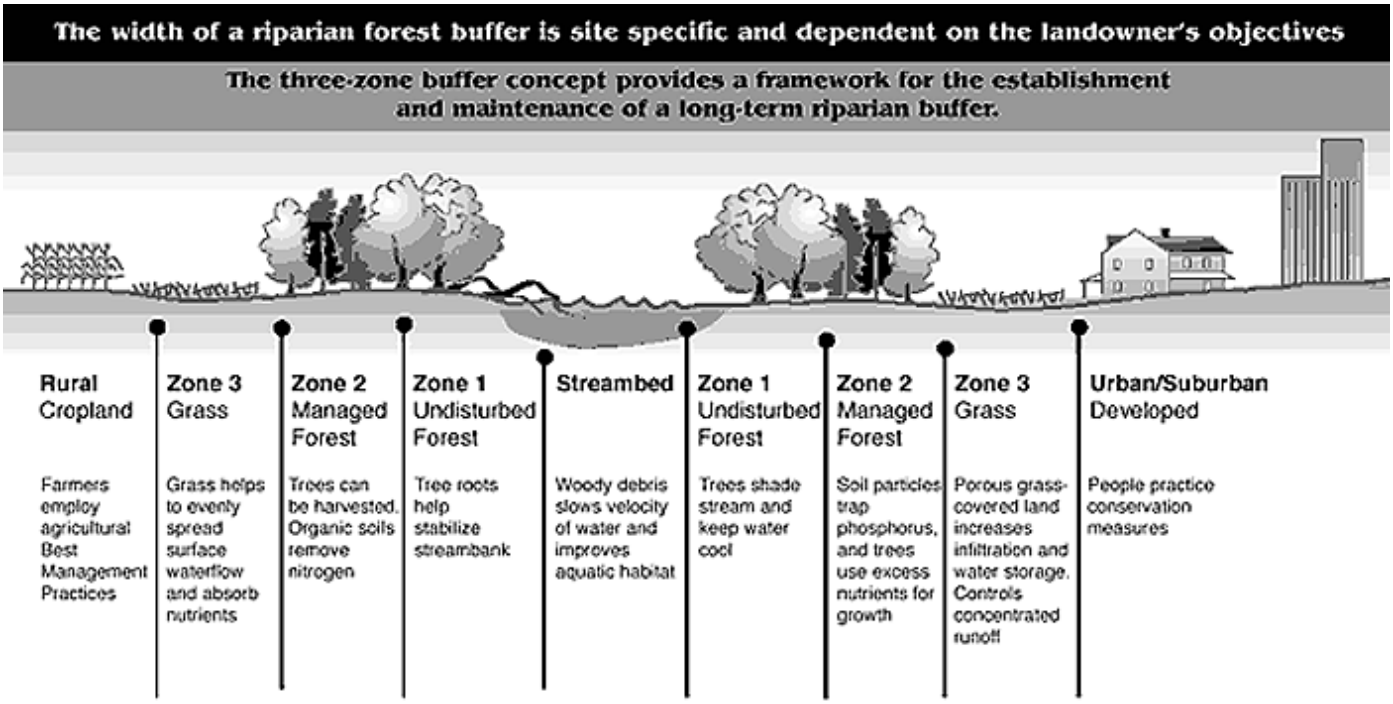
FILTER STRIPS:

Are bands of dense vegetation planted downstream of a runoff source.



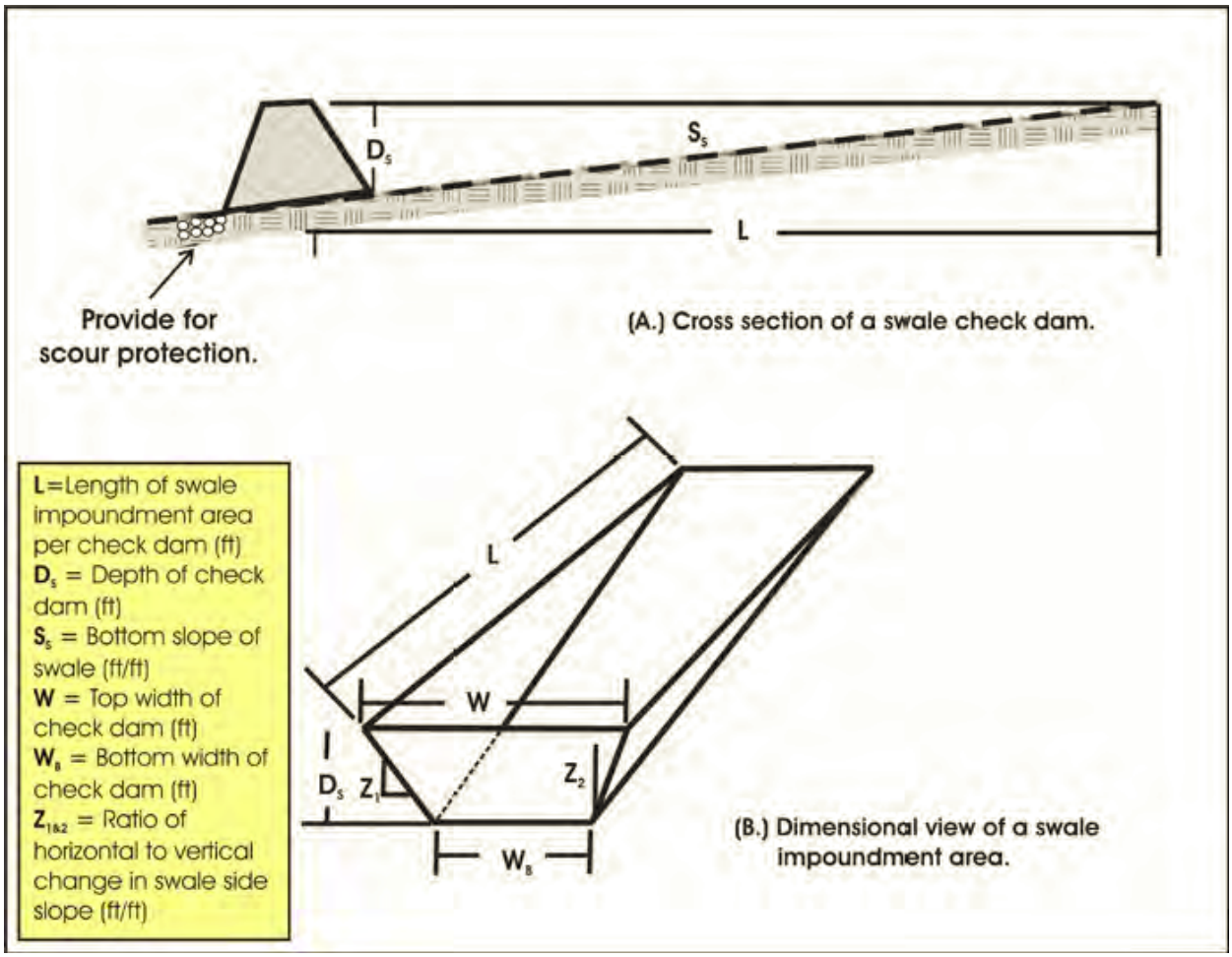
VEGETATED BUFFERS:

Vegetated buffers trap and filter sediments, nutrients, and chemicals from surface runoff and shallow groundwater.



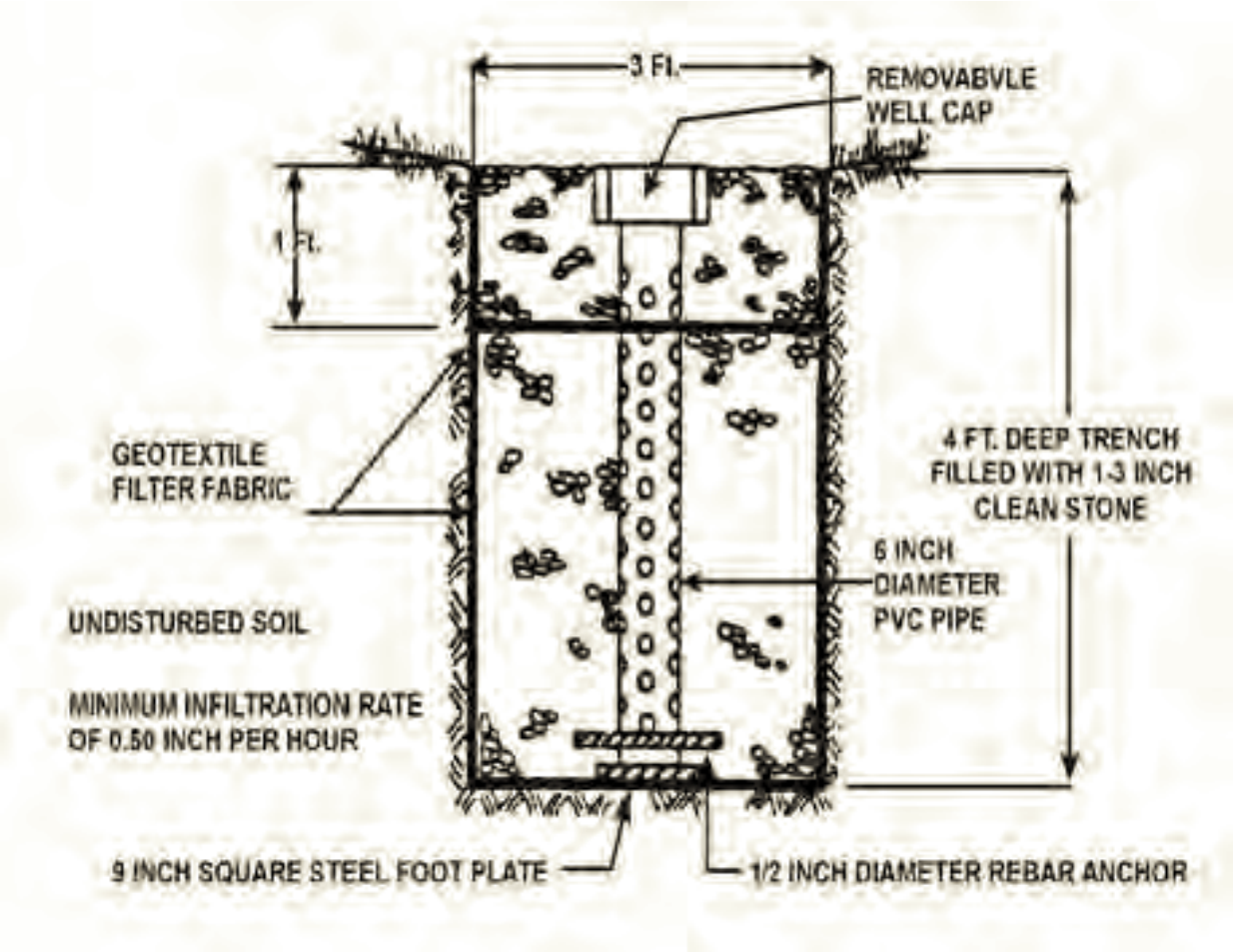
GRASSED SWALES:

Are shallow grass-covered hydraulic conveyances that help to slow runoff and facilitate infiltration.



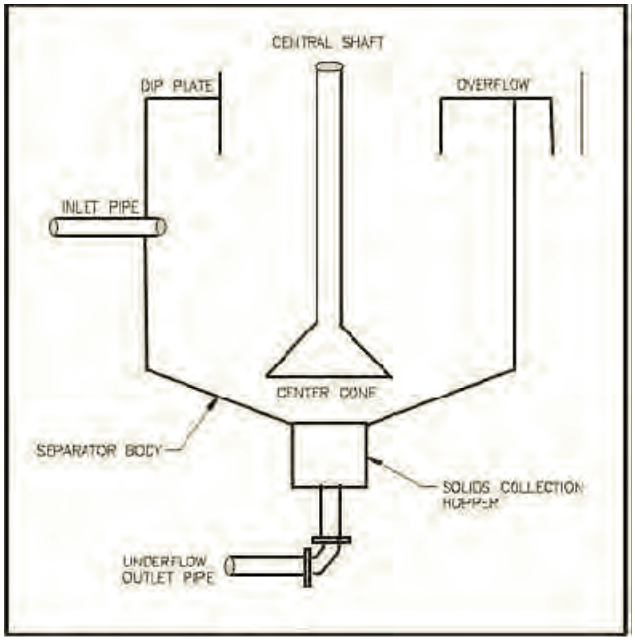
INFILTRATION TRENCHES:

Infiltration trenches are trenches that have been back-filled with stone. These trenches collect runoff during a storm event and release it into the soil by infiltration.



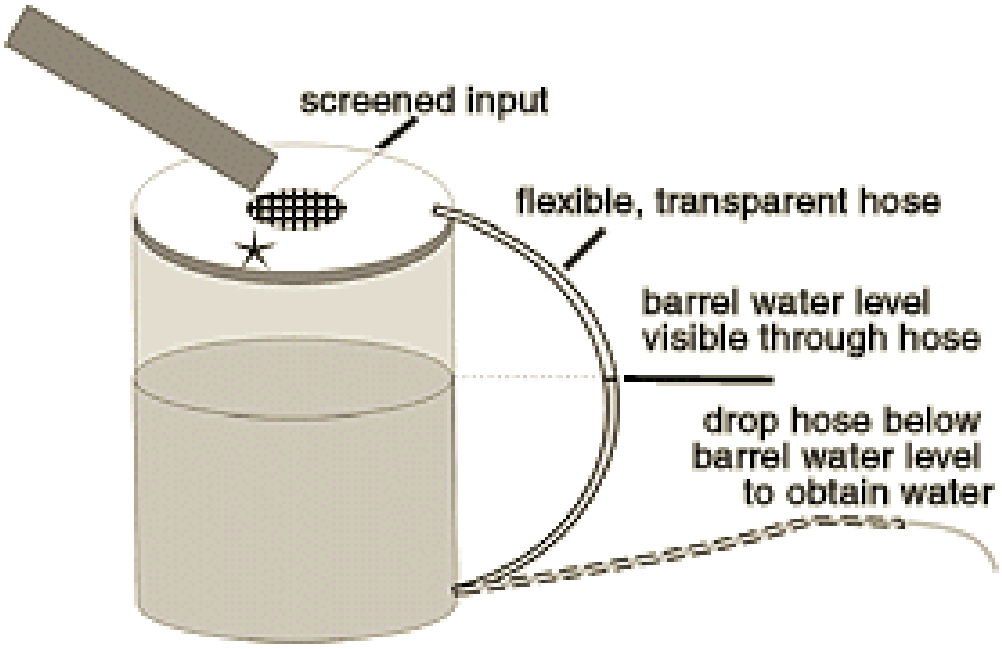
INLET DEVICES (A.K.A. HYDRODYNAMIC SEPARATORS):

Inlet devices are flow through structures with a settling or separation unit to remove sediments and other stormwater pollutants.



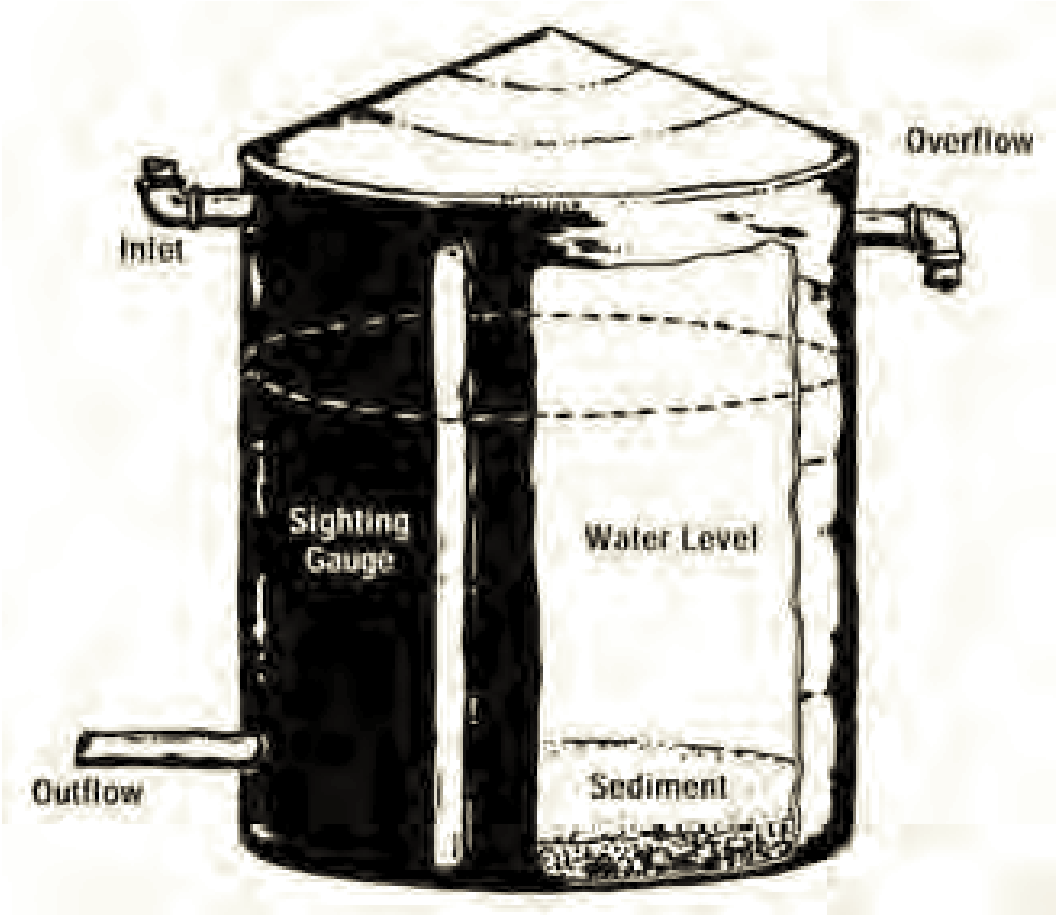
RAIN BARRELS:

Rain barrels are placed outside of a building at roof downspouts to store rooftop runoff for later reuse in lawn and garden watering.



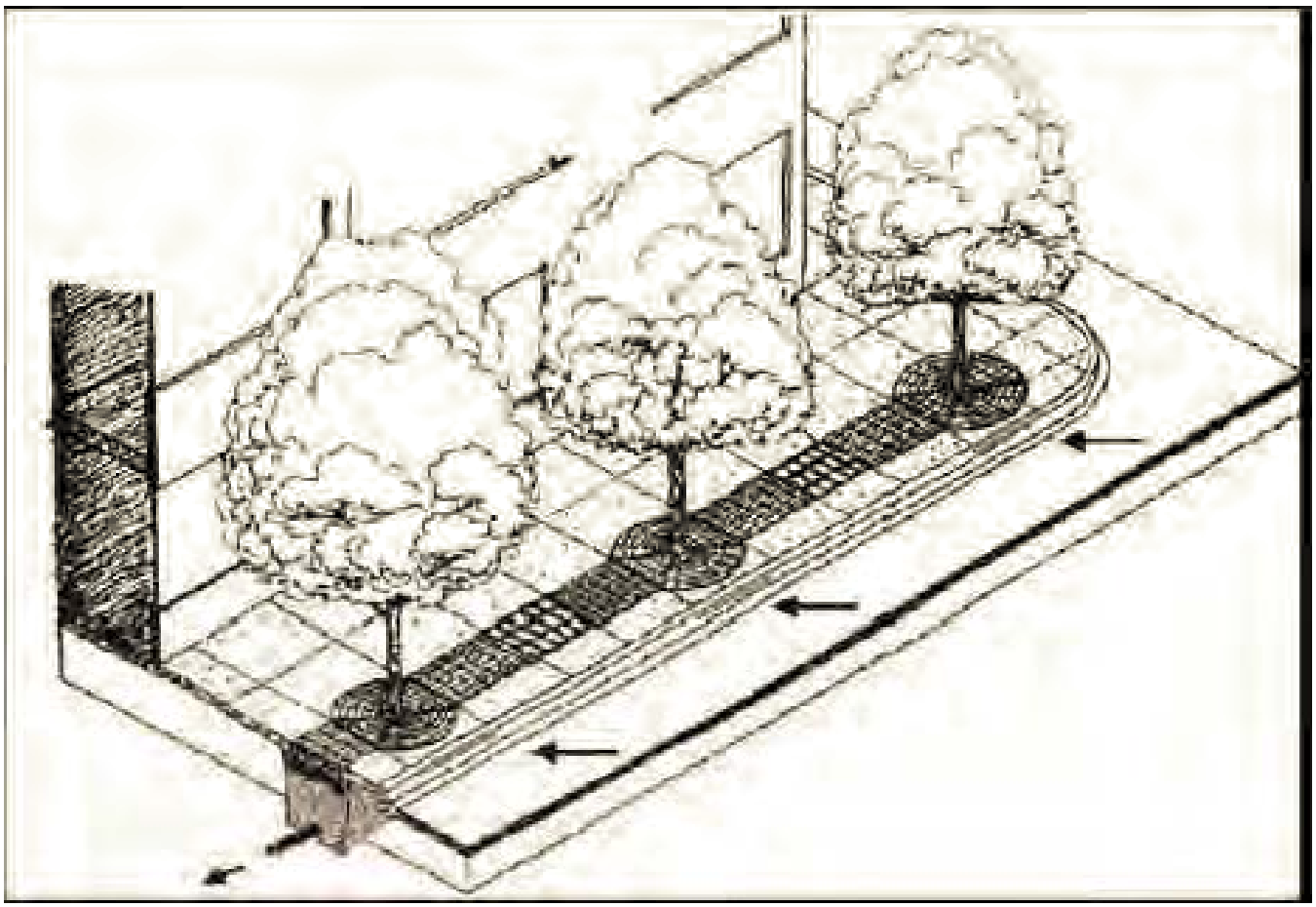
CISTERNS:

Also collect rooftop runoff but store the water in significantly larger volumes in manufactured tanks or built underground storage areas. Both cisterns and rain barrels can be implemented without the use of pumping devices, instead relying on gravity flow.



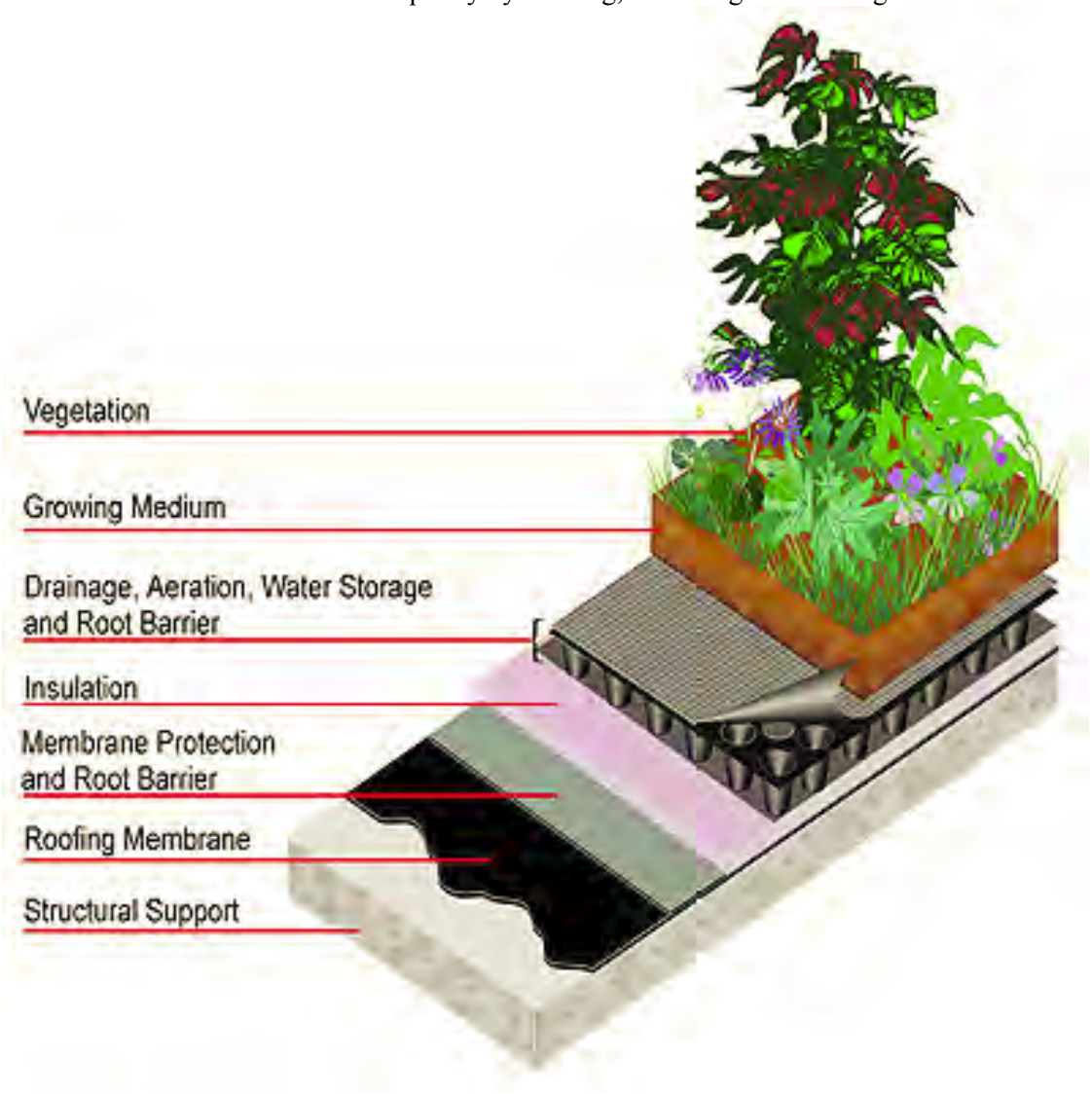
TREE BOX FILTERS:

Tree box filters are in-ground containers typically containing street trees in urban areas. These filters can be very effective at controlling runoff water quality, especially when numerous units are distributed throughout a site. Runoff is directed to the tree box, where it is filtered by vegetation and soil before entering a catch basin.



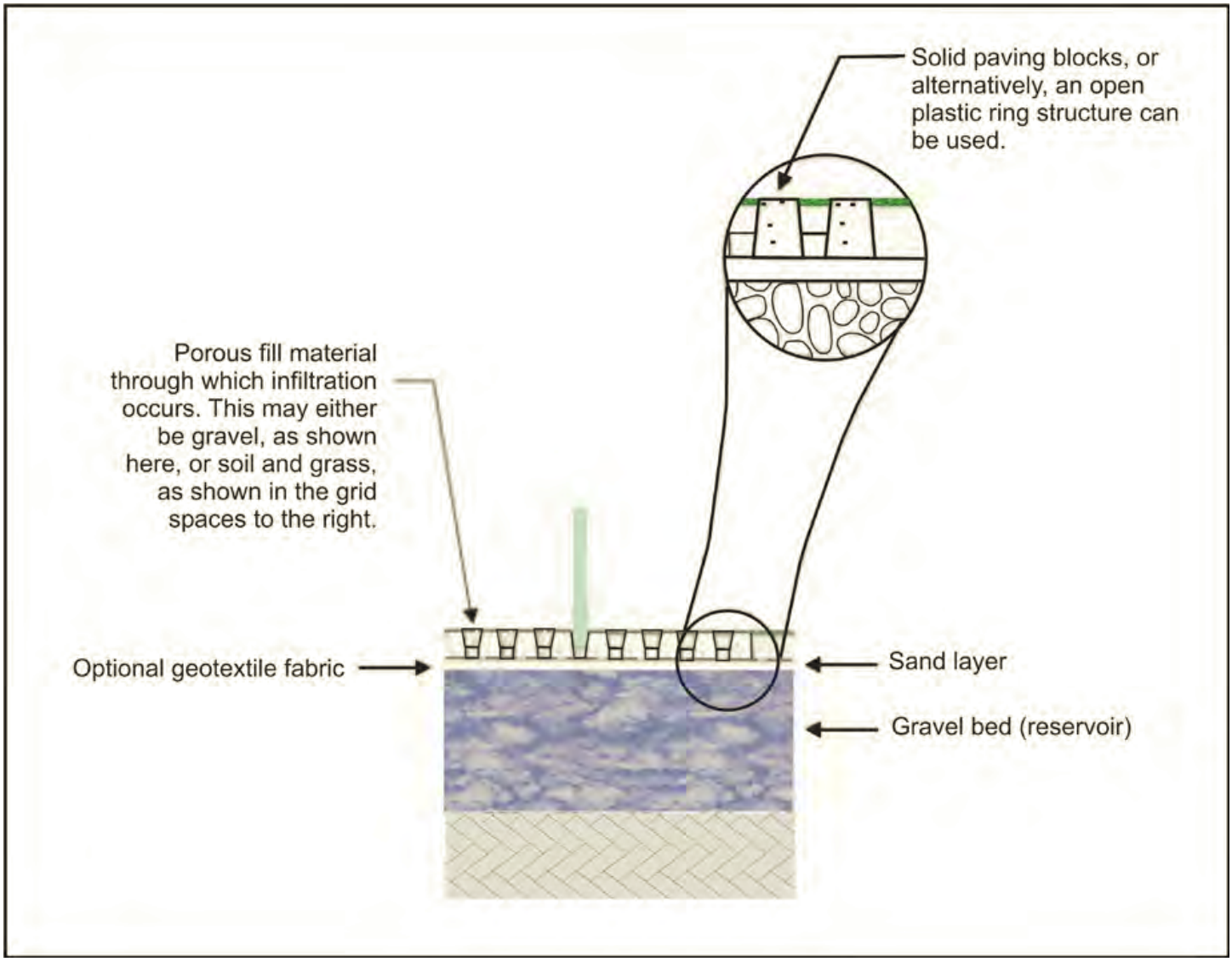
VEGETATED ROOFS:

Vegetated roofs, also known as green roofs, ecoroofs or nature roofs, are structural components that help to mitigate the effects of urbanization on water quality by filtering, absorbing or detaining rainfall.



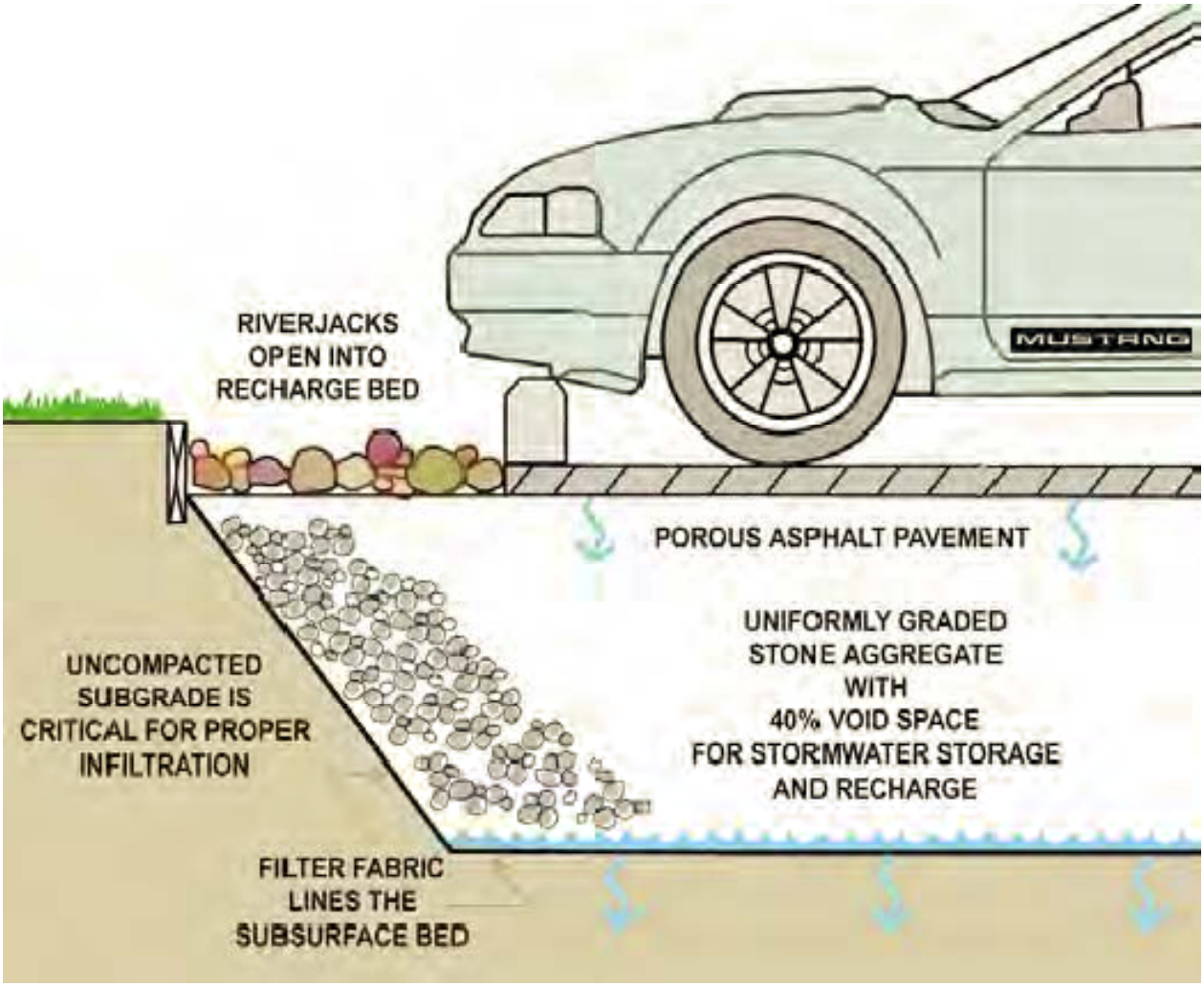
PERMEABLE PAVERS:

Permeable pavers allow water to seep through regularly interspersed void areas in order to reduce runoff and associated pollutants.



PERMEABLE PAVEMENT:

Can be either asphalt or concrete. As with permeable pavers, water is allowed to pass through voids and infiltrate into the underlying soil. Permeable pavement lacks most of the fine material found in conventional pavements, allowing water to flow through voids in the aggregate. (By contrast, paver blocks themselves are not necessarily permeable; infiltration occurs in the gaps between the blocks.) A layer of clean, uniformly graded gravel lies beneath the pavement, and geotextile separates this stone bed from the soil below. Runoff from the paved surface and adjacent impervious areas slowly passes through the gravel layer, which also may serve as a storage area. Permeable pavement has the same structural properties as conventional pavement. Environmental benefits are similar to other IMPs: reduction of runoff volume and rate, pollutant filtering, flow dispersion, and groundwater recharge. In addition, permeable pavements reduce the footprint of a site's impervious area.



Additional References:

For further understanding and a few additional resources, you can visit the websites listed below:

EPA – NATIONAL POLLUTANT DISCHARGE ELIMINATION SYSTEM:

The following website, http://cfpub.epa.gov/npdes/home.cfm?program_id=6 will take to you the EPA website for their National Pollutant Discharge Elimination System (NPDES), storm water program. You can find basic information about storm water here as well as informational guides on LID and even ones that help you design a SWPPP. You can find templates, examples, etc. on this site.

LID DESIGN GUIDANCE:

http://www.epa.gov/owow/NPS/lid/

- Here you will find design strategies, help with hydrologic analysis, and the LID Development manual (UFC 3-270-10) which was created by the Department of Defense, and it provides guidance on integrating LID into your designs.

SWPPP DESIGN GUIDANCE:

http://cfpub.epa.gov/npdes/stormwater/swppp.cfm

- Here you will find resources such as guidance on developing a SWPPP. You can view examples and templates as well as webcasts to walk you through creating an effective SWPPP

DCR – RUNOFF REDUCTION METHOD:

The Runoff Reduction Method is an innovative system for storm water design. The Runoff Reduction Method focuses on determining a BMPs' capacity for pollutant removal as well as to reduce the overall volume of runoff . The following website, http://www.dcr.virginia.gov/lr2f.shtml will take to you to the DCR Runoff Reduction Method. Here you will find several spreadsheets and guides to help you in your design process.

There are two spreadsheets, one for new development and one for redevelopment projects. There are also instructional documents, including spreadsheet instructions, a process flow chart, a document regarding assigning land cover values, and BMP design tables for use in applying the spreadsheet(s).

Supplementary Documents:

The following pages contain Supplementary Documents mentioned throughout this guidance packet. You will find the Permit Application Fee Form which outlines the application fee amounts for specified permits.
Second, you will find the General Permit Application Form that is needed to apply for your storm water permit. This form needs to be filled out completely as well, along with the Permit Application Fee Form, and both signed originals need to be forwarded to NREA along with your original check, with proper fees, made out to Treasurer of Virginia. NREA will forward your forms and check along with our cover letter to DCR.
After the General Permit Application Form you will find the Notice of Termination Form. You will need this form when your construction project is complete and you have achieved Final Stabilization. Remember, NREA defines Final Stabilization as 90% coverage with 2 – 3" cuttings, or when sodded or mulched completely.

If needed, and applicable, the E&SC Plan Short Form has been included as well. An example of a concise form for calculations has been provided. This is a simplified form that allows the designer to compile all calculations and present them in one easy to read document that can be inserted into the design proposal.

In addition the needed forms, you will also find three checklists; E&SC Plan Review Checklist, SWPPP Plan Review Checklist, and the LID Plan Review Checklist. These are the same checklists NREA uses to review all plan submissions. Prior to submitting your plans, use the checklist to see if you have covered all points that NREA will be looking for in your plans. Utilizing the checklists should help to speed your application and review process by helping to eliminate unwanted and unnecessary plan changes.

Department of Conservation & Recreation
CONSERVING VIRGINIAS NATURAL & RECREATIONAL RESOURCES

DEPARTMENT OF CONSERVATION AND RECREATION PERMIT FEE FORM

Instructions:
Applicants for an individual Virginia Stormwater Management Program (VSMP) Permit are required to pay permit application fees. Fees are also required for registration coverage under General Permits. Fees must be paid when applications for permit issuance or modification are submitted. Applications will be considered incomplete if the proper fee is not paid and will not be processed until the fee is received.

The permit fee schedule is included with this form. Fees for permit issuance, reissuance, modification and maintenance are included. Once you have determined the fee for the type of application you are submitting, complete this form. The original copy of the form and your check or money order payable to "Treasurer of Virginia" should be mailed to:

Department of Conservation and Recreation
Division of Finance, Accounts Payable
203 Governor Street, 4th Floor
Richmond, Virginia 23219

A copy of the form and a copy of your check or money order should accompany the permit registration statement (application). You should retain a copy for your records. Please direct any questions regarding this form or fee payment to SWMESquestions@dcr.virginia.gov.

Construction Activity Operator:

Name:_____ FIN: _____

Mailing Address:_____

City:_____ State:_____ Zip:_____ Phone:_____

Daytime Phone Number: (_____) _____ - _____

Name and Location of Construction Activity:

Name:_____

Town, City, or County:_____

Type of VSMP Permit (from Fee Schedule):

_____ MS4 Individual Permit _____ MS4 General Permit

_____ Construction Individual Permit _____ Construction General Permit

Type of Action: _____ New Issuance _____ Reissuance

_____ Modification _____ Maintenance

Amount of Fee Submitted (from Fee Schedule): _____

Existing Permit Number (if applicable): _____

FOR DCR USE ONLY

Date: _____ DC #: _____

(DCR 199-145) (03/09)

Department of Conservation & Recreation
CONSERVING VIRGINIA'S NATURAL & RECREATIONAL RESOURCES

Virginia Stormwater Management Program (VSMP) Permit Fee Schedule

A. VSMP Individual Permits. Applications for issuance of new individual VSMP permits, and for permittee initiated major modifications that occur (and become effective) before the stated permit expiration date. [NOTE: Individual VSMP permittees pay an Annual Permit Maintenance Fee instead of a reapplication fee. The permittee is billed separately by DCR for the Annual Permit Maintenance Fee.]

TYPE OF VSMP PERMIT	ISSUANCE	MODIFICATION
Municipal Stormwater / MS4 Individual (Large and Medium)	$21,300	$10,650
Municipal Stormwater / MS4 Individual (Small)	$2,000	$1,000
Construction Stormwater Individual	$0	$0

B. Registration Statements for VSMP MS4 General Permit Coverage. The fee for filing a permit application (registration statement) for coverage under a VSMP MS4 stormwater general permit issued by the permit issuing authority is as follows:

TYPE OF VSMP PERMIT	ISSUANCE
Municipal Stormwater / MS4 General Permit (Small)	$600

C. Registration Statements for VSMP Construction General Permit Coverage. The fee for filing a permit application (registration statement) for coverage under a VSMP Construction stormwater general permit issued by the permit issuing authority is as follows:

TYPE OF VSMP PERMIT	ISSUANCE
Construction General / Stormwater Management - Phase I Land Clearing ("Large" Construction Activity - Sites or common plans of development or sale equal to or greater than 5 acres)	$500
Construction General / Stormwater Management - Phase II Land Clearing ("Small" Construction Activity - Sites or common plans of development or sale equal to or greater than 1 acre and less than 5 Acres)	$300
Construction General / Stormwater Management - 2,500 square feet of land disturbance and less than 1 acre in designated Chesapeake Bay Preservations Area and not part of a common plan of development or sale.	$0

D. Permit Maintenance Fees. The annual permit maintenance fees apply to each VSMP permit identified below, including expired permits that have been administratively continued.

TYPE OF PERMIT	MAINTENANCE
VSMP Municipal Stormwater / MS4 Individual (Large and Medium)	$3,800
VSMP Municipal Stormwater / MS4 Individual (Small)	$400
VSMP General / Stormwater Management - Phase I Land Clearing ("Large" Construction Activity - Sites or common plans of development equal to or greater than 5 acres)	$0
VSMP General / Stormwater Management - Phase II Land Clearing ("Small" Construction Activity - Sites or common plans of development equal to or greater than 1 acre and less than 5 Acres)	$0

(DCR 199-145) (03/09)

Department of Conservation & Recreation
CONSERVING VIRGINIAS NATURAL & RECREATIONAL RESOURCES

VSMP General Permit for Discharges of Stormwater from Construction Activities (VAR10)

Registration Statement

(Please Type or Print All Information)

1. **Construction Activity Operator** *(The permit will be issued to this operator, and the Certification in Item #13 must be signed by the appropriate person associated with this operator [see the instructions])*

   Name:_____

   Mailing Address:_____

   City:_____ State:_____ Zip:_____ Phone:_____

2. **(Must be included for renewals of coverage only) Existing Permit Coverage #:**_____

3. **Location of Construction Activity**

   Name:_____

   Address:_____

   Town, City, County:_____ State:_____ Zip:_____

   Decimal degrees to the nearest 15 seconds : Latitude _____ Longitude _____

   Location of all Offsite Support Activities to be Covered Under the Permit

   Name:_____

   Address:_____

   Town, City, or County:_____ State:_____ Zip:_____

   If street address unavailable: Latitude _____ Longitude _____

4. **Status of Activity:** Federal ❑ State ❑ Public ❑ Private ❑ (Check one only)

5. **The Nature of the Construction Activity** (e.g., commercial, industrial, residential, agricultural, oil and gas, etc.)**:**

   _____

6. **Name of the Receiving Water(s):** _____

   Hydrologic Unit Code (HUC): _____

   (Receiving waters identified as impaired on the 305(b)/303(d) Water Quality Assessment Integrated Report or for which a TMDL WLA has been established for stormwater discharges from a construction site shall be noted in an attached list.)

7. **If the discharge is through a Municipal Separate Storm Sewer System (MS4), the name of the municipal operator of the storm sewer:**_____

8. **Estimated Project Start Date (mm/dd/yyyy):** _____ **Estimated Project Completion Date (mm/dd/yyyy)**: _____

9. **Total Land Area of Development** (to the nearest one-tenth acre)**:** _____

   Estimated Area to be Disturbed (to the nearest one-tenth acre)**:** _____

10. **Is the area to be disturbed by the construction activity part of a larger common plan of development or sale?** Yes❑ No❑

11. **Are nutrient offsets intended to be acquired for this activity?** Yes❑ No❑ Under consideration❑

12. **A stormwater pollution prevention plan (SWPPP) must be prepared in accordance with the requirements of the General VSMP Permit for Discharges of Stormwater from Construction Activities <u>prior to</u> submitting this Registration Statement. By signing this Registration Statement the operator is certifying that the SWPPP has been prepared.**

13. **Certification:** "I certify under penalty of law that I have read and understand this Registration Statement and that this document and all attachments were prepared in accordance with a system designed to assure that qualified personnel properly gathered and evaluated the information submitted. Based on my inquiry of the person or persons who manage the system or those persons directly responsible for gathering the information, the information submitted is to the best of my knowledge and belief true, accurate, and complete. I am aware that there are significant penalties for submitting false information including the possibility of fine and imprisonment for knowing violations."

    Print Name: _____ Title: _____

    Signature:_____ Date:_____

(Please sign in INK. The person signing this form must be authorized to sign on behalf the operator identified in Item #1 above.)

Mail to: Department of Conservation and Recreation, Stormwater Permitting, 203 Governor Street, Suite 206 Richmond, VA 23219

INSTRUCTIONS for FORM DCR 199-146

VSMP General Permit Registration Statement - Construction Activity Stormwater Discharges

General

A Registration Statement must be submitted to the Department of Conservation and Recreation to register for coverage under the General VSMP Permit for Stormwater Discharges from Construction Activities.

Section 1 Construction Activity Operator Information

"Operator" means the owner or operator of any facility or activity subject to the VSMP permit regulation. In the context of stormwater associated with a large or small construction activity, operator means any person associated with a construction project that meets either of the following two criteria: (i) the person has direct operational control over construction plans and specifications, including the ability to make modifications to those plans and specifications or (ii) the person has day-to-day operational control of those activities at a project that are necessary to ensure compliance with a stormwater pollution prevention plan for the site or other permit conditions (i.e., they are authorized to direct workers at a site to carry out activities required by the stormwater pollution prevention plan or comply with other permit conditions).

The entities who are considered operators will commonly consist of the owner or developer of a project (the party with control of project specifications) and the general contractor (the party with day to day operational control of the activities at the project site which are necessary to ensure compliance with the permit). Contractors and subcontractors who are under the general supervision of the general contractor are not considered operators and would not need to submit a registration statement. Give the legal name of the operator, do not use a colloquial name. Enter the complete address and phone number of the operator. **The permit will be issued to this operator.**

Section 2 Existing Permit Coverage Number

For reapplications only, indicate the existing permit coverage number for the project. This section does not need to be completed for initial applications for coverage for new projects.

Section 3 Location of Construction Activity Information

Enter the activity's official name and complete street address, including town, city or county, state and ZIP code.

If the site lacks a street address, enter the town, city or county and the latitude and longitude in degrees to the nearest 15 seconds of the approximate center of the site (example 37° 30' 15" N 77° 20' 15" W).

Location of Offsite Support Activities

This permit also authorize stormwater discharges from support activities (e.g., concrete or asphalt batch plants, equipment staging yards, material storage areas, excavated material disposal areas, borrow areas) located on-site or off-site provided that: (a) The support activity is directly related to the construction site that is required to have VSMP permit coverage for discharges of stormwater associated with construction activity; (b) The support activity is not a commercial operation serving multiple unrelated construction projects by different operators, and does not operate beyond the completion of the construction activity at the last construction project it supports; and (c) Appropriate control measures are identified in a stormwater pollution prevention plan and implemented to address the discharges from the support activity areas.

Provide the information required for each off-site support activity seeking coverage. If an off-site support activity is going to be covered by this permit the total land area of the off-site support activity and area to be disturbed by the off-site support activity need to be included in the Estimated Area to be Disturbed (Section 8).

Section 4 Status of Activity

Indicate the appropriate status (Federal, State, Public, or Private) of the activity.

Section 5 Nature of the Construction Project

Indicate the nature of the construction project (commercial, residential, agricultural, oil and gas, etc). This list is not all inclusive.

Section 6 Name of Receiving Water(s)

Enter the name of the receiving water(s) for all stormwater discharge(s), including any stormwater discharges from off-site support activities to be covered under the permit. Receiving waters identified as impaired on the 305(b)/303(d) Water Quality Assessment Integrated Report or for which a Total Maximum Daily Load (TMDL) Waste Load Allocation (WLA) has been established for stormwater discharges from a construction site shall be noted.

Hydrologic Unit Code (HUC) is a watershed unit established in the most recent version of Virginia's 6th order national watershed boundary dataset.

Section 7 Name of MS4 Operator

If the stormwater is discharged through a municipal separate storm sewer system (MS4), enter the name of the operator of the MS4. The name of the MS4 operator is usually the Town, City, County, Institute or Federal facility where the construction activity is located.

Section 8 Estimated Project Start Date

Enter the date (Month/Day/Year) the projected is expected to start.

Estimated Project Completion Date

Enter the date (Month/Day/Year) the project is expected to be complete.

Section 9 Total Land Area of the Development

Enter the total area (to the nearest one tenth acre) of the development (meaning the total acreage of the larger common plan of development or sale). Include the total acreage of any offsite support activities to be covered under the permit.

Estimated Area to be Disturbed

Enter an estimate of the total number of acres (to the nearest one tenth acre) to be disturbed. Include in the Estimated Area to be Disturbed the area of disturbance that will occur at off-site support activities to be covered under the permit.

Section 10 Larger Common Plan of Development or Sale

Indicate if the area to be disturbed by the construction activity is part of a larger common plan of development or sale. Larger common plan of development or sale defines a contiguous are where separate and distinct construction may be taking place at different times on different schedules. Plan is broadly defined as any announcement or documentation, including a sign, public notice or hearing, sales pitch, advertisement, drawing, permit application, zoning request, etc., or physical demarcation such as boundary signs, lot stake, and surveyor markings indicating that construction activities may occur.

Section 11 Nutrient Offsets

Indicate if nutrient offsets are intended to be acquired in accordance with §10.1-603.8:1 of the Code of Virginia. If the acquisition of offsets is being considered but is not certain, select "under consideration."

Section 12 A stormwater pollution prevention plan (SWPPP) must be prepared in accordance with the requirements of the General VSMP Permit for Discharges of Stormwater from Construction Activities prior to submitting this Registration Statement. By signing this Registration Statement the operator is certifying that the SWPPP has been prepared.

Section 13 Certification

The operator identified in Section 1 of this Registration Statement is responsible for certifying and submitting this Registration Statement. Please sign the form in INK. State statutes provide for severe penalties for submitting false information. State regulations require this Registration Statement to be signed as follows:

For a corporation: by a responsible corporate officer. For the purpose of this part, a responsible corporate officer means: (i) a president, secretary, treasurer, or vice-president of the corporation in charge of a principal business function, or any other person who performs similar policy-making or decision-making functions for the corporation; or (ii) the manager of one or more manufacturing, production, or operating facilities, provided the manager is authorized to make management decisions that govern the operation of the regulated facility including having the explicit or implicit duty of making major capital investment recommendations, and initiating and directing other comprehensive measures to assure long-term compliance with environmental laws and regulations; the manager can ensure that the necessary systems are established or actions taken to gather complete and accurate information for permit application requirements; and where authority to sign documents has been assigned or delegated to the manager in accordance with corporate procedures.

For a partnership or sole proprietorship: by a general partner or the proprietor, respectively.

For a municipality, state, federal, or other public agency: by either a principal executive officer or ranking elected official. For purposes of this part, a principal executive officer of a public agency includes: (i) the chief executive officer of the agency or (ii) a senior executive officer having responsibility for the overall operations of a principal geographic unit of the agency.

The Department of Conservation and Recreation reserves the right to request additional information not directly addressed by the Registration Statement if, in its discretion, a facility or operation poses a potential impact on water quality.

Department of Conservation & Recreation
CONSERVING VIRGINIA'S NATURAL & RECREATIONAL RESOURCES

VSMP General Permit Notice of Termination - Construction Activity Stormwater Discharges (VAR10)

(Please Type or Print All Information)

1. **Construction Activity Operator:**

   Name:_____

   Mailing Address:_____

   City:_____ State:_____ Zip:_____ Phone:_____

2. **Name and Location of Construction Activity** (As listed on registration statement)**:**

   Name:_____

   Address: _____

   City, Town or County:_____ State:_____ Zip:_____

   If street address unavailable: Latitude _____ Longitude _____

3. **VSMP Stormwater General Permit Number:** _____

4. **The Reason for Terminating Coverage Under the General Permit** (The construction activity operator may only submit a Notice of Termination after one or more of the conditions below have been met)**:**
   - ❑ **Necessary post-construction control measures included in the SWPPP for the site are in place and functioning effectively and final stabilization has been achieved on all portions of the site for which the operator is responsible;**
   - ❑ **Another operator has assumed control over all areas of the site that have not been finally stabilized and obtained coverage for the ongoing discharge;**
   - ❑ **Coverage under an alternative VPDES or VSMP permit has been obtained; or**
   - ❑ **For residential construction only, temporary stabilization has been completed and the residence has been transferred to the homeowner.**

The Notice of Termination must be submitted within 30 days of one of the above conditions being met. Authorization to discharge terminates at midnight on the date that the Notice of Termination is submitted.

5. **Permanent Control measures Installed:** Attach a list of permanent control measures (both structural and non-structural) that will be installed at the construction site. For each BMP, include the following information: (a) Type of control measure installed and the date that it became functional as a permanent control measure; (b) Geographic location (county or city and Hydrologic Unit Code) (latitude and longitude may additionally be included if available); (c) Waterbody the control measures discharge into; and, (d) Number of acres that will be treated (to the nearest one-tenth of an acre). If no permanent control measures were installed please check this box ❑
6. **Participation in a Regional Stormwater Management Plan:** Where applicable, attach the following information related to participation in a regional stormwater management plan: (a) type of regional facility or facilities to which the site contributes; (b) geographic location of any regional facility to which the site contributes (county or city and Hydrologic Unit Code); (c) geographic location of the site (county or city and Hydrologic Unit Code) (latitude and longitude may additionally be included if available); and (d) number of acres treated by a regional facility.
7. **Nutrient Offsets:** Where applicable, attach the following information related to nutrient offsets that were acquired in accordance with §10.1-603.8:1 of the Code of Virginia: (a) name of the broker from which offsets were acquired; (b) geographic location (county or city and Hydrologic Unit Code) of the broker's offset generating facility; (c) number of nutrient offsets acquired (lbs. per acre per year); and (d) nutrient reductions achieved on site (lbs. per acre per year).
8. **Certification:**
   "I certify under penalty of law that I have read and understand this notice of termination and that this document and all attachments were prepared in accordance with a system designed to assure that qualified personnel properly gathered and evaluated the information submitted. Based on my inquiry of the person or persons who manage the system or those persons directly responsible for gathering the information, the information submitted is to the best of my knowledge and belief true, accurate, and complete. I am aware that there are significant penalties for submitting false information including the possibility of fine and imprisonment for knowing violations."

   Print Name: _____ Title: _____

   Signature:_____ Date:_____

(Please sign in INK. The person signing this form must be authorized to sign on behalf the operator identified in Item #1 above.)

Mail to: Department of Conservation and Recreation
Stormwater Permitting
203 Governor Street, Suite 206
Richmond, VA 23219

DCR
Department of Conservation & Recreation
CONSERVING VIRGINIA'S NATURAL & RECREATIONAL RESOURCES

INSTRUCTIONS for FORM DCR 199-147

VSMP General Permit Notice of Termination - Construction Activity Stormwater Discharges

General

A VSMP General Permit Notice of Termination must be submitted when an operator no longer wishes to be covered under the VSMP General Permit for Stormwater Discharges from Construction Activities.

Mail to: Department of Conservation and Recreation
Stormwater Permitting
203 Governor Street, Suite 206
Richmond, VA 23219

Section 1 Activity Operator Information

Give the legal name of the person, firm, public organization, or any other entity that was issued the general permit for the site described in this Notice of Termination. Do not use a colloquial name. Enter the complete address and phone number of the operator.

Section 2 Activity Location Information

Enter the activity's official name and complete street address, including city, state and ZIP code. If the activity or site lacks a street address, indicate the latitude and longitude to the nearest 15 seconds of the approximate center of the site.

Section 3 Permit Information

Enter the existing VSMP Stormwater General Permit number assigned to the activity or site identified in Section 1 that the operator wishes to be terminated.

Section 4 Reason for Termination

Check the appropriate statement indicating the reason for submitting this Notice of Termination. The Notice of Termination may only be submitted after one or more of the following conditions have been met:

1. Necessary post-construction control measures included in the SWPPP for the site are in place and functioning and final stabilization has been achieved on all portions of the site for which the operator is responsible;
2. Another operator has assumed control over all areas of the site that have not been finally stabilized;
3. Coverage under an alternative VPDES or VSMP permit has been obtained; or
4. For residential construction only, temporary stabilization has been completed and the residence has been transferred to the homeowner.

The Notice of Termination must be submitted within 30 days of one of the above conditions being met. Authorization to discharge terminates at midnight on the date that the Notice of Termination is submitted.

Section 5 Permanent Control Measures Installed

Attach a list of the permanent control measures (both structural and non-structural) that will be installed at the construction site. For each control measure, include the following information:

(a) Type of control measure installed
(b) Geographic location (county or city and Hydrologic Unit Code)
(c) Waterbody the control measure discharge into
(d) Number of acres that will be treated (to the nearest one-tenth of an acre)

Check the box if no permanent control measures were installed.

Section 6 Participation in a Regional Stormwater Management Plan

Where applicable, attach the following information related to participation in a regional stormwater management plan: (a) type of regional facility or facilities to which the site contributes; (b) geographic location of any regional facility to which the site contributes (county or city and Hydrologic Unit Code); (c) geographic location of the site (county or city and Hydrologic Unit Code) (latitude and longitude may additionally be included if available); and (d) number of acres treated by a regional facility.

Section 7 Nutrient Offsets

Where applicable, attach the following information related to nutrient offsets that were acquired in accordance with §10.1-603.8:1 of the Code of Virginia: (a) name of the broker from which offsets were acquired; (b) geographic location (county or city and Hydrologic Unit Code) of the broker's offset generating facility; (c) number of nutrient offsets acquired (lbs. per acre per year); and (d) nutrient reductions achieved on site (lbs. per acre per year).

Section 8 Certification

State statutes provide for severe penalties for submitting false information on this Notice of Termination.

State regulations require this Notice of Termination to be signed as follows:

For a corporation: by a responsible corporate officer. For the purpose of this section, a responsible corporate officer means: (1) A president, secretary, treasurer, or vice-president of the corporation in charge of a principal business function, or any other person who performs similar policy- or decision-making functions for the corporation, or (2) the manager of one or more manufacturing, production, or operating facilities provided the manager is authorized to make management decisions which govern the operation of the regulated facility including having the explicit or implicit duty of making major capital investment recommendations, and initiating and directing other comprehensive measures to assure long term environmental compliance with environmental laws and regulations; the manager can ensure that the necessary systems are established or actions taken to gather complete and accurate information for permit application requirements; and where authority to sign documents has been assigned or delegated to the manager in accordance with corporate procedures

For a partnership or sole proprietorship: by a general partner or the proprietor; or

For a municipality, state, Federal, or other public facility: by either a principal executive officer or ranking elected official.

The Department of Conservation and Recreation reserves the right to request additional information not directly addressed by the registration statement if, in its discretion, a facility or operation poses a potential impact on water quality.

Erosion and Sediment Control Plan for Projects with Land Disturbance Less Than 1 Acre

Project: _____

Project Manager: _____

Responsible Land Disturber: _____

Land Area to be Disturbed _____ (acres or square feet)

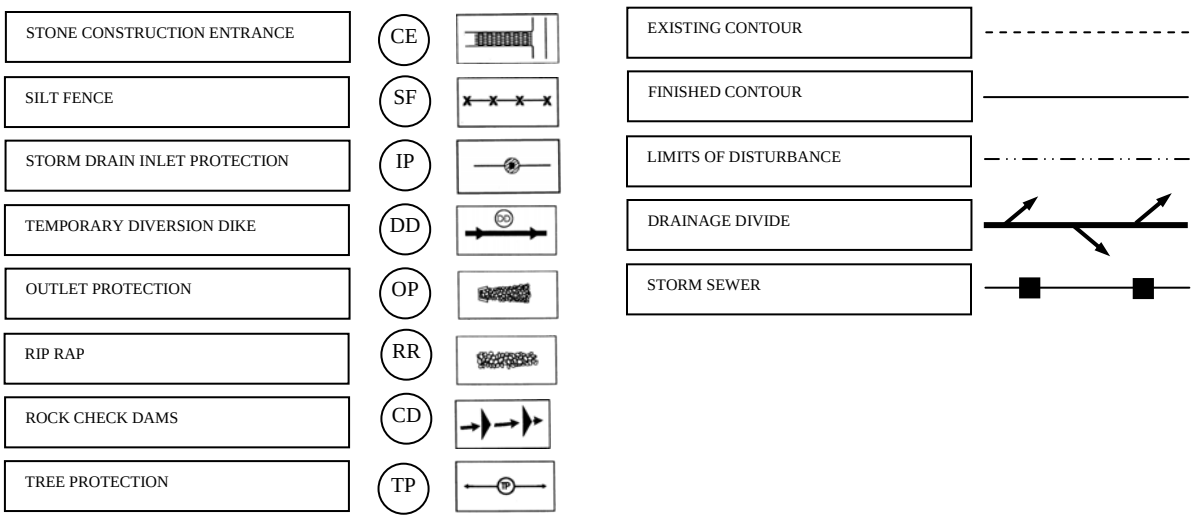
The following information is required:

1. Describe the nature, purpose, and scope of land disturbing activity
2. List all E&SC practices that will be required during all land-disturbing activities provided on the next two pages. Responsible Land Disturber should sign the acknowledgement.
3. Provide a Site Map with description of E&SC practices.

Map must include the following:

- Indicate North
- Indicate all areas that are to be cleared and graded.
- Show all improvements such as buildings, parking lots, access roads, utility construction, etc.
- Show the locations of all erosion and sediment controls and stormwater management practices used on the site.
- Show existing and final contour lines and drainage divides.

Recommended Plan Symbols:



4. Describe any off-site land-disturbing activities that will occur (including borrow sites, stockpiles, etc.)
5. Provide a schedule of regular inspections and repair of erosion and sediment control structures. Identify all post-construction maintenance requirements and responsible party for effecting all actions.
6. Use Fax Cover provided and Fax information to the Environmental Compliance Section, NREA Branch.

Erosion and Sediment Control Notes:

1. Permanent or temporary soil stabilization shall be applied to denuded areas within seven days after final grade is reached on any portion of the site.

2. Temporary soil stabilization shall be applied within seven days to denuded areas that may not be at final grade but will remain dormant for longer than 30 days.

3. Permanent stabilization shall be applied to areas that are to be left dormant for more than one year.

4. During construction of the project, soil stockpiles and borrow areas shall be stabilized or protected with sediment trapping measures.

5. The applicant is responsible for the temporary protection and permanent stabilization of all soil stockpiles on site as well as borrow areas and soil intentionally transported from the project site.

6. A permanent vegetative cover shall be established on denuded areas not otherwise permanently stabilized.

7. Permanent vegetation shall not be considered established until a ground cover is achieved that, is uniform, mature enough to survive and will inhibit erosion.

8. All measures intended to trap sediment shall be constructed as a first step in any land-disturbing activity and shall be made functional before upslope land disturbance takes place.

9. Stabilization measures shall be applied to earthen structures such as dams, dikes and diversions immediately after installation.

10. Cut and fill slopes shall be designed and constructed in a manner that will minimize erosion.

11. Slopes that are found to be eroding excessively within one year of permanent stabilization shall be provided with additional slope stabilizing measures until the problem is corrected.

12. Concentrated runoff shall not flow down cut or fill slopes unless contained within an adequate temporary or permanent channel, flume or slope drain structure.

13. Whenever water seeps from a slope face, adequate drainage or other protection shall be provided.

14. All storm sewer inlets that are made operable during construction shall be protected so that sediment-laden water cannot enter the conveyance system without first being filtered or otherwise treated to remove sediment.

15. Before newly constructed stormwater conveyance channels or pipes are made operational, adequate outlet protection and any required temporary or permanent channel lining shall be installed in both the conveyance channel and receiving channel.

16. Underground utility lines shall be installed in accordance with the following standards in addition to other applicable criteria:
    a. No more than 500 linear feet of trench may be opened at one time.
    b. Excavated material shall be placed on the uphill side of trenches.
    c. Material used for backfilling trenches shall be properly compacted in order to minimize erosion and promote stabilization.
    d. Restabilization shall be accomplished in accordance with the current edition of the VESCH.
    e. Applicable safety regulations shall be complied with.

17. Where construction vehicle access routes intersect paved or public roads, provisions shall be made to minimize the transport of sediment by vehicular tracking onto the paved surface.

18. Where sediment is transported onto a paved or public road surface, the road surface shall be cleaned thoroughly at the end of each day.

19. Sediment shall be removed from the roads by shoveling or sweeping and transported to a sediment control disposal area. Street washing shall be allowed only after sediment is removed in this manner.

20. All temporary erosion and sediment control measures shall be removed within 30 days after final site stabilization or after the temporary measures are no longer needed, unless otherwise authorized by the local program authority.

21. Trapped sediment and the disturbed soil areas resulting from the disposition of temporary measures shall be permanently stabilized to prevent further erosion and sedimentation.

22. Properties and waterways downstream from development sites shall be protected from sediment deposition, erosion and damage due to increases in volume, velocity and peak flow rate of stormwater runoff. Concentrated stormwater runoff leaving a development site shall be discharged directly into an adequate natural or man-made receiving channel, pipe or storm sewer system.

23. Increased volumes of sheet flows that may cause erosion or sedimentation on adjacent property shall be diverted to a stable outlet, adequate channel, pipe or pipe system, or to a detention facility.

24. All measures used to protect properties and waterways shall be employed in a manner which minimizes impacts on the physical, chemical and biological integrity of rivers, streams and other waters of the state.

25. All Land Disturbing Activities aboard MCB Quantico will be conducted in accordance with the current edition of the Virginia Erosion and Sediment Control Law and Regulations (VESCLR) and the Virginia Erosion and Sediment Control Handbook, 1992 Edition (VESCH). A copy of the handbook and the approved E&SC Plan will be kept on-site at all times.

This Plan is not applicable to projects with the following characteristics:

1. Project requires a sediment trap or basin.
2. Work will be performed in live watercourses.
3. Work will be performed in any areas that could potentially be characterized as wetlands.
4. Project will involve de-watering operations.
5. Project will increase peak flows rates of stormwater runoff, add additional impervious area, or create new drainage channels.
6. Existing conditions at the project site have inadequate stormwater management measures.

Responsible Land Disturber's Acknowledgement:

Signature	**(Date)**
Print Name	
Title	

Facsimile Transmittal

EROSION AND SEDIMENT CONTROL PLAN

MARINE CORPS BASE, QUANTICO, VIRGINIA

FROM: Company: _____

POC: _____

Phone: _____

Fax: _____

E-mail: _____

TO: Water Program, Environmental Compliance Section, NREA Branch (G-5)

Phone: (703) 784-4030

Fax: (703) 784-4953

SUBJ: **EROSION AND SEDIMENT CONTROL PLAN**

PAGES TRANSMITTED: [ ]

Notes:

The Contractor should include in their E&SC and their SWPPP submittal the following type of information. This format is recommended for ease of reference.

	Pre-Construction	Post-Construction	LID Device #1	LID Device #2	LID Device #3	Location within Plans/Specs
Drainage Area A						
Drainage Area B						
Drainage Area C						

LID Practices and BMP's	Drainage Area Location	Volume Required	CFS Required	Actual Volume/CFS	Location within Plans/ Specs
Soil Amendments					
Bioretention					
Dry Wells					
Filter Strips					
Vegetated Buffers					
Grassed Swales					
Infiltration Trenches					
Inlet Devices					
Rain Barrels					
Cisterns					
Tree Box Filters					
Vegetated Roofs					
Permeable Pavers					
Permeable Pavement					

NATURAL RESOURCES & ENVIRONMENTAL AFFAIRS BRANCH
MCB QUANTICO, VIRGINIA

CHECKLIST FOR EROSION & SEDIMENTATION CONTROL (E&SC) PLAN REVIEW FOR MCB QUANTICO CONSTRUCTION PROJECTS

Construction Project Name: _____ Review Date/Time: _____

Reviewer: _____Nikki Bennett_____ Title:__Water Program Manager__

A. PROJECT NARRATIVE REQUIREMENTS

	YES	NO	N/A
1. **Project Description:**			
a. Nature and purpose of land disturbance described?	☐	☐	☐
b. Land area (in acres) to be disturbed specified in the narrative?	☐	☐	☐
2. **Existing Site Conditions:** Description of existing topography, drainage, and vegetation provided?	☐	☐	☐
3. **Adjacent Areas:** Description of neighboring areas which might be affected by the land disturbance provided?		☐ ☐	☐
4. **Off-Site Areas:** Description of any off-site land disturbing activities (borrow pit, waste, surplus, etc.) provided?	☐	☐	☐
5. **Soils:** Brief description of the soils on the site giving such information as soil name, mapping unit, erodibility, permeability, depth, texture and soil structure provided?	☐	☐	☐
6. **Critical Areas:** Description of areas on the site that are potential erosion problems (steep slopes, channels, underground springs) provided?	☐	☐	☐
7. **Erosion and Sedimentation Control Measures:**			
a. Current edition of the VA E&SC Law and Regulations, and the Va E&SC Handbook cited?	☐	☐	☐
b. Enumerated description of methods which will be used to control E&SC on the site provided?	☐	☐	☐
c. Cited the maintenance and use of current VESCHB & approved E&SC plan at job site?	☐	☐	☐
8. **Permanent Stabilization:** Brief description, including specifications, of how the site will be stabilized provided?	☐	☐	☐
9. **Stormwater Runoff Considerations:**			
a. Increase of peak runoff resulting from site development determined?		☐ ☐	☐
b. Flooding or downstream channel degradation as a result of runoff increase determined?	☐	☐	☐
c. Description of strategy used to control stormwater runoff provided?	☐	☐	☐
10. **Calculations:**			
a. Calculations for pre- and post-development runoff provided?	☐	☐	☐
b. Detailed calculations for the design of temp sediment basins, perm storm detention basins, diversions, channels, etc. provided?	☐	☐	☐
11. **Maintenance:** A plan or schedule of regular inspections and repair of E&SC devices described?	☐	☐	☐

B. SITE PLAN REQUIREMENTS

	YES	NO	N/A
1. **Vicinity Map:**			
a. Is a small map showing the site location in relation to surrounding area included in the drawings?	☐	☐	☐
b. Land area (in acres) to be disturbed included in the drawings?	☐	☐	☐
2. **North Arrow:** Is North arrow shown on all pages of E&SC drawings?	☐	☐	☐
3. **Limits of Clearing and Grading:** Are areas to be cleared and/or graded marked?	☐	☐	☐
4. **Existing Contours:**			
a. Existing contours on site shown?	☐	☐	☐
b. Existing contours at offsite areas which will affected by the land disturbance shown?	☐	☐	☐

B. SITE PLAN REQUIREMENTS (Continued)

	YES	NO	N/A
5. **Final Contours:**			
a. Changes to the existing contours shown?	☐	☐	☐
b. Final drainage patterns shown?	☐	☐	☐
6. **Existing Vegetation:** Existing tree lines, grassed areas, or unique vegetation shown?	☐	☐	☐
7. **Soils:** Boundaries of soil types shown?	☐	☐	☐
8. **Existing Drainage Patterns:**			
a. Drainage divides and respective direction of flow shown?	☐	☐	☐
b. Area (in acres) of each drainage divide shown?	☐	☐	☐
9. **Critical Erosion Areas:** Per Chapter 6 of VESCH, are potentially serious erosion areas shown?	☐	☐	☐
10. **Site Development:** Are all site developments such as buildings, parking lots, access roads, utility construction, storm sewer system, final drainage, etc. shown?	☐	☐	☐
11. **Location of Practices:** Locations of E&SC and stormwater management practices used on site shown?	☐	☐	☐
12. **Off-site Areas:**			
a. Any off-site land disturbing activities identified?	☐	☐	☐
b. Adequate E&SC measures, protection, or stabilization shown?	☐	☐	☐
13. **Detail Drawings:** All detail drawings of E&SC devices not referenced to the VESCH explained and/or illustrated?	☐	☐	☐
14. **Minimum Standard Requirements (Per 4VAC50-30-40)**			
MS-1 Has temp or perm stabilization of denuded areas been addressed in the narrative? Seeded? Yes / No Mulched? Yes / No Graveled? Yes / No	☐	☐	☐
MS-2 Has stabilization of soil stockpiles been addressed with seeding and/or sediment trapping devices?	☐	☐	☐
MS-3 Has maintenance of permanent stabilization been addressed?	☐	☐	☐
MS-4 Will all sediment trapping devices be constructed and functional as first step in LDA?	☐	☐	☐
MS-5 For perimeter sediment trapping devices, has stabilization of earthen structures been addressed?	☐	☐	☐
MS-6 Are adequate sediment traps and/or basins required where needed?	☐	☐	☐
MS-7 Has stabilization of cut and fill slopes been adequately addressed?	☐	☐	☐
MS-8 Are paved flumes, channels, or slope drains required where necessary?	☐	☐	☐
MS-9 Has adequate stabilization or protection of surface roughening, outlets, etc. been addressed?	☐	☐	☐
MS-10 Has adequate protection of all operational storm sewer inlets been addressed?	☐	☐	☐
MS-11 Are channel lining or outlet protection adequate for stormwater conveyance channels?	☐	☐	☐
MS-12 Are in-stream construction measures adequately addressed to minimize channel damage?	☐	☐	☐
MS-13 Are temporary stream crossings of non-erodible materials planned for installation where applicable?	☐	☐	☐
MS-15 Has restabilization of areas subject to in-stream construction been adequately addressed?	☐	☐	☐
MS-16 Is stabilization of utility trenches adequately addressed?	☐	☐	☐
MS-17 Is the transport of soil and mud onto public roadways adequately addressed with applicable measures?	☐	☐	☐
MS-18 Has removal of all temp control devices been addressed?	☐	☐	☐
Has maintenance of all control devices been addressed?	☐	☐	☐
MS-19 Are properties and waterways downstream adequately protected from erosion and sediment deposition due to increases in peak runoff?	☐	☐	☐

C. CONCLUSION: ☐ **E&SC Plan Approved** ☐ **E&SC Plan Disapproved**

D. GENERAL JUSTIFICATION/S:

☐ The E&SC Plan does not meet the 19 Minimum Standards of the VESCH.

☐ Verbiage in the E&SC Narrative is either inadequate or insufficient, or both.

☐ Details of E&SC measures on construction drawings (Site Plan) is either inadequate or insufficient, or both.

☐ Other (comment/s shown below)

E. COMMENTS:

_____
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_____
_____
_____
_____

Reviewer's Signature:_____
Email:_____
Phone:_____

Total Area Disturbed: _____

Construction Start Date: _____

Contractor Information: _____
(Address, Phone, etc.) _____
_____
_____
_____

Contractor POC: _____
Email:_____
Phone: _____

MCBQ ROICC POC: _____
Email:_____
Phone: _____

MCBQ PWB POC: _____
Email:_____
Phone: _____

Storm Water Pollution Prevention Plan Checklist

Site:_____ **Inspected by:**_____

SITE DESCRIPTION	YES	NO	N/A
1. Description of the nature of the construction activity			
2. A description of the intended sequence of major activities which disturb soils for major portions of the site (e.g. grubbing, excavation, grading, utilities and infrastructure installation)			
3. Estimates of the total area of the site and the total area of the site that is expected to be disturbed by excavation, grading, or other activities including offsite borrow and fill areas covered by the plan			
4. An estimate of the runoff coefficient of the site prior to construction and after construction activities are completed			
5. Existing data describing the soil or the quality of any discharge from the site			
6. A description of existing vegetation at the site			
7. A description of any other potential pollution sources, such as vehicle fueling, storage of fertilizers or chemicals, sanitary waste facilities, etc.			
8. The name of the receiving water(s) and the ultimate receiving water(s), and areal extent of wetland acreage at the site			
9. A site map indicating:			
a. drainage patterns and approximate slopes or contours anticipated after major grading activities			
b. areas of soil disturbance and areas of the site which will not be disturbed			
c. the location of major structural and nonstructural controls identified in the plan			
d. the location of areas where stabilization practices are expected to occur including the types of vegetative cover			
e. surface waters (including wetlands)			
f. locations where storm water is discharged to a surface water with an outline of the drainage area for each discharge point			
g. existing and planned paved areas and buildings			
h. locations of permanent storm water management practices to be used to control pollutants in storm water after construction activities have been completed			
i. locations of offsite mate Hal, waste, borrow or equipment storage areas covered by the plan			
j. locations of other potential pollution sources as described in 7. above			
10. The location and description of any discharge associated with industrial activity other than construction, including storm water discharges from dedicated asphalt plants and dedicated concrete plants, which is covered by this permit			
CONTROLS	**YES**	**NO**	**N/A**
For ***each*** specific major activity, the plan will address the following:			
1. Erosion and Sediment controls for each site			
a. The plan must address how offsite accumulations of sediment must be removed, at a frequency sufficient to minimize offsite impacts, if sediment escapes the construction site,			
b. Statement saying that if periodic inspections or other information indicates a control has been used inappropriately, or incorrectly, the permittee must replace or modify the control for site situations			
c. Statement saying that sediment must be removed from sediment traps or			

Storm Water Pollution Prevention Plan Checklist

Site:_____ **Inspected by:**_____

sedimentation ponds when design capacity has been reduced by 50%.			
d. Statement saying that litter, construction debris, and construction chemicals exposed to storm water shall be prevented from becoming a pollutant source for storm water discharges (e.g., screening outfalls, picked up daily).			
e. Offsite material storage areas (also including overburden and stockpiles of dirt, borrow areas, etc.) where storm water discharges are authodzed by this permit are considered a part of the project and shall be addressed in the plan			
2. Stabilization Practices			
a. Description of interim and permanent stabilization practices			
b. Site-specific scheduling of the implementation of the practices			
c. Site plans should ensure that existing vegetation is preserved where attainable and that disturbed portions of the site are stabilized			
d. A record of the dates when major grading activities occur, when construction activities temporarily or permanently cease on a portion of the site, and when stabilization measures are initiated shall be maintained and included in the plan			
3. Structural Practices			
a. The plan shall include a description of structural practices to divert flows from exposed soils, store flows or otherwise limit runoff and the discharge of pollutants from exposed areas of the site to the degree attainable			
b. area with 3 or more acres at one time, a temporary (or permanent) sediment basin providing 3,618 cubic feet of storage per acre drained, or equivalent control measures, shall be provided where attainable until final stabilization of the site			
c. For drainage locations serving less than 3 acres, smaller sediment basins or sediment traps should be used. At a minimum, silt fences, vegetative buffer strips or equivalent sediment controls are required for all downslope boundaries (and for those side slope boundaries deemed appropriate as dictated by individual site conditions) of the construction area unless a sediment basin providing storage for 3,618 cubic feet of storage per acre drained is provided			
STORM WATER MANAGEMENT	**YES**	**NO**	**N/A**
1. A description of measures that will be installed during the construction process to control pollutants in storm water discharges that will occur ***after*** construction operations have been completed			
OTHER CONTROLS	**YES**	**NO**	**N/A**
1. Statement saying that no solid materials, including building materials, garbage, and debris shall be discharged to surface waters of the State, except as authorized by a **CWA Section 404 permit**			
2. Sediment removed from the roads each day			
3. The plan shall ensure and demonstrate compliance with applicable State or local waste disposal, sanitary sewer or septic system regulations			
4, Description of construction and waste materials expected to be stored onsite with updates as appropriate			
5. Description of controls to reduce pollutants from these materials including storage practices to minimize exposure of the materials to storm water, and spill prevention and response			
6. Description of pollutant sources from areas other than the permitted construction			

Storm Water Pollution Prevention Plan Checklist

Site:_____ Inspected by:_____

activity (including storm water discharges from dedicated asphalt plants and dedicated concrete plants) that contribute to the permitted discharge			
7. Except for flows from fire fighting activities, sources of nonstorm water that are combined with storm water discharges from the construction site must be identified in the plan. The plan shall identify and ensure the implementation of appropriate pollution prevention measures for the nonstorm water component(s) of the discharge			
MAINTENANCE	**YES**	**NO**	**N/A**
1. Description and schedule of procedures to maintain in good and effective operating conditions vegetation, erosion and sediment control measures and other protective measures during construction identified in the site plan			
2. If site inspections required by Part II.D.4. identify BMPs that are not operating effectively, maintenance shall be performed before the next anticipated storm event, or as necessary to maintain the continued effectiveness of storm water controls			
INSPECTIONS	**YES**	**NO**	**N/A**
1. Inspections shall be conducted at least once every fourteen calendar days and within 48 hours of the end of a storm event that is 0.5 inches or greater			
2. Inspection reports shall include:			
a. name(s) and qualifications of personnel making the inspection, and the date(s) of the inspection			
b. major observations relating to the implementation of the SWPP plan			
c. the location(s) of discharges of sediment or other pollutants from the site			
d. location(s) of BMPs that need to be maintained			
e. location(s) of BMPs that failed to operate as designed or proved inadequate for a particular location			
f. location(s) where additional BMPs are needed that did not exist at the time of inspection			
g. incidents of noncompliance			
h. Where a report does not identify any incidents of noncompliance, the report shall contain a certification that the facility is in compliance with the storm water pollution prevention plan and this permit			
i. Signature			

NATURAL RESOURCES & ENVIRONMENTAL AFFAIRS BRANCH

MCB QUANTICO, VIRGINIA

CHECKLIST FOR LID (Low Impact Development) PLAN REVIEW

FOR MCB QUANTICO CONSTRUCTION PROJECTS

Construction Project Name: Review Date/Time:

Reviewer: **Steve Clark** Title: **Water Programs Manager** Approved? YES ☐ NO ☐

	Yes	No	N/A
1. Do the LID features designed reduce the hydrologic impact of development and maintain or restore the sites hydrologic and hydraulic function?	☐	☐	☐
2. LID site design strategies (check all that apply):			
a. Grading to encourage sheet flow and lengthen flow paths	☐	☐	☐
b. Maintaining natural drainage divides to keep flow paths dispersed	☐	☐	☐
c. Disconnecting impervious areas such as pavement and roofs from the storm drain network, allowing runoff to be conveyed over pervious areas instead	☐	☐	☐
d. Preserving the naturally vegetated areas and soil types that slow runoff, filter out pollutants, and facilitate infiltration	☐	☐	☐
e. Directing runoff into or across vegetated areas to help filter runoff and encourage recharge	☐	☐	☐
f. Providing small-scale distributed features/devices that help meet regulatory and resource objectives	☐	☐	☐
g. Treating pollutant loads where they are generated, or prevent their generation	☐	☐	☐
3. Are the LID features designed site applicable (i.e. size of drainage area, available storage, land use, soil type, slope, vegetative cover, etc.)?	☐	☐	☐
4. Are pre-construction and post-construction calculations and data included in design	☐	☐	☐

5. Estimated Cost for LID features in design $_____

Individual Design Components:

1. Does the LID design provide for the conservation of natural areas	☐	☐	☐
2. Does the LID design provide minimization of development impacts	☐	☐	☐
3. Does the LID design control the watershed timing and runoff patterns	☐	☐	☐
4. Does the LID design use Integrated Management Practices (IMPs)	☐	☐	☐
5. Does the LID design provide for pollution prevention	☐	☐	☐
6. Does the LID design provide for O&M procedures for each LID practice in the site plan	☐	☐	☐

LID Features Used In Design (check all that apply):

a. Soil Amendments	☐	qty. _____	h. Inlet Devices	☐	qty. _____
b. Bioretention	☐	qty. _____	i. Rain Barrels	☐	qty. _____
c. Dry Wells	☐	qty. _____	j. Cisterns	☐	qty. _____
d. Filter Strips	☐	qty. _____	k. Tree Box Filters	☐	qty. _____
e. Vegetated Buffer	☐	qty. _____	l. Vegetated Roofs	☐	qty. _____
f. Grassed Swales	☐	qty. _____	m. Permeable Pavers	☐	qty. _____
g. Infiltration Trenches	☐	qty. _____	n. Permeable Pavement	☐	qty. _____

CONSTRUCTION WASTE MANAGEMENT REPORT

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NREA Rcvd:_____
FY Reporting Period:_____

Construction Waste Management Report
Quantico Marine Corps Base

Report Date: _____
Project Number: _____Project Name: _____
Contract Number: _____Contract Task Order/Delivery Order: _____
Reporting Period: _____ to _____

RETURN THIS FORM TO FAX (703) 784-4953 ATTN: _____

Comments: _____
_____

Waste Stream	Disposal (Tons)	Disposal Cost	Recycled (Tons)	Recycled Cost	Recycled Revenues
C&D		$		$	$

CONSTRUCTION & DEMOLITION DEBRIS (C&D).

- Record hazardous and non-hazardous C&D waste as one entry. Enter total tons of C&D disposed of in a landfill, by incineration, and/or by hazardous waste contract.
- Enter total disposal cost for C&D.
- Enter the recycled hazardous and non-hazardous C&D tons as one entry under the recycling column. You can also claim C&D diversion conducted by a construction contractor or MILCON project. If you have recycled C&D, it is likely that some was disposed of as well. Therefore, if there are recycled tons of C&D there should be some disposed tons of C&D.
- Enter the cost associated with recycling. Recycling costs include handling, processing, transportation, and other costs associated with recycling C&D. Soils that are used at another location or that are reclaimed count toward recycling.
- Enter Recycling Revenues. Enter only actual revenues received from recycling. Do not enter cost avoidance for recycling revenues.

Reported by:
Company: _____Contact: _____
Address: _____Title: _____
_____E-mail address: _____
Telephone: _____
Fax: _____

Definitions:

Construction and Demolition (C&D) Debris. Waste derived from the construction, renovation, demolition or deconstruction of residential and commercial buildings and their infrastructure. C&D waste typically includes concrete, wood, metals, gypsum wallboard, asphalt, and roofing material.

Other Select Waste (OSW). Construction and demolition debris are the “Other Select Waste” categories for purposes of DoD metric reporting via SW module. If the Other Select Wastes are hazardous they must also be reported in the calendar year HW module.

Form created 11/2008, revised 1/2010 for P2ADS support

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NAVFAC P-307 CRANE GUIDE

NAVFAC P-307
NAVY CRANE CENTER
DEC 2009

SECTION 1 - GENERAL OVERVIEW
(Excerpt only pertaining to Contractor Operated Crane)

1.7.2 Contractor Operated Cranes (and Multi-Purpose Machines, Material Handling Equipment (Forklifts), and Construction Equipment When Used as Cranes to Lift Suspended Loads) and Rigging Equipment in Weight Handling Operations. In addition to cranes rented or leased for operation by an activity, other non-Navy owned cranes, multi-purpose machines, material handling equipment (forklifts), and construction equipment are used on Navy property to lift suspended loads. Rigging equipment may be used with these machines or by itself in weight handling operations. These cranes and equipment can be from a variety of sources and are generally incidental to construction contracts, ship repair contracts, demolition contracts, maintenance and other service contracts, deliveries of supplies and equipment, etc. Numerous organizations, including tenant activities, ships, supply departments, ROICCs, etc., have contracting authority and very often the need for cranes is not anticipated when contract documents are written. The following requirements apply to any contracted work utilizing cranes (and multi-purpose machines, material handling equipment, construction equipment used to lift loads suspended by rigging gear) and to all rigging equipment used in weight handling operations at a naval activity. These requirements do not apply to shipboard cranes or rigging equipment. Navy activity (i.e., host activity) commanding officers shall promulgate the following minimum requirements to tenants and contracting officers for inclusion in contracts, statements of work, purchase orders, etc. (These requirements do not apply to cranes that enter the activity but are not used for lifting, or other machines not used to lift loads suspended by rigging equipment.)

a. Require the contractor to comply with specific activity regulations pertaining to crane safety and operation (including allowable access routes and ground loading limitations), and to notify the contracting officer, in advance, of any cranes entering the activity or of any multi-purpose machines, material handling equipment, or construction equipment that may be used in a crane-like application to lift suspended loads. Require the contractor to comply with applicable ANSI or ASME standards (e.g., ASME B30.5 for mobile cranes, ASME B30.22 for articulating boom cranes, ASME B30.3 for construction tower cranes, and ASME B30.8 for floating cranes, ASME B30.9 for slings, ASME B30.20 for below the hook lifting devices, and ASME B30.26 for rigging hardware, ANSI/ITSDF B56.6 for rough terrain forklifts). For cranes, machines and rigging equipment at naval activities in foreign countries, the cranes, machines and rigging equipment shall comply

with the appropriate host country safety standards. For barge-mounted mobile cranes, require a third party certification from an OSHA accredited organization (or a third party certification from a state accredited organization for those states with OSHA approved state plans), a load indicating device, a wind indicating device, and a marine type list and trim indicator readable in one-half degree increments. Third party certification is not required for barge-mounted mobile cranes at naval activities in foreign countries.

b. Require a certificate of compliance from the contractor (appendix P, figure P-1) that the crane (or other machine if used to lift suspended loads) and the rigging equipment meet applicable OSHA and ANSI/ASME regulations (with the contractor citing which OSHA and ANSI/ASME regulations are applicable, e.g., cranes/multi-purpose machines used in cargo transfer shall comply with 29 CFR 1917; cranes/multi-purpose machines used in construction, demolition, or maintenance shall comply with 29 CFR 1926; cranes/multi-purpose machines used in shipbuilding, ship repair, or shipbreaking shall comply with 29 CFR 1915; slings shall comply with ASME B30.9, rigging hardware shall comply with ASME B30.26). For cranes (or other machines used to lift suspended loads) and rigging equipment at naval activities in foreign countries, the contractor shall certify that the crane (or other machine) and the rigging equipment conform to the appropriate host country safety standards. The contractor shall also certify that all of its crane (or other machine) operators working on the naval activity have been trained not to bypass safety devices (e.g., anti-two block devices) during lifting operations. Require that the certifications be posted on the crane.

c. For mobile and commercial truck mounted cranes with OEM rated capacities of greater than 2000 pounds, require that the crane operator be designated as qualified by a source that qualifies crane operators (i.e., a union, a government agency, or an organization that tests and qualifies crane operators). Proof of current qualification shall be provided. Operators of cranes used in construction at activities under US jurisdiction shall follow the qualification and certification requirements of 29 CFR 1926.1427.

d. Require the contractor to certify (appendix P, figure P-1) that the operator is qualified and trained for the operation of the crane or machine to be used.

e. For multi-purpose machines, material handling equipment, and construction equipment used to lift loads suspended by rigging equipment, require proof of authorization from the machine OEM that the machine is capable of making lifts of loads suspended by rigging equipment. Require the contractor to demonstrate that the equipment is properly configured to make such lifts and is equipped with a load chart.

f. Require that all hooks used on cranes, hoists, other machines, and rigging gear shall have self-closing latches or the throat opening

shall be "moused" (secured with wire, rope, heavy tape, etc.) or otherwise secured to prevent the attached item from coming free of the hook under a slack condition. The following exceptions apply and shall be approved by the contractor’s technical organization: items where the hook throat is fully obstructed and not available for manual securing and lifts where securing the hook throat increases the danger to personnel such as forge shop, dip tank, or underwater work.

g. Require a critical lift plan for each of the following lifts: lifts over 75 percent of the capacity of the crane, hoist, or other machine (lifts over 50 percent of the capacity of a barge mounted mobile crane’s hoists) at any radius of lift; lifts involving more than one crane, hoist, or other machine; lifts of personnel (lifts of personnel suspended by rigging equipment from multi-purpose machines, material handling equipment, or construction equipment shall not be permitted); lifts made in the vicinity of overhead power lines; erection of cranes; and lifts involving non-routine rigging or operation, sensitive equipment, or unusual safety risks. The plan shall include the following as applicable:

(1) The size and weight of the load to be lifted, including crane (or other machine) and rigging equipment that add to the weight. The OEM's maximum load capacities for the entire range of the lift shall also be provided.

(2) The lift geometry, including the crane (or other machine) position, boom length and angle, height of lift, and radius for the entire range of the lift. Applies to both single and multiple crane/machine lifts.

(3) A rigging plan, showing the lift points, rigging equipment, and rigging procedures.

(4) The environmental conditions under which lift operations are to be stopped.

(5) For lifts of personnel, the plan shall demonstrate compliance with the requirements of 29 CFR 1926.1431.

(6) For barge mounted mobile cranes, barge stability calculations identifying crane placement/footprint; barge list and trim based on anticipated loading; and load charts based on calculated list and trim specific to the barge the crane is mounted on. The amount of list and trim shall be within the crane manufacturer’s requirements.

(7) For lifts in the vicinity of overhead power lines (i.e., if any part of the crane or other machine, including the fully extended boom of a telescoping boom crane or machine, or the load could approach the distances noted in figure 10-3 during a proposed operation), the plan shall demonstrate compliance to 29 CFR 1926.1408-1411.

h. Require the contractor to notify the contracting officer as soon as practical, but not later than four hours, after any WHE accident. (See definition in section 12.) Require the contractor to secure the accident site and protect evidence until released by the contracting officer. Require the contractor to conduct an accident investigation to establish the root cause(s) of any WHE accident. Crane operations shall not proceed until cause is determined and corrective actions have been implemented to the satisfaction of the contracting officer.

i. Require the contractor to provide the contracting officer within 30 days of any accident a Crane and Rigging Gear Accident Report using the form provided in section 12 consisting of a summary of circumstances, an explanation of causes(s), photographs (if available), and corrective actions taken. These notifications and reporting requirements are in addition to those promulgated by OPNAVINST 5100.23 and related command instructions.

j. Require the contractor to certify that signal persons used in construction work are qualified in accordance with 29 CFR 1926.1428.

The host activity shall ensure that contracts contain the above requirements, concur with the contracting officer's oversight plan (paragraph 1.7.2.2), ensure that the oversight plan is being carried out, and provide oversight of contractor accident investigations and corrective actions.

1.7.2.1 Additional Requirements For Tower Cranes. Contractor provided tower cranes used in construction must meet the additional requirements of CFR 1926.1435. The following additional documentation is required for contractor provided tower cranes (those cranes defined by ASME B30.3).

a. Foundation design and requirements.
b. Installation instructions.
c. Assembly and disassembly instructions including climbing/jumping instructions if applicable.
d. Operating manual, limitations, and precautions.
e. Periodic inspection and maintenance requirements.

1.7.2.2 Contracting Officer Responsibilities

a. The contracting officer shall include the minimum requirements of paragraph 1.7.2 and 1.7.2.1 for contractor cranes in contracts, ensure compliance with contract requirements, provide oversight of contractor crane and rigging operations, and provide oversight of contractor accident investigations and corrective actions. The degree of oversight shall be based upon the risk to Government personnel and property. Appendix P, figure P-2, provides a checklist that shall be used during oversight of contractor crane and rigging operations. The host activity shall concur with the oversight plan. Copies of appendix P, figure P-2, shall be kept on file for one year.

b. The contracting officer shall notify the host activity of any WHE accident upon notification by the contractor. Additionally, the

contracting officer shall notify the Navy Crane Center of an accident involving a fatality, in-patient hospitalization, overturned crane, collapsed boom, or any other major damage to the crane or adjacent property as soon as possible, preferably within 24 hours of notification by the contractor. For all other accidents, notify the Navy Crane Center as soon as practical but no later than three working days after the accident.

c. The contracting officer shall provide the Navy Crane Center and host activity a copy of every accident report, regardless of severity, upon receipt from the contractor. These requirements are in addition to any notification and reporting requirements promulgated in OPNAVINST 5100.23 and command instructions. When the contracting office is not in the local area, the contracting officer shall designate a local representative to ensure compliance with the above noted requirements.

CERTIFICATE OF COMPLIANCE

This certificate shall be signed by an official of the company that provides cranes (or multi-purpose machines, material handling equipment, or construction equipment used to lift loads suspended by rigging gear) or rigging gear for any application under this contract. Post a completed certificate on each crane or alternate machine (or in the contractor's on-site office for rigging operations) brought onto Navy property.

CONTRACTING OFFICER'S POINT OF CONTACT (Government Representative)	PHONE
PRIME CONTRACTOR/PHONE	CONTRACT NUMBER
CRANE OR ALTERNATE MACHINE SUPPLIER/PHONE (if different from prime contractor)	CRANE OR ALTERNATE MACHINE NUMBER (i.e., ID number)
CRANE OR ALTERNATE MACHINE MANUFACTURER/TYPE/CAPACITY	
CRANE OR ALTERNATE MACHINE OPERATOR'S NAME(S)	

I certify that

1. The above noted crane or alternate machine and all rigging gear conform to applicable OSHA regulations (host country regulations for naval activities in foreign countries) and applicable ASME B30 standards. The following OSHA regulations and ASME standards apply:_____
2. The operators noted above have been trained and are qualified for the operation of the above noted crane(s) or alternate machine(s).
3. The operators noted above have been trained not to bypass safety devices during lifting operations.
4. The operators, riggers and company officials are aware of the actions required in the event of an accident as specified in the contract.

COMPANY OFFICIAL SIGNATURE	DATE
COMPANY OFFICIAL NAME/TITLE	

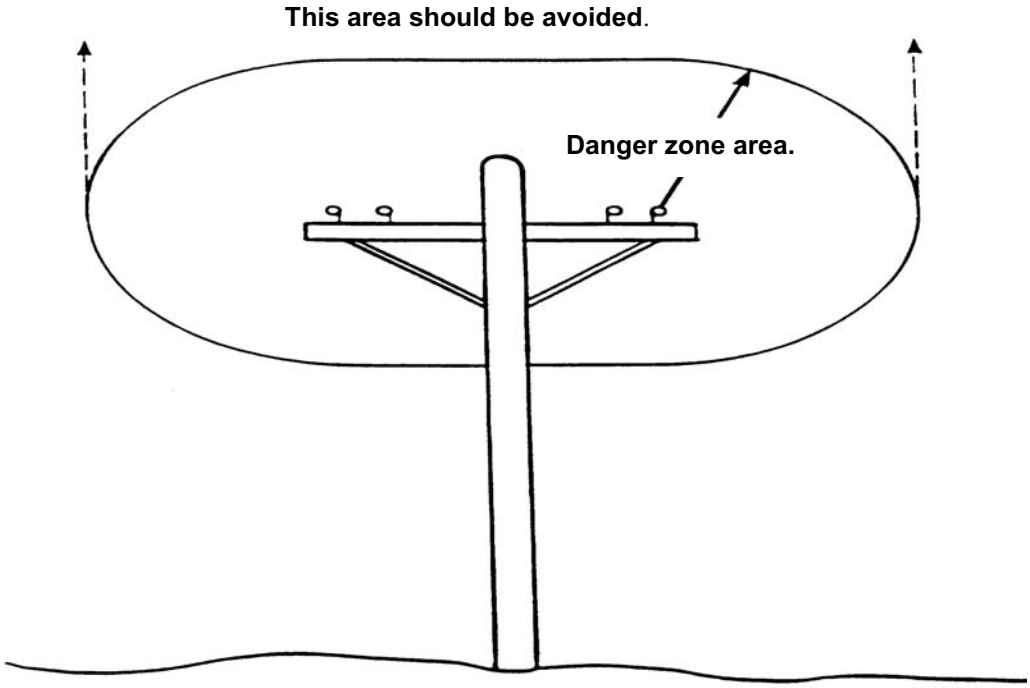
POST ON CRANE (OR ALTERNATE MACHINE)

(IN CAB OR VEHICLE)

(or in the contractor's on-site office for rigging operations)

FIGURE P-1

DANGER ZONE FOR CRANES AND LIFTED LOADS
OPERATING NEAR ELECTRICAL TRANSMISSION LINES.



Required clearance for normal voltage in operation near high voltage power lines and operation in transit with no load and boom or mast lowered.

NORMAL VOLTAGE, KV (PHASE TO PHASE)	MINIMUM REQUIRED CLEARANCE, FT (M)
Operation Near High Voltage Power Lines	
0 to 50	20 (6.10)
Over 50 to 200	20 (6.10)
Over 200 to 350	20 (6.10)
Over 350 to 500	50 (15.24)
Over 500 to 750	50 (15.24)
Over 750 to 1000	50 (15.24)
Operation in Transit with No Load and Boom or Mast Lowered	
0 to 0.75	4 (1.22)
Over 0.75 to 50	6 (1.83)
Over 50 to 345	10 (3.05)
Over 345 to 750	16 (4.87)
Over 750 to 1000	20 (6.10)

FIGURE 10-3

CHANGE 1 March 2011

MARINE CORPS BASE QUANTICO
REFRIGERANT SERVICE FORM
AND
ODS EQUIPMENT REPORTING FORM

Marine Corps Base, Quantico, ODS Equipment Reporting Form

Please Fax to NREA Air Program Manager at (703) 784-4953 within 24 hours

Company:
Building #:
Specific Location:

☐ **New unit installation**
☐ **Replacement unit**
If a replacement unit, please complete the disposal section.
☐ **Unit disposal**

Date installed:
PW #:
Manufacturer:
Model:
Serial Number:
Duty Type: ☐ Comfort ☐ Industrial Process ☐ Under 50 Lbs. ☐ Commercial ☐ Other Refrigeration ☐ Other

Appliance type:
Chiller, Air Cooled Condenser, Heat Pump, Window A/C, etc.
Horsepower:
Lubricant:
Capacity:
Volts/Ph/Hz:

Circuits

Circuit	Refrigerant	Charge	Class 1, II, or Non-ODS
#1			
#2			
#3			

General Installation Notes:

Date disposed:
PW #:
Manufacturer:
Model:
Serial Number:
Unit Status:
☐ **Operational**
☐ **Non-Operational**

By:
☐ **Refrigerant Recovered**
☐ **Unit tagged "Refrigerant Recovered"**
Amount of Recovered Refrigerant _____
Recovery Vacuum Level Achieved _____

General Disposal Notes:

NREA Processing: Date received: _____ ☐ **Entered in RCM**

Marine Corps Base, Quantico Refrigerant Service Form

Please Fax to NREA Air Program Manager at (703) 784-4953 within 24 hours

Work Order #: _____ **Date Issued:** _____

Building #: _____ Specific Location: _____

Technicians: _____

_____

Completed: _____

PW #: _____ **Manufacturer:** _____

Model: _____

Serial #: _____

Refrigerant Type: _____

Charge: Circuit 1: _____ **Circuit 2:** _____ **Circuit 3:** _____

Reason for Dispatch

Service Description

☐ Confirmed Charge ☐ Non-Major Maintenance

☐ Upgrades Performed ☐ Major Maintenance

☐ Isolated Leak

☐ Refrigerant Conversion

☐ Disposed Unit

If disposed unit then complete the following boxes:

☐ Refrigerant Recovered ☐ Unit Tagged - "Refrigerant Recovered"

Recovery Unit: _____

Vacuum Level:

☐ 0 ☐ 10 ☐ 15 ☐ 28.2 Inches

☐ Recovery Terminated (Air) ☐ Transferred to Receiver/Condenser, or Pump Out Unit

☐ Unit Flat at "0" psi Could Not Recover

Service Description Notes

Refrigerant	**Cylinder ID**	**Type**	**Condition**	**Quantity**
Recovered				
			Total Recovered:	
Added				
	☐ **Startup Charge**		**Total Added:**	

☐ Accidental Release Occurred Estimated Amount Released: _____

Description: _____

_____

Leaks

☐ Leak Found Date: _____

Leak Type: _____

☐ Leak Repaired Date: _____

☐ Initial Leak Verification Test Date: _____

Test done after repair before charging.

Method: _____

☐ Follow-up Verification Test Date: _____

Test done with unit running under normal load.

Method: _____

☐ Leak Audit Date: _____

☐ Trace Gas Used

Refrigerant: _____

Cylinder ID: _____ Quantity: _____

Leak Notes:

Exact location of leak and description of how repaired.

NREA Processing: Date received: _____ ☐ Equipment verified ☐ Entered in RCM Annual Leak Rate: _____

PULL-UP BAR

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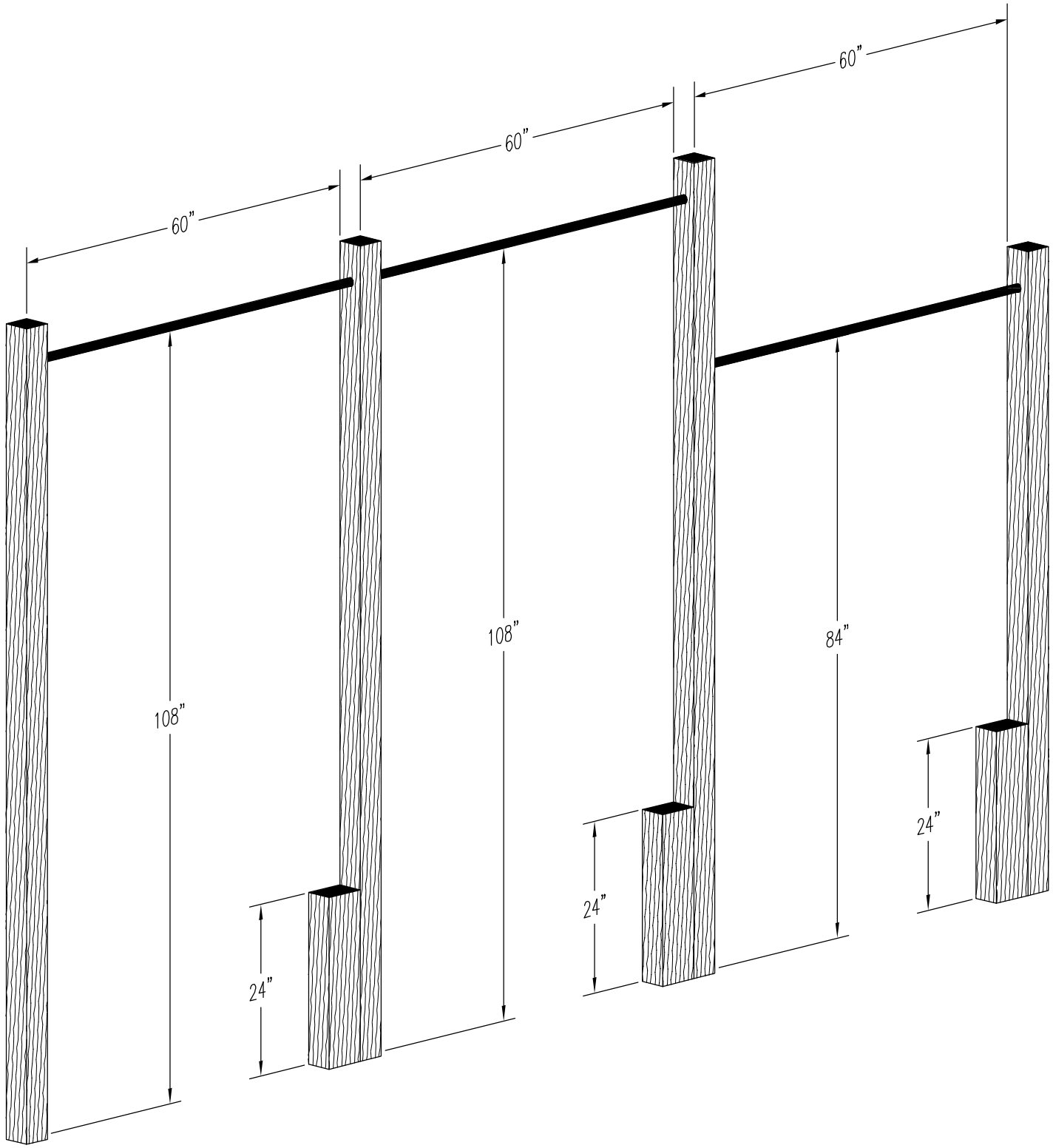

PULL-UP BARS

NO SCALE

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FACILITY RECOGNITION PLAQUE

Example text for Plaque. Coordinate actual text with MCBQ PM.

☆ ☆

BARBER FITNESS CENTER

COLONEL WILLIAM E. BARBER (1 3/8”)

UNITED STATES MARINE CORPS (3/4”)

COMMANDING OFFICER, COMPANY F, SECOND BATTALION

SEVENTH MARINES, FIRST MARINE DIVISION

AWARDED THE MEDAL OF HONOR, CHOSIN RESERVOIR, KOREA, FROM
28 NOVEMBER TO 2 DECEMBER, 1950

THIS GALLANT MARINE FOUGHT BRAVELY FOR
HIS COUNTRY (1/2”)

☆ ☆

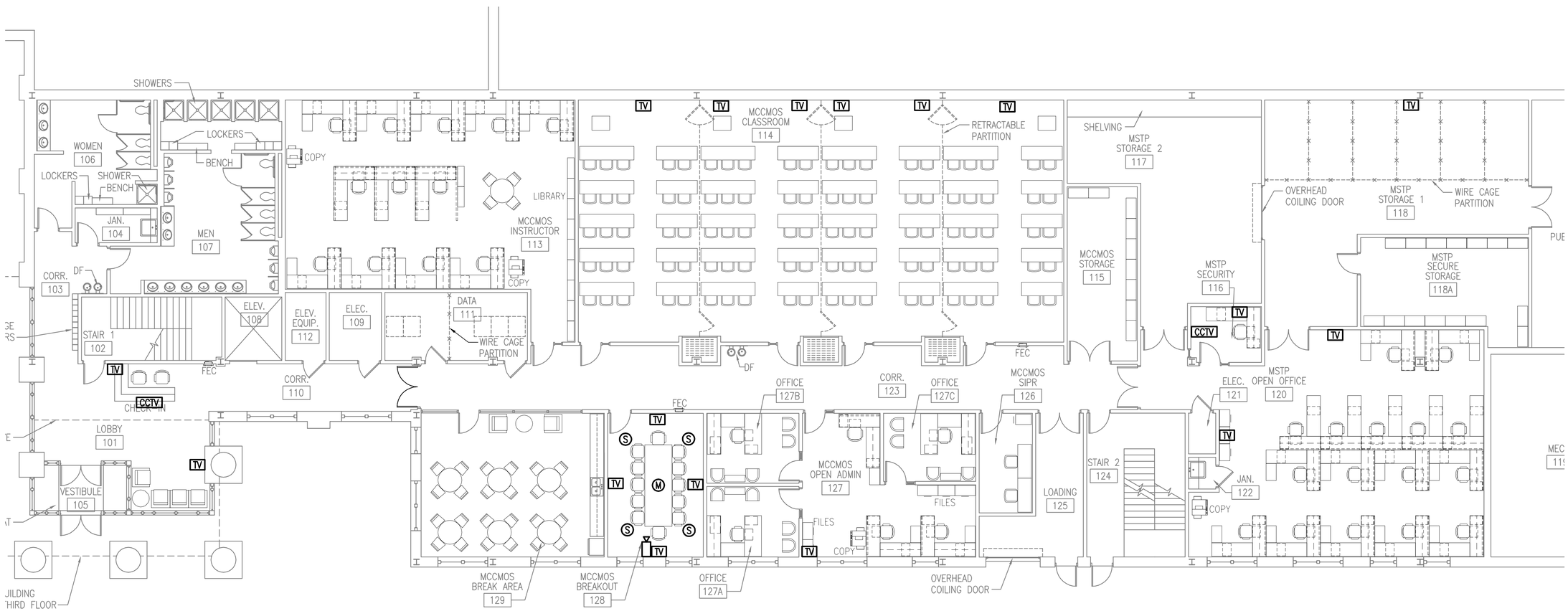
- WIDTH OF PLAQUE: 20 1/8 INCES
- HEIGHT OF PLAQUE: 24 1/4 INCES
- DEPTH: 9/16 INCES
- MARINE CORPS EMBLEM TOP AND CENTERED (EGA) 1 ½ INCES
- STARS: 1 1/2 INCES

Provided as EXAMPLE Only!!!
KELLY HALL
PRIVATE JOHN JOSEPH KELLY
UNITED STATES MARINE CORPS
SEVENTY-EIGHTH COMPANY,
SIXTH MARINE REGIMENT
AWARDED TWO MEDALS OF HONOR FOR ACTION
AGAINST THE ENEMY, BLANC RIDGE, FRANCE,
3 OCTOBER 1918
THIS GALLANT MARINE FOUGHT BRAVELY FOR
HIS COUNTRY
8. 1. 2002

A/V DRAWINGS

LEGEND

TV	DISPLAY OUTLET
AV	AV TOUCH PANEL CONTROL
CCTV	CCTV SYSTEM
S	SPEAKER, (⊣) INDICATES BRACKET, WALL MOUNTED SPEAKER.
M	CEILING MOUNTED MICROPHONE
	VTC CAMERA
DAMC	DIGITAL AUDIO MIXER, CONTROL SYSTEM
GUEST	GUEST A/V CONNECTION



FIRST FLOOR

1/8" = 1'-0"

NORTH

SYM	DESCRIPTION	DATE	APPR

NAVFAC

NOT FOR CONSTRUCTION

PROJECT STATUS

FINAL SUBMITTAL

2-03-2014

PRELIMINARY NOT FOR CONSTRUCTION

SEAL

CLARK NEXSEN

Architecture & Engineering

6160 KEMPSVILLE CIRCLE
SUITE 200A
NORFOLK, VA 23502
757.455.5800 FAX 757.455.5638
WWW.CLARKNEXSEN.COM

A/E INFO

APPROVED

FOR COMMANDER NAVFAC

ACTIVITY

XXXXX

SATISFACTORY TO DATE DD/MM/YY

DES	DRW	CHK
<<PM/DM>>	XXXX	
BRANCH MANAGER	XX	
CHIEF ENG/ARCH	XXX	
<<XX>>	XX	

DEPARTMENT OF THE NAVY
NAVAL FACILITIES ENGINEERING COMMAND
NAVFAC – WASHINGTON, D.C.
QUANTICO MARINE CORPS BASE
MARINE CORPS BASE QUANTICO
QUANTICO, VIRGINIA

P677 TECOM
ACADEMIC INSTRUCTION FACILITY

SCALE: 1/8"=1"-0"

EPROJECT NO.:

CONSTR. CONTR. NO.
N40080-10-D-0303-86

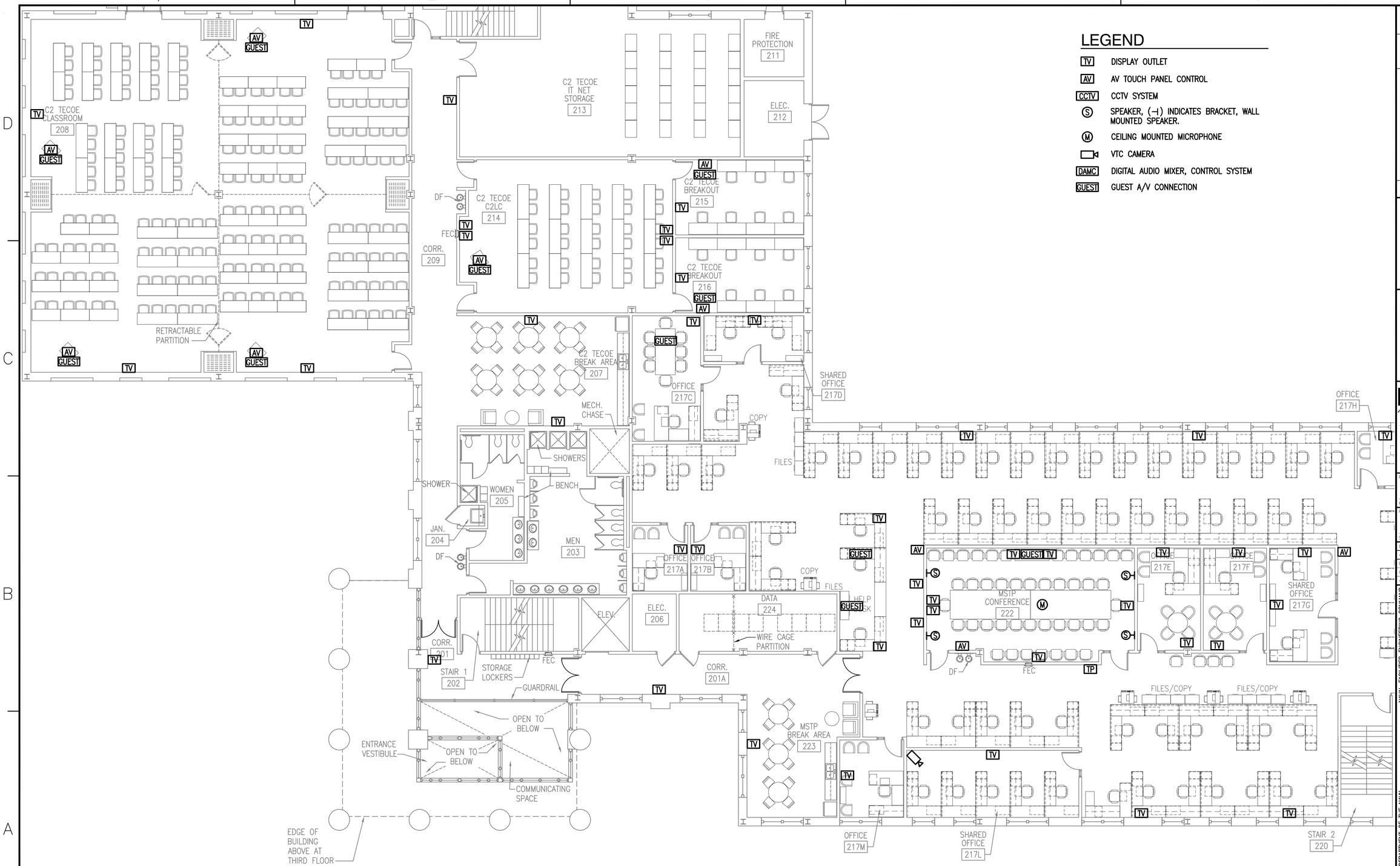
NAVFAC DRAWING NO.

SHEET 1 OF 5

ET101

DRAWFORM REVISION: 10 MARCH 2009

FILE NAME: H:\2012\4618-P677 Academic Instruction Facility TECOM\CAD-Norfolk\Constructs\E\E-FTPlr1.dwg LAYOUT NAME: 1ST FLOOR PLOTTED: Tuesday, January 28, 2014 - 8:08am USER: kroth



LEGEND

TV	DISPLAY OUTLET
AV	AV TOUCH PANEL CONTROL
CCTV	CCTV SYSTEM
S	SPEAKER, (⊣) INDICATES BRACKET, WALL MOUNTED SPEAKER.
M	CEILING MOUNTED MICROPHONE
	VTC CAMERA
DAMC	DIGITAL AUDIO MIXER, CONTROL SYSTEM
GUEST	GUEST A/V CONNECTION

PARTIAL SECOND FLOOR

1/8" = 1'-0"

SYM	DESCRIPTION	DATE	APPR

NAVFAC

NOT FOR CONSTRUCTION

PROJECT STATUS

FINAL SUBMITTAL

2-03-2014

SEAL

PRELIMINARY NOT FOR CONSTRUCTION

CLARK NEXSEN
Architecture & Engineering
6160 KEMPSVILLE CIRCLE
SUITE 200A
NORFOLK, VA 23502
757 455-5800 FAX 757 455-5638
WWW.CLARKNEXSEN.COM
A/E INFO

APPROVED

FOR COMMANDER NAVFAC

ACTIVITY

XXXXX

SATISFACTORY TO DATE DD/MM/YY

DES	DRW	CHK
<<PM/DM>>	XXXX	
BRANCH MANAGER	XX	
CHIEF ENG/ARCH	XXX	
<<XX>>	XX	

DEPARTMENT OF THE NAVY
NAVAL FACILITIES ENGINEERING COMMAND
NAVFAC – WASHINGTON, D.C.
QUANTICO MARINE CORPS BASE
MARINE CORPS BASE QUANTICO
QUANTICO, VIRGINIA

P677 TECOM
ACADEMIC INSTRUCTION FACILITY

SCALE: 1/8"=1"-0"

EPROJECT NO.:

CONSTR. CONTR. NO.
N40080-10-D-0303-86

NAVFAC DRAWING NO.

SHEET 2 OF 5

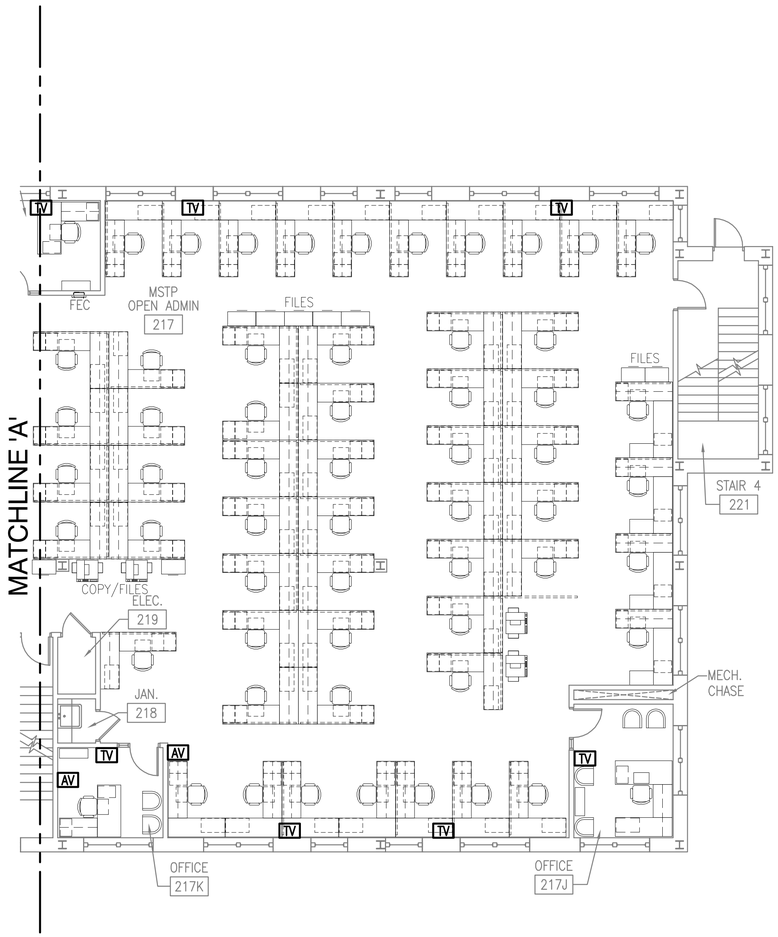
ET102

DRAWFORM REVISION: 10 MARCH 2009

FILE NAME: H:\2012\4618-P677 Academic Instruction Facility TECOM\CAD-Norfolk\Construct3\E1E-1TPlr1.dwg LAYOUT NAME: 2ND FLOOR 'A' PLOTTED: Tuesday, January 28, 2014 - 8:09am USER: keith

LEGEND

TV	DISPLAY OUTLET
AV	AV TOUCH PANEL CONTROL
CCTV	CCTV SYSTEM
S	SPEAKER, (–I) INDICATES BRACKET, WALL MOUNTED SPEAKER.
M	CEILING MOUNTED MICROPHONE
	VTC CAMERA
DAMC	DIGITAL AUDIO MIXER, CONTROL SYSTEM
GUEST	GUEST A/V CONNECTION



PARTIAL SECOND FLOOR

1/8" = 1'-0"

NORTH

SYM	DESCRIPTION	DATE	APPR

NAVFAC

NOT FOR CONSTRUCTION

PROJECT STATUS

FINAL SUBMITTAL

2-03-2014

PRELIMINARY NOT FOR CONSTRUCTION

SEAL

CLARK NEXSEN
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ACTIVITY

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SATISFACTORY TO DATE DD/MM/YY

DES DRW CHK

<<PM/DM>> XXXX

BRANCH MANAGER XX

CHIEF ENG/ARCH XXX

<<XX>> XX

DEPARTMENT OF THE NAVY
NAVAL FACILITIES ENGINEERING COMMAND
QUANTICO MARINE CORPS BASE
NAVFAC – WASHINGTON, D.C.

MARINE CORPS BASE QUANTICO
QUANTICO, VIRGINIA

P677 TECOM
ACADEMIC INSTRUCTION FACILITY

SCALE: 1/8"=1"-0"

EPROJECT NO.:

CONSTR. CONTR. NO.
N40080-10-D-0303-86

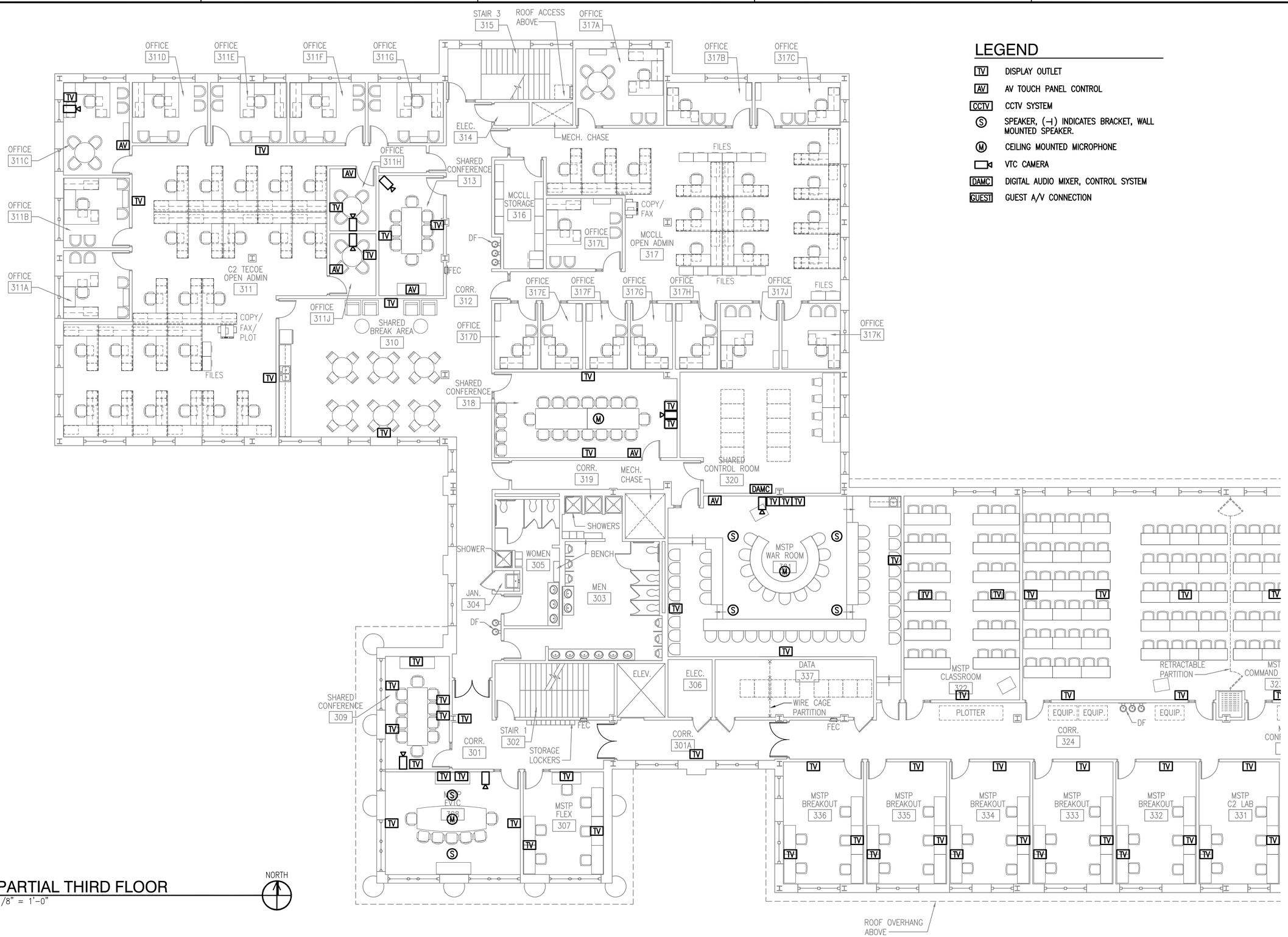
NAVFAC DRAWING NO.

SHEET 3 OF 5

ET103

DRAWFORM REVISION: 10 MARCH 2009

FILE NAME: H:\2012\46118-P677 Academic Instruction Facility TECOM\CAD-Norfolk\Constructs\E\E-1PHr1.dwg LAYOUT NAME: 2ND FLOOR 'B' PLOTTED: Tuesday, January 28, 2014 - 8:09am USER: kroth



LEGEND

TV	DISPLAY OUTLET
AV	AV TOUCH PANEL CONTROL
CCTV	CCTV SYSTEM
S	SPEAKER, (⊣) INDICATES BRACKET, WALL MOUNTED SPEAKER.
M	CEILING MOUNTED MICROPHONE
	VTC CAMERA
DAMC	DIGITAL AUDIO MIXER, CONTROL SYSTEM
GUEST	GUEST A/V CONNECTION

PARTIAL THIRD FLOOR

1/8" = 1'-0"

SYM	DESCRIPTION	DATE	APPR

NAVFAC

NOT FOR CONSTRUCTION

PROJECT STATUS

FINAL SUBMITTAL

2-03-2014

SEAL

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A/E INFO

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FOR COMMANDER NAVFAC

ACTIVITY

XXXXX

SATISFACTORY TO DATE DD/MM/YY

DES	DRW	CHK
<<PM/DM>>	XXXX	
BRANCH MANAGER	XX	
CHIEF ENG/ARCH	XXX	
<<XXX>>	XX	

DEPARTMENT OF THE NAVY
NAVAL FACILITIES ENGINEERING COMMAND
NAVFAC – WASHINGTON, D.C.

MARINE CORPS BASE QUANTICO
QUANTICO, VIRGINIA

P677 TECOM
ACADEMIC INSTRUCTION FACILITY

MATCH LINE SEE DRAWING ET103

SCALE: 1/8"=1'-0"

EPROJECT NO.:

CONSTR. CONTR. NO.
N40080-10-D-0303-86

NAVFAC DRAWING NO.

SHEET 4 OF 5

ET104

DRAWFORM REVISION: 10 MARCH 2009

FILE NAME: H:\2012\46168-P677 Academic Instruction Facility TECOM\CAD-Norfolk\Construct\E\E-TPlr1.dwg LAYOUT NAME: 3RD FLOOR "A" PLOTTED: Tuesday, January 28, 2014 - 8:09am USER: kroth

MCB QUANTICO MAXIMO REQUIREMENTS

MAXIMO DATA & TAGGING
04 2007
PART 1 GENERAL
1.1 DEFINITIONS

MAXIMO DATA: A COLLECTION OF PERTINENT DATA ON SPECIFIC EQUIPMENT PROVIDED UNDER THIS CONTRACT, RECORDED AND SUBMITTED IN SPECIFIC FORMAT (ON THE FORMS ATTACHED IN APPENDIX A), AND REQUIRED FOR THE EXECUTION OF THE MAXIMO COMPUTER PROGRAM ESSENTIAL TO MCB QUANTICO OPERATION & MAINTENANCE PROCEDURES, AND MANAGEMENT THEREOF.

MAXIMO EQUIPMENT TAG: A TAG WITH A VISIBLE UNIQUE PUBLIC WORKS NUMBER (PW00000) AND A READABLE/SCANABLE BAR CODE, AFFIXED TO INDIVIDUAL EQUIPMENT.

MAXIMO EQUIPMENT TAGGING: OBTAINING & AFFIXING A MAXIMO EQUIPMENT TAG TO INDIVIDUAL EQUIPMENT.

MAXIMO EQUIPMENT TAG REPORTING: REPORTING OF EXISTING MAXIMO EQUIPMENT TAG NUMBER(S) TO THE DESIGNATED GOVERNMENT MAXIMO ENGINEERING TECH PRIOR TO REMOVAL AND/OR REPLACEMENT OR REINSTALLATION OF ANY SUCH EQUIPMENT DURING CONSTRUCTION.

1.2 SUBMITTALS

Government approval is required for submittals with a "G" designation; submittals not having a "G" designation are for information only or as otherwise designated. When used, a designation following the "G" designation identifies the office that will review the submittal for the Government. The following shall be submitted in accordance with Section 01330 SUBMITTAL PROCEDURES:

SD-10 Operation and Maintenance Data

MAXIMO DATA; G

Submit MAXIMO DATA in the format identical to the MAXIMO Equipment Data Forms attached as APPENDIX A to this Section, for each piece of provided equipment, and as further explained in Part 2, herein. If equipment abbreviation is added that is not listed on the Title sheet add an accurate description of the equipment.

MAXIMO EQUIPMENT TAG REPORT; G

Submit MAXIMO EQUIPMENT TAG REPORT in the EXCEL format listing all MAXIMO EQUIPMENT TAG NUMBERS of MAXIMO EQUIPMENT to be removed, replaced, relocated or
reinstalled, and as further explained in Part 2, herein.

PART 2 EXECUTION

2.1 MAXIMO DATA COLLECTION

Collect and retrieve the MAXIMO DATA from the data, information, and submittals already required by other Project Specification Sections and subsequent submittals. Project Specification Sections such as 01 77 XX AND 01 78 XX CLOSEOUT PROCEDURES, 01 78 23 OPERATION AND MAINTENANCE DATA; MECHANICAL SECTIONS SUCH AS DESIGNATED 33 XX EXTERIOR HVAC OR GAS DISTRIBUTION SYSTEMS, 23 XX MECHANICAL SECTIONS, 26 29 XX AND 26 32 XX DIESEL GENERATOR & VFD's; PLUMBING SECTIONS 22 XX; ELECTRICAL SECTIONS 26 29 XX MOTORS; FIRE PROTECTION & PREVENTION SECTIONS 21 XX; AND CIVIL SECTIONS 33 XX EXTERIOR WATER & SEWER SYSTEMS, 33 XX STORM DRAINAGE AND SEWER SYSTEMS, AND 32 84 XX UNDERGROUND SPRINKLER & IRRIGATION SPRINKLER SYSTEMS, are all excellent references requiring the necessary equipment data.

2.2 MAXIMO DATA CONFIGURATION
SEPARATE ALL MAXIMO DATA INTO THE FOLLOWING MAIN DISCIPLINES: MECHANICAL, PLUMBING, CIVIL, FIRE PROTECTION & PREVENTION, ELECTRICAL, DISCIPLINES (SEE PARAGRAPH 2.1, MAXIMO DATA COLLECTION)

2.3 APPENDIX A: SUPPLEMENT TO SECTION 01 78 23.01N
NOTE: APPENDIX A IS NOT AVAILABLE IN SPECSINTACT (SI) FORMAT, HOWEVER, APPENDIX A IS AVAILABLE IN PDF FORMAT AS A SEPARATE FILE FOR CONTRACT DOCUMENTATION PURPOSES, AND AS A MICROSOFT EXCEL FILE FOR CONSTRUCTION CONTRACTOR USE. PLEASE REQUEST THE SEPARATE FILE(S) YOU NEED FROM THE CONTRACTING OFFICER OR DESIGNATED GOVERNMENT REPRESENTATIVE.

2.4 MAXIMO EQUIPMENT TAGGING
OBTAIN AND SECURE MAXIMO EQUIPMENT TAGS TO EACH NEW MAXIMO EQUIPMENT. SUBMIT A MAXIMO EQUIPMENT TAG REPORT FOR ALL MAXIMO EQUIPMENT TO BE REMOVED, REPLACED, RELOCATED OR REINSTALLED DURING CONSTRUCTION. THE APPENDIX TO THIS SPECIFICATION SECTION INCLUDES AN EXAMPLE MAXIMO EQUIPMENT TAG DIAGRAM. MAXIMO EQUIPMENT TAGS ARE RELATIVELY SMALL (APPROXIMATELY 3"x4").

2.4.1 OBTAINING MAXIMO EQUIPMENT TAGS
CONTACT THE MCB QUANTICO MAXIMO ENGINEERING TECH LOCATED IN BUILDING 3252 BARNETT AVE @ TELEPHONE NUMBER (703) 784-1484. HAVE ALL PERTINENT MAXIMO EQUIPMENT DATA AVAILABLE BEFORE CALLING FOR NEW MAXIMO TAGS.

2.4.2 AFFIXING MAXIMO EQUIPMENT TAGS
AFFIX THE APPROPRIATE MAXIMO EQUIPMENT TAG TO MAXIMO EQUIPMENT AS SPECIFIED AND AS DIRECTED BY THE CONTRACTING OFFICER OR HIS DESIGNATED GOVERNMENT REPRESENTATIVE.

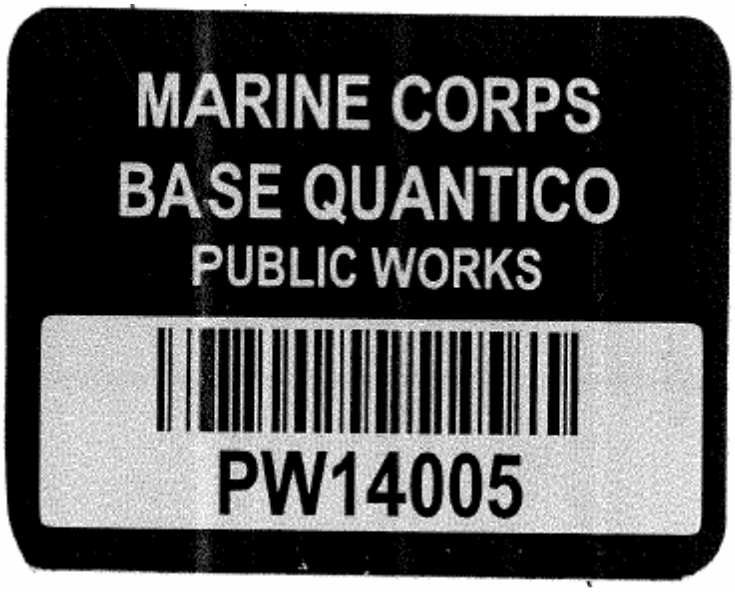
2.4.3 MAXIMO INPUT TO AS-BUILT DRAWING PREPARATION
INCORPORATE ALL NEW AND APPROPRIATE MAXIMO EQUIPMENT TAG NUMBERS INTO THE AS-BUILT DRAWINGS BY PLACING EACH MAXIMO EQUIPMENT TAG NUMBER ON THE CORRESPONDING DRAWING SCHEDULE FOR THE DESIGNATED EQUIPMENT, AND ON THE DRAWING PLAN INDICATING THE EXACT LOCATION INSTALLED. THE MAXIMO EQUIPMENT NUMBERS SHOULD BE RED IN COLOR TO HIGHLIGHT THE NUMBERS. REFER OTHERWISE

TO THE SPECIFICATION SECTION(S) CONCERNING AS-BUILT DRAWING PREPARATION & REQUIREMENTS.

-- End of Section --

Quantico Marine Corps Base Equipment Tag

Sample



EQUIPMENT LIST

PARENT		DESCRIPTION
ACC		AIR COOLED CONDENSING UNIT (ACC)
ACP		AIR COOLED PACKAGE UNIT (ACP)
AHU		AIR HANDLING UNIT (AHU)
ASU		A/C SPLIT UNIT (ASU)
ATS		AUTOMATIC TRANFER SWITCH (ATS)
BLR		STEAM BOILER, OVER 1000 MBH (BLR-1)
CHR		CHILLER (CHR)
CIR		CIRULATING PUMP (CIR)
COM		AIR COMPRESSOR (COM)
COMP		COMPRESSOR (COMP)
CTW		COOLING TOWER (CTW)
DCV		BACKFLOW PREVENTER (DCV)
DHUM		DEHUMIDIFIER
DRY		DRYER
EXF		EXHAUST FAN (EXF)
FCU		FAN COIL UNIT (FCU)
FS		CONDENSATE RETURN SYSTEM (FS)
FUR		FURNACE (FUR)
GEN		GENERATOR (GEN)
HTP_EXT		HEAT PUMP EXTERIOR (HTP)
HTP_INT		HEAT PUMP INTERIOR (HTP)
HUM		HUMIDIFIER
RPZ		BACKFLOW PREVENTER (RPZ)
UTH		UNIT HEATERS (UTH)
VAV		VARIABLE AIR VOLUME (VAV)
WCP		WATER COOLED PACKAGE UNIT

If a new tab is added please give an accurate description

COC PAD ELECTRICAL PLUG INFORMATION

- Connect shore power cable to shore power input jack
- Connect pigtail end to 60-amp, 3-phase, 120/208-volt service

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SECURITY PLANS

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FIRST FLOOR SECURITY PLAN

SCALE: 3/32"=1'-0"

NORTH

LEGEND

- SAFE
- ACU TOUCHPAD
- SWIPE ACCESS
- WORKSTATION
- X09 LOCK
- RAISED FLOORS
- VON DUPRIN LOCKING DEVICE

ROOM SCHEDULE

ROOM NUMBER	ROOM DESCRIPTION		
FIRST FLOOR			
101	LOBBY	118	MSTP, STORAGE 1
102	STAIR 1	118A	MSTP, SECURE STORAGE
103	CORRIDOR	118B	MSTP, PUBS & ADMIN STORAGE
104	JANITOR	119	MECHANICAL
105	VESTIBULE	120	MSTP, OPEN OFFICE
106	WOMEN'S TOILET/SHOWER	121	ELECTRICAL
107	MEN'S TOILET/SHOWER	122	JANITOR
108	ELEVATOR	123	CORRIDOR
109	ELECTRICAL ROOM	124	STAIR 2
110	CORRIDOR	125	LOADING AREA
111	DATA	126	MCCMOS, SIPR
112	ELEVATOR EQUIPMENT	127A	MCCMOS, OFFICE
113	MCCMOS, INSTRUCTOR	127B	MCCMOS, OFFICE
114	MCCMOS, CLASSROOM	127C	MCCMOS, OFFICE
115	MCCMOS, STORAGE	128	MCCMOS, BREAKOUT
116	MSTP, SECURITY	129	MCCMOS, BREAK AREA
117	MSTP, STORAGE 2		

TECOM P-677 (IDS)

(See ESRD503005 Security Systems for additional information.)

Room #	Equipment	Remarks
First Deck		
120	1 Keypad, 2 PIRs, 2 BMSs	
126	1 Keypad, 1 PIR, 1 BMS	
Second Deck		
208	1 Keypad, 2 PIRs, 2 BMSs	
213	1 Keypad, 1 PIRs, 1 BMSs	
214	1 Keypad, 1 PIR, 2 BMSs	
217	1 Keypad, 3 PIRs, 4 BMSs	
Third Deck		
311	1 Keypad, 2 PIRs, 2 BMSs	
317	1 Keypad, 2 PIRs, 2 BMSs	
324	1 Keypad, 2 PIRSs, 2 BMSs	
321	1 PIR, 1 BMS	
325	2 PIR, 3 BMSs	

SYMBOLS LEGEND

SECURITY BOUNDARY TO BE DESIGNED AS A SECURE ROOM (OPEN STORAGE AREA) IN ACCORDANCE WITH SECNAV 5510.36 DEPARTMENT OF NAVY INFORMATION SECURITY PROGRAM

GRAPHIC SCALE

3/32" = 1'-0" 0 5' 10' 20' 40'

SYM	DESCRIPTION	DATE	APPR

NAVFAC

NOT FOR CONSTRUCTION

PROJECT STATUS

FINAL SUBMITTAL

2-03-2014

PRELIMINARY NOT FOR CONSTRUCTION

CLARK NEXSEN
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A/E INFO

APPROVED

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ACTIVITY XXXXX

SATISFACTORY TO DATE DD/MM/YY

DES JPG DRW KAF CHK RAM

<<PM/DM>> XXXX

BRANCH MANAGER XX

CHIEF ENG/ARCH XXX

<<XXX>> XX

DEPARTMENT OF THE NAVY NAVAL FACILITIES ENGINEERING COMMAND NAVFAC – WASHINGTON, D.C.

QUANTICO MARINE CORPS BASE QUANTICO, VIRGINIA

MARINE CORPS BASE QUANTICO

P677 TECOM ACADEMIC INSTRUCTION FACILITY

FIRST FLOOR SECURITY PLAN

SCALE: 3/32"=1'-0"

EPROJECT NO.

CONSTR. CONTR. NO. N40080-10-D-0303-86

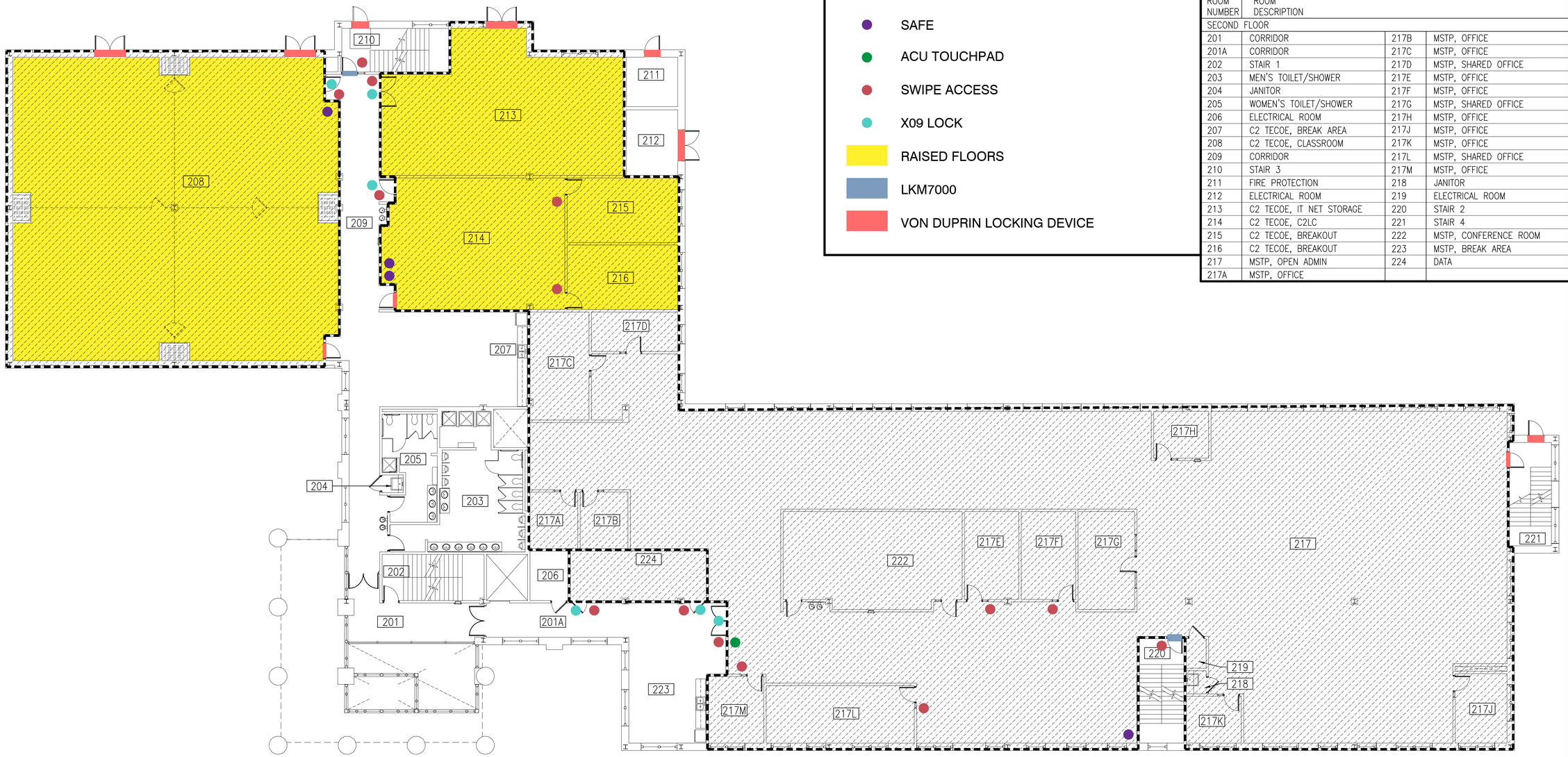
NAVFAC DRAWING NO. –

SHEET 1 OF 3

AE701

DRAWFORM REVISION: 10 MARCH 2009

FILE NAME: H:\2012\4618-P677 Academic Instruction Facility TECOM\CAD-Norfolk\RFP Appendices\AE701.dwg LAYOUT NAME: AE701 FIRST FLOOR SECURITY PLAN PLOTTED: Tuesday, January 28, 2014 - 10:45am USER: ppglagher



LEGEND

- SAFE
- ACU TOUCHPAD
- SWIPE ACCESS
- X09 LOCK
- RAISED FLOORS
- LKM7000
- VON DUPRIN LOCKING DEVICE

ROOM SCHEDULE

ROOM NUMBER	ROOM DESCRIPTION		
SECOND FLOOR			
201	CORRIDOR	217B	MSTP, OFFICE
201A	CORRIDOR	217C	MSTP, OFFICE
202	STAIR 1	217D	MSTP, SHARED OFFICE
203	MEN'S TOILET/SHOWER	217E	MSTP, OFFICE
204	JANITOR	217F	MSTP, OFFICE
205	WOMEN'S TOILET/SHOWER	217G	MSTP, SHARED OFFICE
206	ELECTRICAL ROOM	217H	MSTP, OFFICE
207	C2 TECOE, BREAK AREA	217J	MSTP, OFFICE
208	C2 TECOE, CLASSROOM	217K	MSTP, OFFICE
209	CORRIDOR	217L	MSTP, SHARED OFFICE
210	STAIR 3	217M	MSTP, OFFICE
211	FIRE PROTECTION	218	JANITOR
212	ELECTRICAL ROOM	219	ELECTRICAL ROOM
213	C2 TECOE, IT NET STORAGE	220	STAIR 2
214	C2 TECOE, C2LC	221	STAIR 4
215	C2 TECOE, BREAKOUT	222	MSTP, CONFERENCE ROOM
216	C2 TECOE, BREAKOUT	223	MSTP, BREAK AREA
217	MSTP, OPEN ADMIN	224	DATA
217A	MSTP, OFFICE		

SECOND FLOOR SECURITY PLAN

SCALE: 3/32"=1'-0"

NORTH

SYMBOLS LEGEND

SECURITY BOUNDARY TO BE DESIGNED AS A SECURE ROOM (OPEN STORAGE AREA) IN ACCORDANCE WITH SECNAV 5510.36 DEPARTMENT OF NAVY INFORMATION SECURITY PROGRAM

GRAPHIC SCALE

3/32" = 1'-0" 0 5' 10' 20' 40'

SYM	DESCRIPTION	DATE	APPR

NAVFAC

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PROJECT STATUS

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ACTIVITY

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SATISFACTORY TO DATE DD/MM/YY

DES JPG DRW KAF CHK RAM

<<PM/DM>> XXXX

BRANCH MANAGER XX

CHIEF ENG/ARCH XXX

<<XX>> XX

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NAVAL FACILITIES ENGINEERING COMMAND
NAVFAC – WASHINGTON, D.C.
QUANTICO MARINE CORPS BASE
MARINE CORPS BASE QUANTICO
QUANTICO, VIRGINIA

P677 TECOM
ACADEMIC INSTRUCTION FACILITY

SECOND FLOOR SECURITY PLAN

SCALE: 3/32"=1'-0"

EPROJECT NO.:

CONSTR. CONTR. NO.
N40080-10-D-0303-86

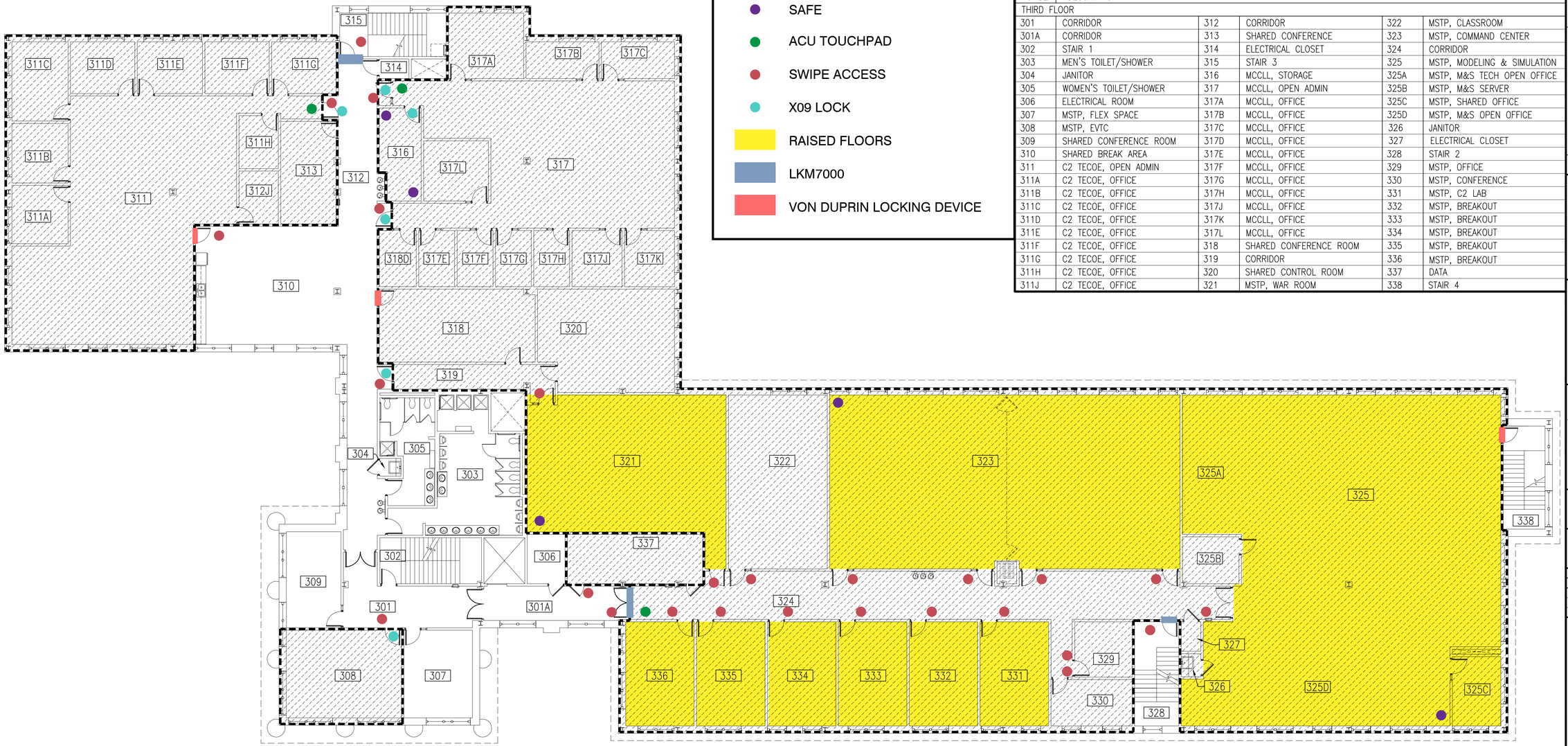
NAVFAC DRAWING NO.
–

SHEET 2 OF 3

AE702

DRAWFORM REVISION: 10 MARCH 2009

FILE NAME: H:\2012\4618-P677 Academic Instruction Facility TECOM\CAD-Norfolk\RFP Appendices\AE702.dwg LAYOUT NAME: AE702 SECOND FLOOR SECURITY PLAN PLOTTED: Monday, January 27, 2014 – 11:52am USER: ppallagher



LEGEND

- SAFE
- ACU TOUCHPAD
- SWIPE ACCESS
- X09 LOCK
- RAISED FLOORS
- LKM7000
- VON DUPRIN LOCKING DEVICE

ROOM SCHEDULE

ROOM NUMBER	ROOM DESCRIPTION				
THIRD FLOOR					
301	CORRIDOR	312	CORRIDOR	322	MSTP, CLASSROOM
301A	CORRIDOR	313	SHARED CONFERENCE	323	MSTP, COMMAND CENTER
302	STAIR 1	314	ELECTRICAL CLOSET	324	CORRIDOR
303	MEN'S TOILET/SHOWER	315	STAIR 3	325	MSTP, MODELING & SIMULATION
304	JANITOR	316	MCCLL, STORAGE	325A	MSTP, M&S TECH OPEN OFFICE
305	WOMEN'S TOILET/SHOWER	317	MCCLL, OPEN ADMIN	325B	MSTP, M&S SERVER
306	ELECTRICAL ROOM	317A	MCCLL, OFFICE	325C	MSTP, SHARED OFFICE
307	MSTP, FLEX SPACE	317B	MCCLL, OFFICE	325D	MSTP, M&S OPEN OFFICE
308	MSTP, EVTC	317C	MCCLL, OFFICE	326	JANITOR
309	SHARED CONFERENCE ROOM	317D	MCCLL, OFFICE	327	ELECTRICAL CLOSET
310	SHARED BREAK AREA	317E	MCCLL, OFFICE	328	STAIR 2
311	C2 TECOE, OPEN ADMIN	317F	MCCLL, OFFICE	329	MSTP, OFFICE
311A	C2 TECOE, OFFICE	317G	MCCLL, OFFICE	330	MSTP, CONFERENCE
311B	C2 TECOE, OFFICE	317H	MCCLL, OFFICE	331	MSTP, C2 LAB
311C	C2 TECOE, OFFICE	317J	MCCLL, OFFICE	332	MSTP, BREAKOUT
311D	C2 TECOE, OFFICE	317K	MCCLL, OFFICE	333	MSTP, BREAKOUT
311E	C2 TECOE, OFFICE	317L	MCCLL, OFFICE	334	MSTP, BREAKOUT
311F	C2 TECOE, OFFICE	318	SHARED CONFERENCE ROOM	335	MSTP, BREAKOUT
311G	C2 TECOE, OFFICE	319	CORRIDOR	336	MSTP, BREAKOUT
311H	C2 TECOE, OFFICE	320	SHARED CONTROL ROOM	337	DATA
311J	C2 TECOE, OFFICE	321	MSTP, WAR ROOM	338	STAIR 4

THIRD FLOOR SECURITY PLAN

SCALE: 3/32"=1'-0"

NORTH

SYMBOLS LEGEND

SECURITY BOUNDARY TO BE DESIGNED AS A SECURE ROOM (OPEN STORAGE AREA) IN ACCORDANCE WITH SECNAV 5510.36 DEPARTMENT OF NAVY INFORMATION SECURITY PROGRAM

GRAPHIC SCALE

3/32" = 1'-0" 0 5' 10' 20' 40'

SYM	DESCRIPTION	DATE	APPR

NAVFAC

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PROJECT STATUS

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XXXXX

SATISFACTORY TO DATE DD/MM/YY

DES JPG DRW KAF CHK RAM

<<PM/DM>> XXXX

BRANCH MANAGER XX

CHIEF ENG/ARCH XXX

<<DDD>> XX

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NAVAL FACILITIES ENGINEERING COMMAND
NAVFAC – WASHINGTON, D.C.
QUANTICO MARINE CORPS BASE
MARINE CORPS BASE QUANTICO
QUANTICO, VIRGINIA

P677 TECOM
ACADEMIC INSTRUCTION FACILITY

THIRD FLOOR SECURITY PLAN

SCALE: 3/32"=1'-0"

EPROJECT NO.:

CONSTR. CONTR. NO. N40080-10-D-0303-86

NAVFAC DRAWING NO. –

SHEET 3 OF 3

AE703

DRAWFORM REVISION: 10 MARCH 2009

FILE NAME: H:\2012\4618-P677 Academic Instruction Facility TECOM\CAD-Norfolk\RFP Appendicies\AE703.dwg LAYOUT NAME: AE703 THIRD FLOOR SECURITY PLAN PLOTTED: Monday, January 27, 2014 – 11:52am USER: pgallagher

MSTPD P677 Security Equipment Requirements		
Room Number	**Lock Type**	**Other Security Equipment**
Note: It is a requirement for motion dection monitoring devices to be installed for all Secuirty spaces (greyed out on the drawings) on all three floors of this facility.		
First/Groud Floor		
105		Main swipe access for building / activated release for interior door - telephone
111	X-09 on each of the entry doors	swipe access each door - Data closet is separate Base G6 & MSTP access
116		swipe access
117		
118		swipe access
118A	X-09 (CMCC & EKMS Vault)	swipe access, 3 x 5 drawer @ 505 lbs & 1 x 1 drawer safe @ 1040 lbs = 2555 lbs
118B	Von Duprin locking device exterior exit	swipe access, Von Duprin locking device with alarm activation
120	X-09	swipe access, ACU/IDS touchpad on interior
124	LKM7000 on stairway door & Von Duprin locking device w/alarm on exit door	swipe access in stairway to interior, LKM7000 on interior door to stairway, and Von Duprin locking device with alarm activation on exterior door
125	Von Duprin locking device for exit door	Von Duprin locking device with alarm activation on exterior door
126	X-09 (CMCC Vault)	swipe access, ACU/IDS touchpad on interior, 1 x 5 drawer safe @ 505 lbs.
Second Floor		
208	X-09 on interior main entry, Von Duprin locking device for interior exit door and Von Duprin locking device w/alarm for exterior doors	swipe access, ACU/IDS touchpad on interior for the following rooms: 208, 213, 214, 215, 216, Von Duprin locking device with alarm activation on exterior door, raised floor
208	Von Duprin locking device for exit	Von Duprin locking device with alarm activation on exterior door
210	LKM7000 on stairway door, Von Duprin locking device w/alarm on exterior door	swipe access on exterior door to stairway, Von Duprin locking device with alarm activation on exterior door
211	Von Duprin locking device for exit door	
212	Von Duprin locking device for exit door	
213	X-09 on main entry	swipe access, interior only/alarm activation on exterior door, Von Duprin locking device with alarm activation on exterior door, raised floor
214	X-09 on main entryway, Von Duprin locking device for interior exit door	swipe access, 1 x 1 drawer (115 lbs) and 1 x 2 drawer safe (275 lbs) = 390 lbs, raised floor,
215		swipe access, raised floor
216		swipe access, raised floor
217	X-09 on main entrance, Von Duprin locking device Exit Device on exit door to stairwell 221	swipe access, ACU/IDS touchpad on interior for the following rooms: 217, 217a, 217b, 217c, 217d, 217e, 217 f, 217g, 217h, 217j, 217k, 217l, 217m, 222, 1 x 5 drawer safe @ 505 lbs, Von Duprin locking device with alarm activation on exterior door
217A		
217B		
217C		
217D		
217E		swipe access
217F		swipe access
217G		
217H		
217J		
217K		
217L		swipe access
217M		swipe access
220	LKM7000 on stairway door	swipe access in stairway to interior, LKM7000 on interior door to stairway
221	Von Duprin locking device for exit doors	Von Duprin locking device with alarm activation on exterior door
222		swipe access
224	X-09 on each of the entry doors	swipe access on each door - Data closet is separate Base G6 & MSTP access
Third Floor		
308	X-09	swipe access
311	X-09 on main entrance, Von Duprin locking device Exit Device on exit door to 310	swipe access, ACU/IDS touchpad on interior for the following rooms: 311, 311A, 311B, 311C, 311D, 311E, 311F, 311G, 311H, 312J, 313, Von Duprin locking device on exit door to 310

311A		
311B		
311C		
311D		
311E		
311F		
311G		
311H		
312J		
313		
315	LKM7000 on stairway door	swipe access on exterior door to stairway
316	X-09	swipe access, 2 x five drawer safe @ 505 lbs each - 1,010
317	x09 on both entry doors	swipe access on both entries, ACU/IDS touchpad on interior for the following room: 316, 317, 317a, 317b, 317c, 317d, 317e, 317f, 317g, 317h, 317j, 317k, 317l
317A		swipe access
317B		
317C		
317D		
317E		
317F		
317G		
317H		
317J		
317K		
317L		
318	X-09 on main entry	swipe access on main entry doors, Von Duprin locking device for exit door
319	X-09	swipe access
320	X-09	swipe access
321		swipe access on both entry doors, raised floor, 1 x 2 drawer safe (275 lbs)
322		swipe access
323		swipe access on all 4 entry doors, raised floor, 1 x 2 drawer safe (275 lbs)
324	LKM7000 on main entry door	swipe access, ACU/IDS touchpad on interior for the following rooms: 308, 318, 319, 320, 321, 322, 323, 324, 325, 325a, 325b, 325c, 325d, 326, 327, 329, 330, 331, 332, 333, 334, 335, 336, 337
325	Von Duprin locking device on exit door	swipe access, raised floor, 1 x 4 drawer safe (400 lbs), Von Duprin locking device with alarm activation on exterior door
325A		
325B		
325C		
325D		
328	LKM7000 on stairway door	swipe access in stairway to interior
329		swipe access
330		swipe access
331		swipe access, raised floor
332		swipe access, raised floor
333		swipe access, raised floor
334		swipe access, raised floor
335		swipe access, raised floor
336		swipe access, raised floor
337	X-09 on each of the entry doors	swipe access on each door - Data closet is separate Base G6 & MSTP access
338	Von Duprin locking device for exit door	Von Duprin locking device with alarm activation on exterior door

TECOM P-677 (AACS)

Room #	Equipment	Remarks
First Deck		
105	2 Card Reader	Entry
101	1 Workstation	
111B	2 Card Reader	Comm Closet
126	1 Card Reader	
120	1 Card Reader	
116	1 Card Reader	
118	1 Card Reader	
118B	1 Card Reader	
118A	1 Card Reader	
124	1 Card Reader	Stairwell
Second Deck		
208	1 Card Reader	
210	1 Card Reader	Stairwell
213	1 Card Reader	
214	1 Card Reader	
215	1 Card Reader	
216	1 Card Reader	
217	1 Card Reader	
217E	1 Card Reader	
217F	1 Card Reader	
217M	1 Card Reader	
217L	1 Card Reader	
220	1 Card Reader	Stairwell
224B	2 Card Readers	Comm Closet
Third Deck		
308	1 Card Reader	
311	2 Card Readers	
315	1 Card Reader	Stairwell
317	2 Card Readers	
319	1 Card Reader	
321	1 Card Reader	
323	2 Card Readers	
324	1 Card Reader	
325	1 Card Reader	
328	1 Card Reader	Stairwell
329	1 Card Reader	
330	1 Card Reader	
331	1 Card Reader	
332	1 Card Reader	
333	1 Card Reader	
334	1 Card Reader	
335	1 Card Reader	
336	1 Card Reader	
337B	1 Card Reader	Comm Closet

TECOM P-677 (IDS)		
First Deck		
Room #	*Equipment*	*Remarks*
120	1 Keypad, 2 PIRs, 2 BMSs	
126	1 Keypad, 1 PIR, 1 BMS	
Second Deck		
208	1 Keypad, 2 PIRs, 2 BMSs	
213	1 Keypad, 1 PIRs, 1 BMSs	
214	1 Keypad, 1 PIR, 2 BMSs	
217	1 Keypad, 3 PIRs, 4 BMSs	
Third Deck		
311	1 Keypad, 2 PIRs, 2 BMSs	
317	1 Keypad, 2 PIRs, 2 BMSs	
324	1 Keypad, 2 PIRSs, 2 BMSs	
321	1 PIR, 1 BMS	
325	2 PIR, 3 BMSs	

Specifications

SMART Board® 8070i-G4 interactive flat panel

Model 8070i-G4-SMP

Overview

The SMART Board® 8070i-G4 interactive flat panel features SMART's proprietary DVIT® (Digital Vision Touch) technology on an LCD screen with e-LED backlight which enables you to select, write and erase on the interactive surface. By touching the surface, you can do everything on the interactive flat panel that you can do at your computer, and you can use an array of gestures within applications.

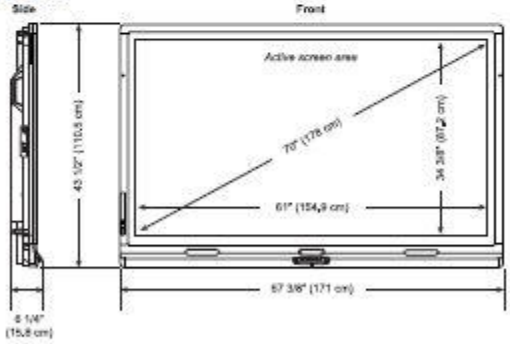
You can also write or draw over any application in digital ink using one of the supplied pens or your finger, and then erase the digital ink using the supplied eraser or your palm. Two users can write or draw at the same time.

The interactive flat panel has two presence detection sensors on its frame that can detect people up to 16' (5 m) away. When the sensors detect people in the room, the interactive flat panel turns on. When the sensors no longer detect people in the room, the interactive flat panel turns off.

See smarttech.com for more information on this product.

Dimensions and weights*

Dimensions



Weight

205 lb. (93 kg)

Shipping dimensions (including pallet)

77 1/8" W × 56 1/4" H × 15 3/8" D
(196 cm × 143 cm × 39 cm)

Shipping weight

251 lb. (114 kg)

*All dimensions ± 1/8" (0.3 cm). All weights ± 2 lb. (0.9 kg).

8.50 x 11.00 in

Hardware

Display	
Aspect ratio	16 × 9
Optimal resolution	1920 × 1080 at 60 Hz
Horizontal frequency	54–69.75 kHz (analog and digital)
Vertical frequency	48–62 Hz
Contrast ratio (typical)	4000:1
Brightness (typical)	180–250 cd/m²
Pixel pitch	0.807 mm
Audio	Two 10 W integrated front firing speakers
Noise level	35 dBA
Included cables and hardware	8' (2.4 m) country-specific power cable 4' 3" (1.3 m) USB cable 16' 5" (5 m) USB extender 20' 8" (6.3 m) HDMI cable Infrared remote control (batteries included) Pens and eraser Spare nibs for pens I/O extension module for external PCs (SBID-G4-XTM) CAT 5 USB extender SMART GoWire™ auto-launch cable with SMART Meeting Pro™ PE (Personal Edition) software (see smarttech.com/kb/151506) M12 eye bolts
Mounting holes	For a standard VESA® 800 mm × 400 mm mounting plate 16 1/4" (41.2 cm) from the bottom of the interactive flat panel
Mounting bracket depth	Minimum depth of 1 5/8" (4.2 cm) for all components on the back of the interactive flat panel to clear the wall

Connectors

Top panel	19V DC Molex® Micro-Fit 2-pin connector Stereo 3.5 mm out USB 3.0 Type-A
Left panel	19V DC Molex Micro-Fit 2-pin connector Stereo 3.5 mm out USB 2.0 Type-A
Right panel	19V DC Molex Micro-Fit 2-pin connector Stereo 3.5 mm out

Back	AC power inlet AC power pass-through USB 2.0 Type-B RS-232 in RS-232 out/pass-through DisplayPort in HDMI in (×2) DVI-D in	VGA in (×2) VGA out Component video in (Y, Pb, Pr) Composite video in S-video in Stereo 3.5 mm in Dual RCA audio in (×2) Dual RCA audio out Speaker wire connector, 8 Ω of resistance
I/O extension module	HDMI in USB 2.0 Type-B	

Installation requirements

Installation	See the *SMART Board 8000i-G4 interactive flat panel setup and maintenance guide* (smarttech.com/kb/170446)
Computer	See smarttech.com/SMARTMeetingProReleaseNotes

Storage and operating requirements

Power requirements	8.9A at 100V to 4.5A at 240V AC, 50 Hz to 60 Hz
Power consumption at 77°F (25°C)	
Normal Standby mode	40 W
Eco Standby mode	< 0.5 W
Normal operating	310 W
Operating temperature	41°F to 95°F (5°C to 35°C)
Storage temperature	-4°F to 140°F (-20°C to 60°C)
Humidity	5% to 80% relative humidity, non-condensing

Certification and compliance

Regulatory certification	UL (U.S. and Canada), FCC, IC, C-Tick, NOM, CU, CB, VCCI, KC, PSB and BIS
Environmental compliance	
China	EIP
European Union	REACH, RoHS, WEEE, Battery, Packaging and ErP Standby
U.S.	Packaging and Conflict Minerals

8.50 x 11.00 in

Purchasing information

Order numbers

SBID 8070i-G4-SMP	SMART Board 8070i-G4 interactive flat panel, including a SMART Meeting Pro software license key and a SMART GoWire cable with SMART Meeting Pro PE software
Optional accessories	See smarttech.com/businessaccessories
Warranty	Two-year limited equipment warranty

smarttech.com/support
smarttech.com/contactsupport

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DRAWINGS