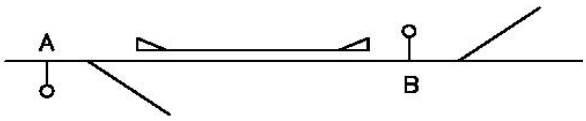
BACK–TO–POINT TURNOUTS OF OPPOSITE HAND
(SMALLER FROG ANGLE LEADING)

TURNOUT & HAND		11'–0" END APPROACH		5'–6" END APPROACH	
A	B	MINIMUM	DESIRED	MINIMUM	DESIRED
6R	6L	N.A.	N.A.	81.71'	82.00'
6L	6R	"	"	"	"
8R	6L	"	"	104.21'	109.13'
8L	6R	"	"	"	"
8R	8L	104.08'	109.00'	104.08'	109.00'
8L	8R	"	"	"	"
10R	6L	N.A.	N.A.	117.04'	127.56'
10L	6R	"	"	"	"
10R	8L	116.92'	127.44'	116.92'	127.44'
10L	8R	"	"	"	"
10R	10L	"	"	"	"
10L	10R	"	"	"	"
15R	6L	N.A.	N.A.	154.35'	173.79'
15L	6R	"	"	"	"
15R	8L	154.23'	173.67'	154.23'	173.67'
15L	8R	"	"	"	"
15R	10L	"	"	"	"
15L	10R	"	"	"	"
15R	15L	"	183.13'	"	183.13'
15L	15R	"	"	"	"



NOTE: CONTACT RAIL IS REQUIRED IN ALL THE ABOVE CASES.

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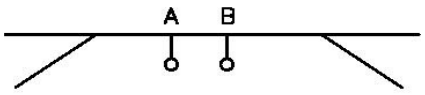
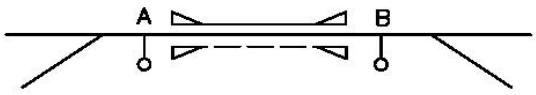
REQUIRED DISTANCES
BETWEEN SWITCH POINTS–IV

FIGURE 11.25

POINT–TO–POINT TURNOUTS OF OPPOSITE HAND

TURNOUT		REQ'D DIST. W/O SPACER RAIL OR CONTACT RAIL	MINIMUM DISTANCES WITH SPACER RAIL AND CONTACT RAIL	
A	B		11'–0" APPROACH	5'–6" APPROACH
4Y	4Y	N.A.	N.A.	76.0'
4Y	6R	"	"	"
4Y	8R	"	"	"
4Y	10R	"	"	83.0'
4Y	15R	"	"	111.0'
6^{R}_{L}	6^{L}_{R}	11.53'	"	61.0'
6^{R}_{L}	8^{L}_{R}	11.41'	"	71.0'
6^{R}_{L}	10^{L}_{R}	"	"	62.0'
6^{R}_{L}	15^{L}_{R}	N.A.	"	"
8^{R}_{L}	8^{L}_{R}	11.28'	95.0'	81.0'
8^{R}_{L}	10^{L}_{R}	"	86.0'	72.0'
8^{R}_{L}	15^{L}_{R}	N.A.	"	"
10^{R}_{L}	10^{L}_{R}	"	77.0'	63.0'
10^{R}_{L}	15^{L}_{R}	"	"	"
15^{R}_{L}	15^{L}_{R}	"	"	"





NOTE: SPACER RAIL IS A 19' LENGTH OF RAIL PLACED BETWEEN THE STOCK RAILS OF THE POINT–TO–POINT TURNOUTS.

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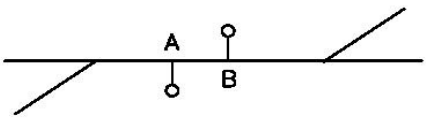
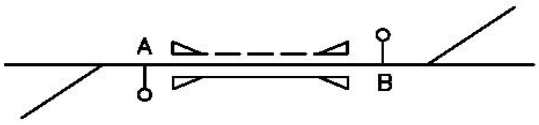
REQUIRED DISTANCES BETWEEN SWITCH POINTS–V

FIGURE 11.26

POINT–TO–POINT TURNOUTS OF SAME HAND

TURNOUT		REQ'D DIST. W/O SPACER RAIL OR CONTACT RAIL	MINIMUM DISTANCES WITH SPACER RAIL AND CONTACT RAIL	
A	B		11'–0" APPROACH	5'–6" APPROACH
4Y	4Y	N.A.	N.A.	76.0'
4Y	6L	"	"	62.0'
4Y	8L	"	"	72.0'
4Y	10L	"	"	63.0'
4Y	15L	"	"	"
$6\frac{L}{R}$	$6\frac{L}{R}$	13.53'	"	61.0'
$6\frac{L}{R}$	$8\frac{L}{R}$	13.41'	"	71.0'
$6\frac{L}{R}$	$10\frac{L}{R}$	"	"	62.0'
$6\frac{L}{R}$	$15\frac{L}{R}$	N.A.	"	"
$8\frac{L}{R}$	$8\frac{L}{R}$	13.28'	95.0'	81.0'
$8\frac{L}{R}$	$10\frac{L}{R}$	"	86.0'	72.0'
$8\frac{L}{R}$	$15\frac{L}{R}$	N.A.	"	"
$10\frac{L}{R}$	$10\frac{L}{R}$	"	77.0'	63.0'
$10\frac{L}{R}$	$15\frac{L}{R}$	"	"	"
$15\frac{L}{R}$	$15\frac{L}{R}$	"	"	"





NOTE: SPACER RAIL IS A 19' LENGTH OF RAIL PLACED BETWEEN THE STOCK RAILS OF THE POINT–TO–POINT TURNOUTS.

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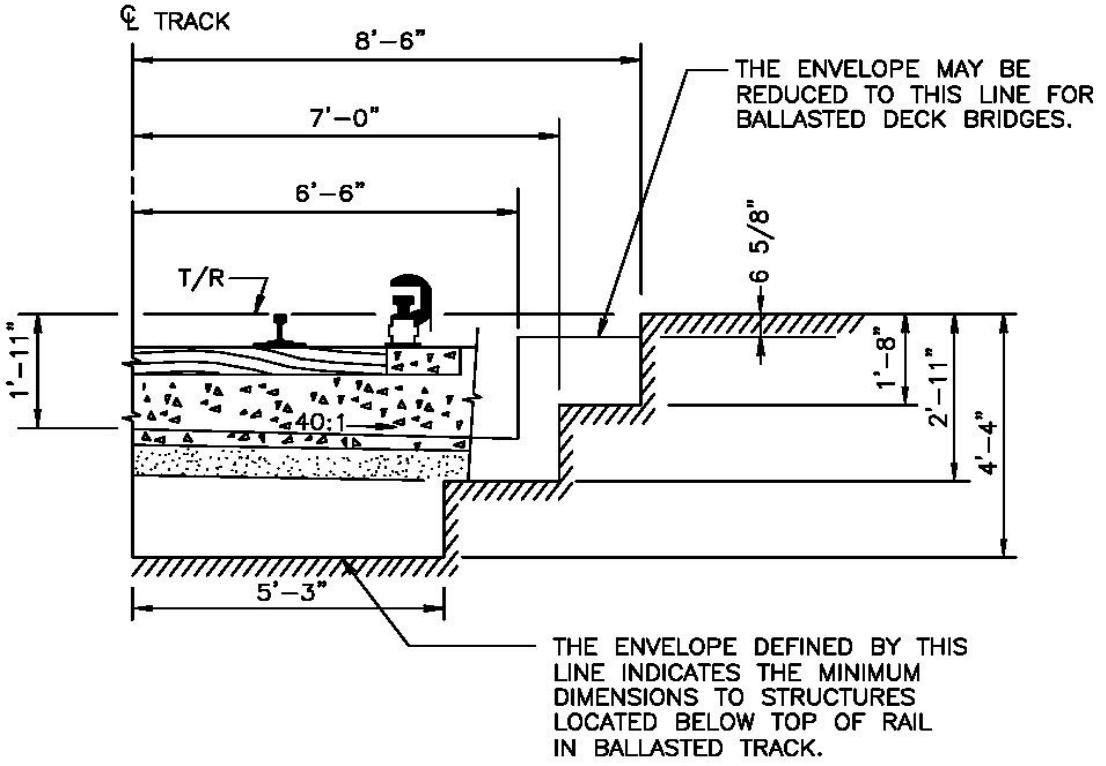
REQUIRED DISTANCES BETWEEN SWITCH POINTS–VI

FIGURE 11.27



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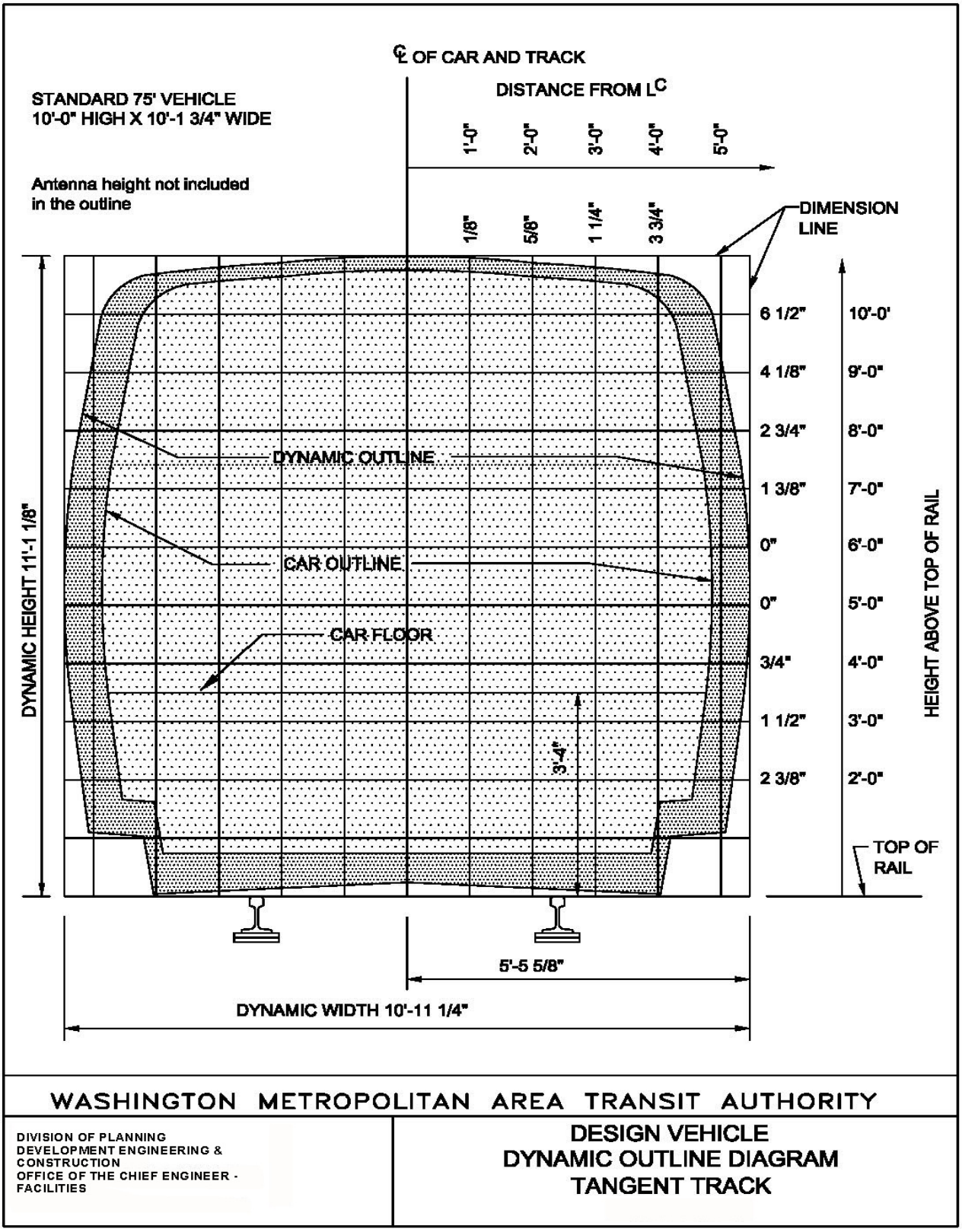
CLEARANCE ENVELOPE FOR STRUCTURES BELOW T/R IN BALLASTED TRACK

FIGURE 11.28


℄ OF CAR AND TRACK
STANDARD 75' VEHICLE
10'-0" HIGH X 10'-1 3/4" WIDE
Antenna height not included
in the outline
DISTANCE FROM LC
1'-0"
2'-0"
3'-0"
4'-0"
5'-0"
1/8"
5/8"
1 1/4"
3 3/4"
DIMENSION LINE
6 1/2"
4 1/8"
2 3/4"
1 3/8"
0"
0"
3/4"
1 1/2"
2 3/8"
10'-0'
9'-0"
8'-0"
7'-0"
6'-0"
5'-0"
4'-0"
3'-0"
2'-0"
HEIGHT ABOVE TOP OF RAIL
DYNAMIC OUTLINE
CAR OUTLINE
CAR FLOOR
DYNAMIC HEIGHT 11'-1 1/8"
3'-4"
TOP OF RAIL
5'-5 5/8"
DYNAMIC WIDTH 10'-11 1/4"
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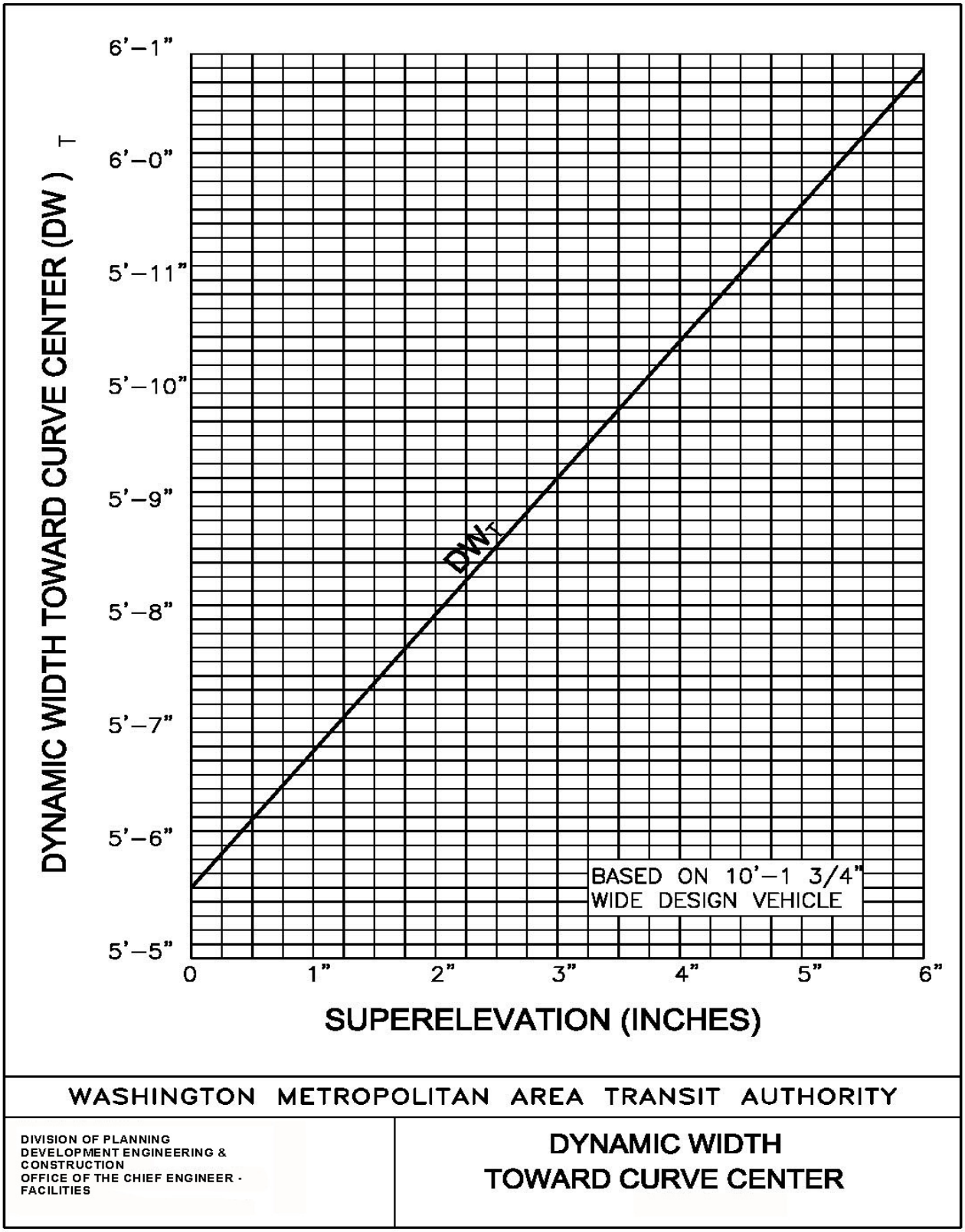
DESIGN VEHICLE
DYNAMIC OUTLINE DIAGRAM
TANGENT TRACK

FIGURE 11.29


DYNAMIC WIDTH TOWARD CURVE CENTER (DW) T
6'–1"
6'–0"
5'–11"
5'–10"
5'–9"
5'–8"
5'–7"
5'–6"
5'–5"
DW T
BASED ON 10'–1 3/4"
WIDE DESIGN VEHICLE
0
1"
2"
3"
4"
5"
6"
SUPERELEVATION (INCHES)
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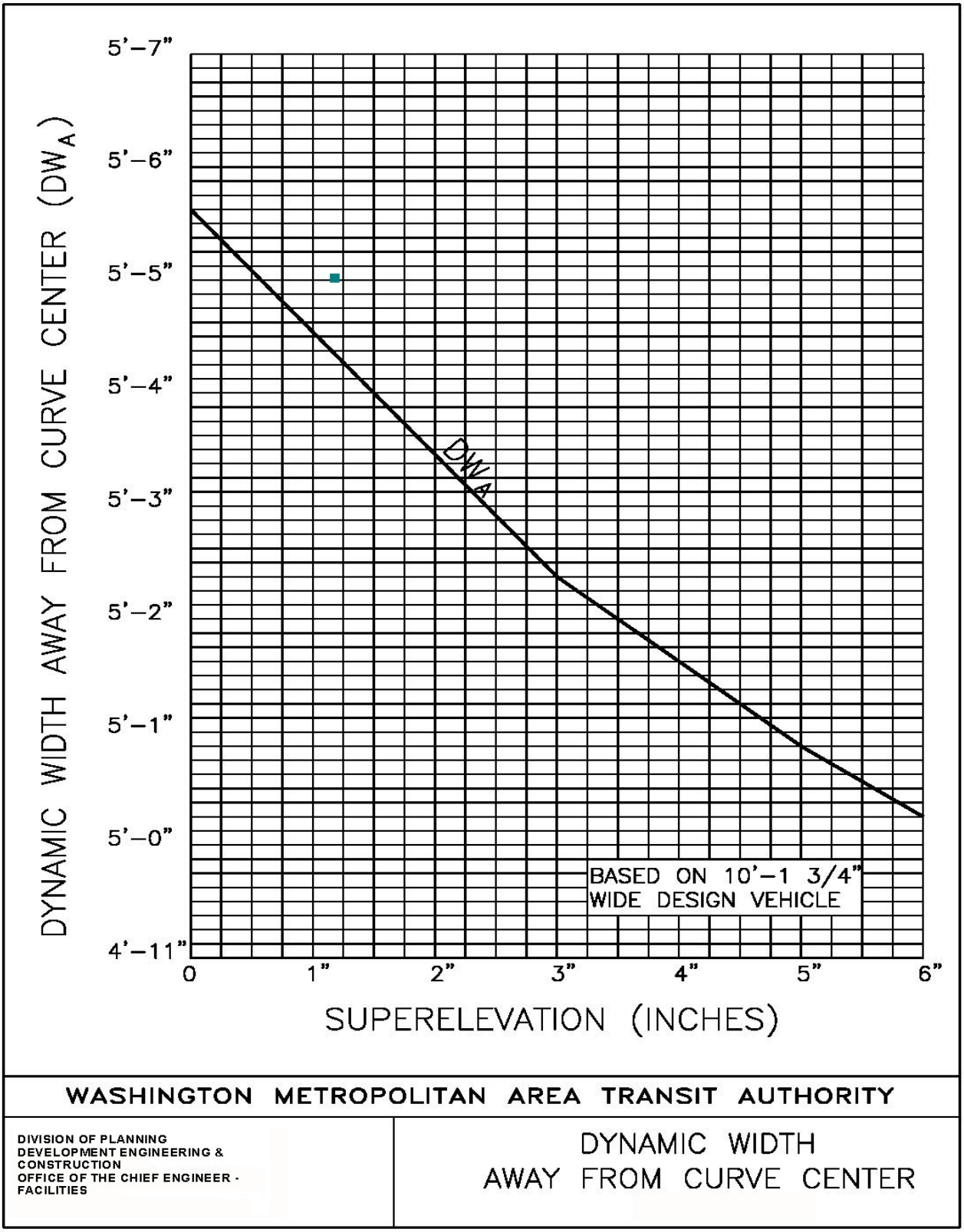
FACILITIES
DYNAMIC WIDTH
TOWARD CURVE CENTER

FIGURE 11.30


DYNAMIC WIDTH AWAY FROM CURVE CENTER (DW_A)
5'–7"
5'–6"
5'–5"
5'–4"
5'–3"
5'–2"
5'–1"
5'–0"
4'–11"
DW_A
BASED ON 10'–1 3/4" WIDE DESIGN VEHICLE
0
1"
2"
3"
4"
5"
6"
SUPERELEVATION (INCHES)
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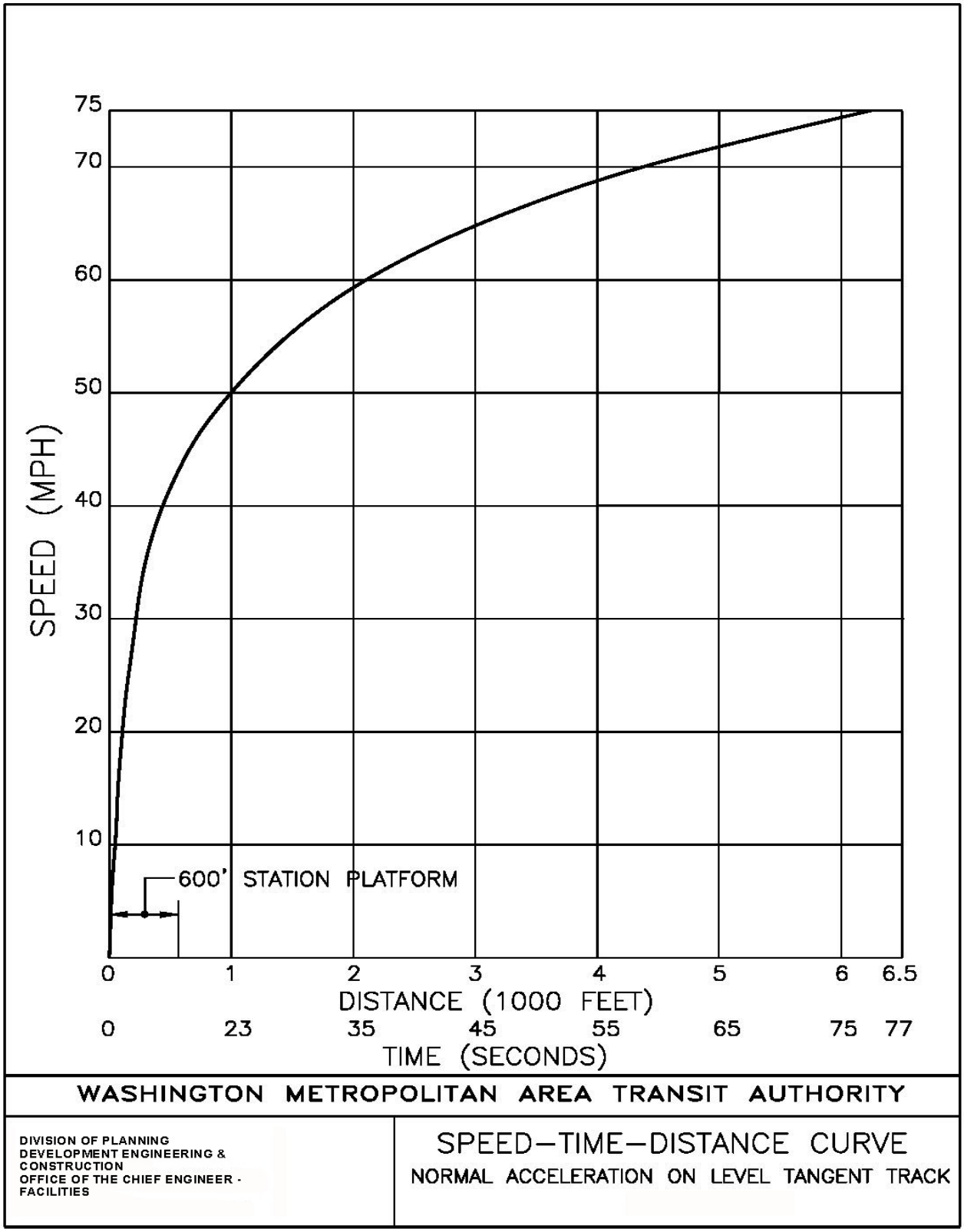
DYNAMIC WIDTH
AWAY FROM CURVE CENTER

FIGURE 11.31


75
70
60
50
40
30
20
10
SPEED (MPH)
600' STATION PLATFORM
0
1
2
3
4
5
6
6.5
DISTANCE (1000 FEET)
0
23
35
45
55
65
75
77
TIME (SECONDS)
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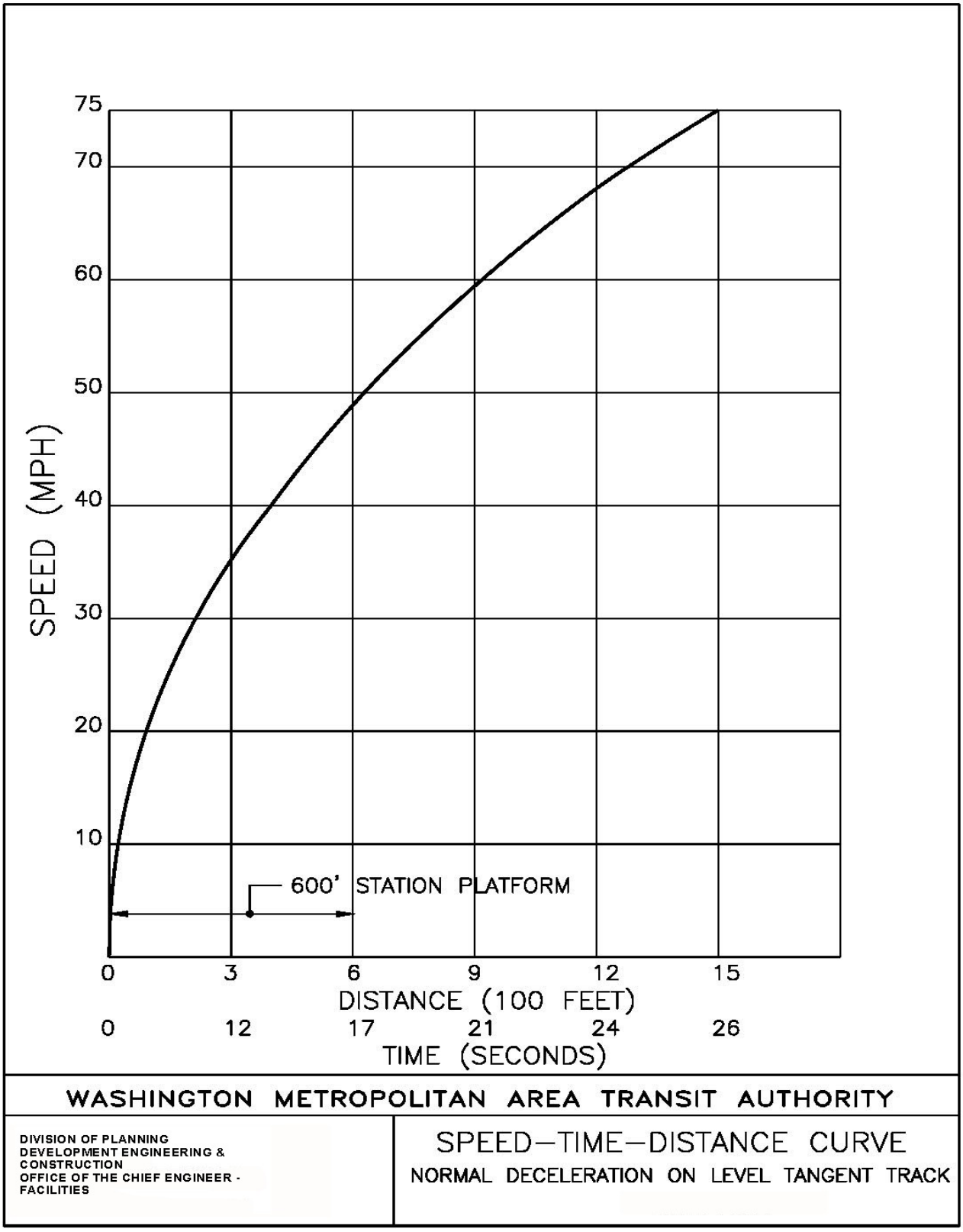
SPEED–TIME–DISTANCE CURVE
NORMAL ACCELERATION ON LEVEL TANGENT TRACK

FIGURE 11.32


75
70
60
50
40
30
20
10
SPEED (MPH)
600' STATION PLATFORM
0
3
6
9
12
15
DISTANCE (100 FEET)
0
12
17
21
24
26
TIME (SECONDS)
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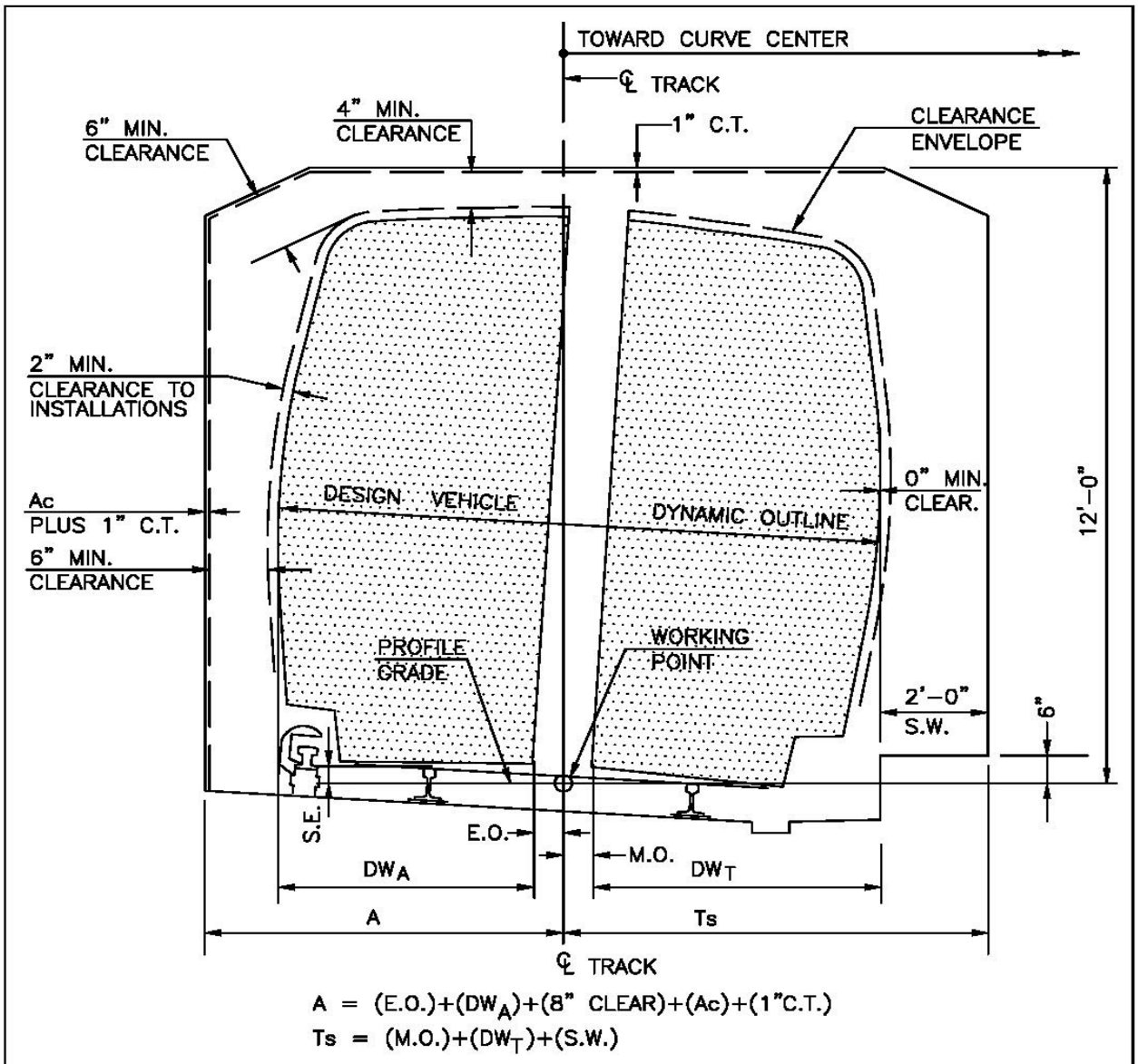
SPEED–TIME–DISTANCE CURVE
NORMAL DECELERATION ON LEVEL TANGENT TRACK

FIGURE 11.33



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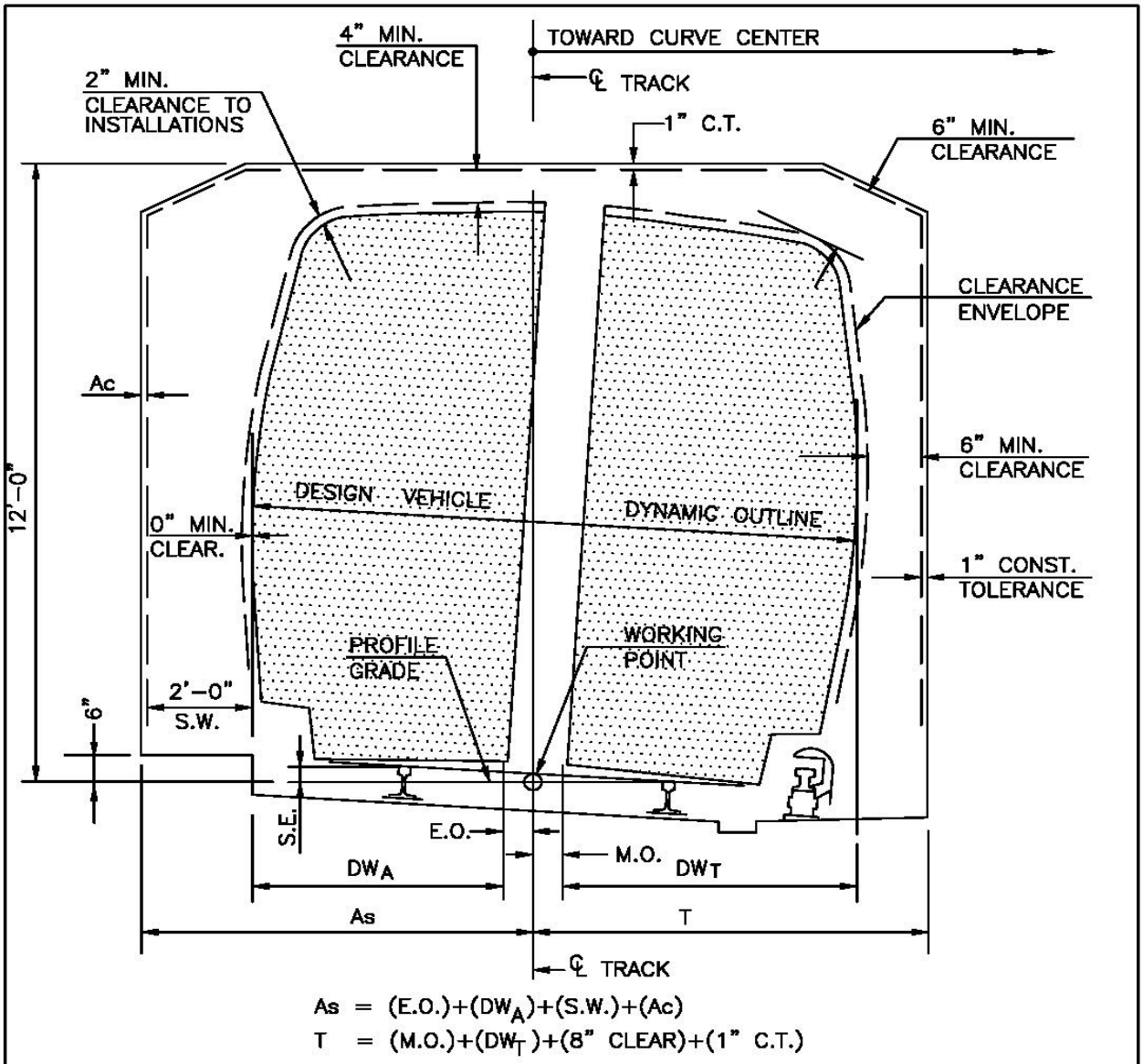
CUT & COVER RECTANGULAR SECTIONS
CLEARANCE DIAGRAM
SAFETY WALK TOWARD CURVE CENTER

FIGURE 11.34



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CUT & COVER RECTANGULAR SECTIONS
CLEARANCE DIAGRAM
SAFETY WALK AWAY FROM CURVE CENTER

FIGURE 11.35

RADIUS	SUPERELEVATION=0"				SUPERELEVATION=1"			
	A	Ts	As	T	A	Ts	As	T
200'	8'-4 1/4"	9'-2"	9'-7 1/4"	7'-11"	8'-3 1/4"	9'-3 1/4"	9'-6 1/4"	8'-0 1/4"
300'	7'-7 1/2"	8'-7 1/8"	8'-10 1/2"	7'-4 1/8"	7'-6 1/2	8'-8 3/8"	8'-9 1/2"	7'-5 3/8"
400'	7'-3 1/4"	8'-3 3/4"	8'-6 1/4"	7'-0 3/4"	7'-2 1/4"	8'-5"	8'-5 1/4"	7'-2"
500'	7'-0 3/4"	8'-1 3/4"	8'-3 3/4"	6'-10 3/4"	6'-11 3/4"	8'-3"	8'-2 3/4"	7'-0"
600'	6'-11"	8'-0 3/8"	8'-2"	6'-9 3/8"	6'-10"	8'-1 5/8"	8'-1"	6'-10 5/8"
700'	6'-9 3/4"	7'-11 3/8"	8'-0 3/4"	6'-8 3/8"	6'-8 3/4"	8'-0 5/8"	7'-11 3/4"	6'-9 5/8"
800'	6'-9"	7'-10 3/4"	8'-0"	6'-7 3/4"	6'-8"	8'-0"	7'-11"	6'-9"
1000'	6'-7 3/4"	7'-9 3/4"	7'-10 3/4"	6'-6 3/4"	6'-6 3/4"	7'-11"	7'-9 3/4"	6'-8"
1200'	6'-6 7/8"	7'-9"	7'-9 7/8"	6'-6"	6'-5 7/8"	7'-10 1/4"	7'-8 7/8"	6'-7 1/4"
1400'	6'-6 1/4"	7'-8 1/2"	7'-9 1/4"	6'-5 1/2"	6'-5 1/4"	7'-9 3/4"	7'-8 1/4"	6'-6 3/4"
1600'	6'-5 3/4"	7'-8 1/8"	7'-8 3/4"	6'-5 1/8"	6'-4 3/4"	7'-9 3/8"	7'-7 3/4"	6'-6 3/8"
1800'	6'-5 3/8"	7'-7 7/8"	7'-8 3/8"	6'-4 7/8"	6'-4 3/8"	7'-9 1/8"	7'-7 3/8"	6'-6 1/8"
2000'	6'-5 1/8"	7'-7 5/8"	7'-8 1/8"	6'-4 5/8"	6'-4 1/8"	7'-8 7/8"	7'-7 1/8"	6'-5 7/8"
2500'	6'-5 3/4"	7'-7 1/4"	7'-8 3/4"	6'-4 1/4"	6'-4 3/4"	7'-8 1/2"	7'-7 3/4"	6'-5 1/2"
3000'	6'-5 1/4"	7'-7"	7'-8 1/4"	6'-4"	6'-4 1/4"	7'-8 1/4"	7'-7 1/4"	6'-5 1/4"
4000'	6'-4 5/8"	7'-6 5/8"	7'-7 5/8"	6'-3 5/8"	6'-3 5/8"	7'-7 7/8"	7'-6 5/8"	6'-4 7/8"
5000'	6'-4 1/4"	7'-6 3/8"	7'-7 1/4"	6'-3 3/8"	6'-3 1/4"	7'-7 3/4"	7'-6 1/4"	6'-4 3/4"
6000'	6'-3 7/8"	7'-6 1/4"	7'-6 7/8"	6'-3 1/4"	6'-2 7/8"	7'-7 1/2"	7'-5 7/8"	6'-4 1/2"
7000'	6'-3 3/4"	7'-6 1/4"	7'-6 3/4"	6'-3 1/4"	6'-2 3/4"	7'-7 1/2"	7'-5 3/4"	6'-4 1/2"
8000'	6'-3 5/8"	7'-6 1/8"	7'-6 5/8"	6'-3 1/8"	6'-2 5/8"	7'-7 3/8"	7'-5 5/8"	6'-4 3/8"
9000'	6'-3 1/2"	7'-6 1/8"	7'-6 1/2"	6'-3 1/8"	6'-2 1/2"	7'-7 3/8"	7'-5 1/2"	6'-4 3/8"
10,000'	6'-3 1/2"	7'-6 1/8"	7'-6 1/2"	6'-3 1/8"	6'-2 3/8"	7'-7 1/4"	7'-5 3/8"	6'-4 1/4"
15,000'	6'-3 1/4"	7'-6"	7'-6 1/4"	6'-3"	6'-2 1/8"	7'-7 1/8"	7'-5 1/8"	6'-4 1/8"
25,000'	6'-3"	7'-6"	7'-6"	6'-3"	6'-1 7/8"	7'-7"	7'-4 7/8"	6'-4"
TANGENT	6'-3"	7'-6"	7'-6"	6'-3"				

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CUT & COVER RECTANGULAR SECTIONS
DESIGN TABLES

FIGURE 11.36

RADIUS	SUPERELEVATION=2"				SUPERELEVATION=3"			
	A	Ts	As	T	A	Ts	As	T
200'	8'–2 1/8"	9'–4 3/8"	9'–5 1/8"	8'–1 3/8"	8'–1"	9'–5 5/8"	9'–4"	8'–2 5/8"
300'	7'–5 3/8"	8'–9 1/2"	8'–8 3/8"	7'–6 1/2"	7'–4 1/4"	8'–10 3/4"	8'–7 1/4"	7'–7 3/4"
400'	7'–1 1/8"	8'–6 1/8"	8'–4 1/8"	7'–3 1/8"	7'–0"	8'–7 3/8"	8'–3"	7'–4 3/8"
500'	6'–10 5/8"	8'–4 1/8"	8'–1 5/8"	7'–1 1/8"	6'–9 1/2"	8'–5 3/8"	8'–0 1/2"	7'–2 3/8"
600'	6'–8 7/8"	8'–2 3/4"	7'–11 7/8"	6'–11 3/4"	6'–7 3/4"	8'–4"	7'–10 3/4"	7'–1"
700'	6'–7 5/8"	8'–1 3/4"	7'–10 5/8"	6'–10 3/4"	6'–6 1/2"	8'–3"	7'–9 1/2"	7'–0"
800'	6'–6 7/8"	8'–1 1/8"	7'–9 7/8"	6'–10 1/8"	6'–5 3/4"	8'–2 3/8"	7'–8 3/4"	6'–11 3/8"
1000'	6'–5 5/8"	8'–0 1/8"	7'–8 5/8"	6'–9 1/8"	6'–4 1/2"	8'–1 3/8"	7'–7 1/2"	6'–10 3/8"
1200'	6'–4 3/4"	7'–11 3/8"	7'–7 3/4"	6'–8 3/8"	6'–3 5/8"	8'–0 5/8"	7'–6 5/8"	6'–9 5/8"
1400'	6'–4 1/8"	7'–10 7/8"	7'–7 1/8"	6'–7 7/8"	6'–3"	8'–0 1/8"	7'–6"	6'–9 1/8"
1600'	6'–3 5/8"	7'–10 1/2"	7'–6 5/8"	6'–7 1/2"	6'–2 1/2"	7'–11 3/4"	7'–5 1/2"	6'–8 3/4"
1800'	6'–3 1/4"	7'–10 1/4"	7'–6 1/4"	6'–7 1/4"	6'–2 1/8"	7'–11 1/2"	7'–5 1/8"	6'–8 1/2"
2000'	6'–3"	7'–10"	7'–6"	6'–7"	6'–1 7/8"	7'–11 1/4"	7'–4 7/8"	6'–8 1/4"
2500'	6'–3 5/8"	7'–9 5/8"	7'–6 5/8"	6'–6 5/8"	6'–2 1/2"	7'–10 7/8"	7'–5 1/2"	6'–7 7/8"
3000'	6'–3 1/8"	7'–9 3/8"	7'–6 1/8"	6'–6 3/8"	6'–2"	7'–10 5/8"	7'–5"	6'–7 5/8"
4000'	6'–2 1/2"	7'–9"	7'–5 1/2"	6'–6"	6'–1 3/8"	7'–10 1/4"	7'–4 3/8"	6'–7 1/4"
5000'	6'–2 1/8"	7'–8 7/8"	7'–5 1/8"	6'–5 7/8"	6'–1"	7'–10 1/8"	7'–4"	6'–7 1/8"
6000'	6'–1 3/4"	7'–8 5/8"	7'–4 3/4"	6'–5 5/8"	6'–0 5/8"	7'–9 7/8"	7'–3 5/8"	6'–6 7/8"
7000'	6'–1 5/8"	7'–8 5/8"	7'–4 5/8"	6'–5 5/8"	6'–0 1/2"	7'–9 7/8"	7'–3 1/2"	6'–6 7/8"
8000'	6'–1 1/2"	7'–8 1/2"	7'–4 1/2"	6'–5 1/2"	6'–0 3/8"	7'–9 3/4"	7'–3 3/8"	6'–6 3/4"
9000'	6'–1 3/8"	7'–8 1/2"	7'–4 3/8"	6'–5 1/2"				
10,000'	6'–1 1/4"	7'–8 3/8"	7'–4 1/4"	6'–5 3/8"				
15,000'	6'–1"	7'–8 1/4"	7'–4"	6'–5 1/4"				

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CUT & COVER RECTANGULAR SECTIONS
DESIGN TABLES

FIGURE 11.37

RADIUS	SUPERELEVATION=4"							
	A	Ts	As	T				
200'	8'–0 1/4"	9'–6 7/8"	9'–3 1/4"	8'–3 7/8"				
300'	7'–3 1/2"	9'–0"	8'–6 1/2"	7'–9"				
400'	6'–11 1/4"	8'–8 5/8"	8'–2 1/4"	7'–5 5/8"				
500'	6'–8 3/4"	8'–6 5/8"	7'–11 3/4"	7'–3 5/8"				
600'	6'–7"	8'–5 1/4"	7'–10"	7'–2 1/4"				
700'	6'–5 3/4"	8'–4 1/4"	7'–8 3/4"	7'–1 1/4"				
800'	6'–5"	8'–3 5/8"	7'–8"	7'–0 5/8"				
1000'	6'–3 3/4"	8'–2 5/8"	7'–6 3/4"	6'–11 5/8"				
1200'	6'–2 7/8"	8'–1 7/8"	7'–5 7/8"	6'–10 7/8"				
1400'	6'–2 1/4"	8'–1 3/8"	7'–5 1/4"	6'–10 3/8"				
1600'	6'–1 3/4"	8'–1"	7'–4 3/4"	6'–10"				
1800'	6'–1 3/8"	8'–0 3/4"	7'–4 3/8"	6'–9 3/4"				
2000'	6'–1 1/8"	8'–0 1/2"	7'–4 1/8"	6'–9 1/2"				
2500'	6'–1 3/4"	8'–0 1/8"	7'–4 3/4"	6'–9 1/8"				
3000'	6'–1 1/4"	7'–11 7/8"	7'–4 1/4"	6'–8 7/8"				
4000'	6'–0 5/8"	7'–11 1/2"	7'–3 5/8"	6'–8 1/2"				
5000'	6'–0 1/4"	7'–11 3/8"	7'–3 1/4"	6'–8 3/8"				
6000'	5'–11 7/8"	7'–11 1/8"	7'–2 7/8"	6'–8 1/8"				

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CUT & COVER RECTANGULAR SECTIONS
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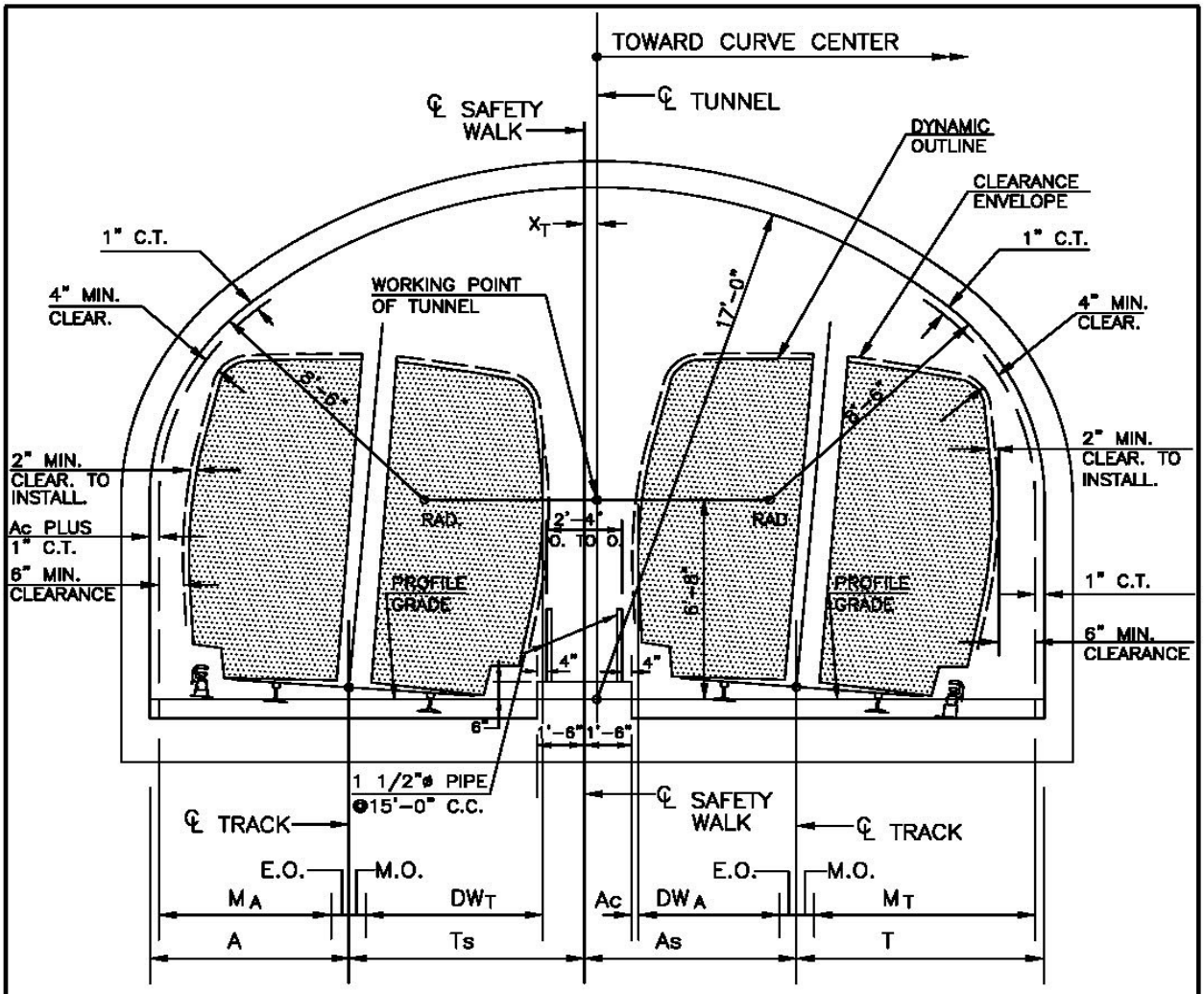
FIGURE 11.38



A = (E.O.)+(M_A)+(Ac)+(1" C.T.)
Ts = (M.O.)+(DW_T)+(1'–6" S.W.)

As = (1'–6" S.W.)+(Ac)+(DW_A)+(E.O.)
T = (M.O.)+(M_T)+(1"C.T.)

NOTES:
FOR A, Ts, As & T VALUES SEE FIGURE III.40 TO III.42.
FOR DW_T & DW_A VALUES SEE FIGURES III.30 & III.31.
FOR X_T VALUES SEE FIGURES III.40 & III.42
FOR M_A & M_T VALUES SEE FIGURES III.40 & III.42.

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DOUBLE TRACK – ROCK TUNNEL
CLEARANCE DIAGRAM
SAFETY WALK BETWEEN TRACKS

FIGURE 11.39

RADIUS	SUPERELEVATION=0"				SUPERELEVATION=1"			
	As	T	A	Ts	As	T	A	Ts
200'	9'-1 1/4"	8'-0"	8'-5 1/8"	8'-8"	9'-0 1/4"	8'-1 7/8"	8'-3 7/8"	8'-9 1/4"
300'	8'-4 1/2"	7'-5 1/8"	7'-8 3/8"	8'-1 1/8"	8'-3 1/2"	7'-7"	7'-7 1/8"	8'-2 3/8"
400'	8'-0 1/4"	7'-1 3/4"	7'-4 1/8"	7'-9 3/4"	7'-11 1/4"	7'-3 5/8"	7'-2 7/8"	7'-11"
500'	7'-9 3/4"	6'-11 3/4"	7'-1 5/8"	7'-7 3/4"	7'-8 3/4"	7'-1 5/8"	7'-0 3/8"	7'-9"
600'	7'-8"	6'-10 3/8"	6'-11 7/8"	7'-6 3/8"	7'-7"	7'-0 1/4"	6'-10 5/8"	7'-7 5/8"
700'	7'-6 3/4"	6'-9 3/8"	6'-10 5/8"	7'-5 3/8"	7'-5 3/4"	6'-11 1/4"	6'-9 3/8"	7'-6 5/8"
800'	7'-6"	6'-8 3/4"	6'-9 7/8"	7'-4 3/4"	7'-5"	6'-10 5/8"	6'-8 5/8"	7'-6"
1000'	7'-4 3/4"	6'-7 3/4"	6'-8 5/8"	7'-3 3/4"	7'-3 3/4"	6'-9 5/8"	6'-7 3/8"	7'-5"
1200'	7'-3 7/8"	6'-7"	6'-7 3/4"	7'-3"	7'-2 7/8"	6'-8 7/8"	6'-6 1/2"	7'-4 1/4"
1400'	7'-3 1/4"	6'-6 1/2"	6'-7 1/8"	7'-2 1/2"	7'-2 1/4"	6'-8 3/8"	6'-5 7/8"	7'-3 3/4"
1600'	7'-2 3/4"	6'-6 1/8"	6'-6 5/8"	7'-2 1/8"	7'-1 3/4"	6'-8"	6'-5 3/8"	7'-3 3/8"
1800'	7'-2 3/8"	6'-5 7/8"	6'-6 1/4"	7'-1 7/8"	7'-1 3/8"	6'-7 3/4"	6'-5"	7'-3 1/8"
2000'	7'-2 1/8"	6'-5 5/8"	6'-6"	7'-1 5/8"	7'-1 1/8"	6'-7 1/2"	6'-4 3/4"	7'-2 7/8"
2500'	7'-2 3/4"	6'-5 1/4"	6'-6 5/8"	7'-1 1/4"	7'-1 3/4"	6'-7 1/8"	6'-5 3/8"	7'-2 1/2"
3000'	7'-2 1/4"	6'-5"	6'-6 1/8"	7'-1"	7'-1 1/4"	6'-6 7/8"	6'-4 7/8"	7'-2 1/4"
4000'	7'-1 5/8"	6'-4 5/8"	6'-5 1/2"	7'-0 5/8"	7'-0 5/8"	6'-6 1/2"	6'-4 1/4"	7'-1 7/8"
5000'	7'-1 1/4"	6'-4 1/2"	6'-5 1/8"	7'-0 1/2"	7'-0 1/4"	6'-6 3/8"	6'-3 7/8"	7'-1 3/4"
6000'	7'-0 7/8"	6'-4 1/4"	6'-4 3/4"	7'-0 1/4"	6'-11 7/8"	6'-6 1/8"	6'-3 1/2"	7'-1 1/2"
7000'	7'-0 3/4"	6'-4 1/4"	6'-4 5/8"	7'-0 1/4"	6'-11 3/4"	6'-6 1/8"	6'-3 3/8"	7'-1 1/2"
8000'	7'-0 5/8"	6'-4 1/8"	6'-4 1/2"	7'-0 1/8"	6'-11 5/8"	6'-6"	6'-3 1/4"	7'-1 3/8"
9000'	7'-0 1/2"	6'-4 1/8"	6'-4 3/8"	7'-0 1/8"	6'-11 1/2"	6'-6"	6'-3 1/8"	7'-1 3/8"
10,000'	7'-0 3/8"	6'-4"	6'-4 1/4"	7'-0"	6'-11 3/8"	6'-5 7/8"	6'-3"	7'-1 1/4"
15,000'	7'-0 1/8"	6'-3 7/8"	6'-4"	6'-11 7/8"	6'-11 1/8"	6'-5 3/4"	6'-2 3/4"	7'-1 1/8"
20,000'	7'-0 1/8"	6'-3 7/8"	6'-4"	6'-11 7/8"	6'-11 1/8"	6'-5 3/4"	6'-2 3/4"	7'-1 1/8"
25,000'	6'-11 7/8"	6'-3 3/4"	6'-3 3/4"	6'-11 3/4"	6'-10 7/8"	6'-5 5/8"	6'-2 1/2"	7'-1"
TANGENT	6'-11 5/8"	6'-3 5/8"	6'-3 5/8"	6'-11 5/8"				

S.E.	XT	MA	MT
0"	0"	6'-2 5/8"	6'-2 5/8"
1"	1/2"	6'-1 1/4"	6'-4 1/2"

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DESIGN TABLES

FIGURE 11.40

RADIUS	SUPERELEVATION=2"				SUPERELEVATION=3"			
	As	T	A	Ts	As	T	A	Ts
200'	8'-11 1/8"	8'-3 5/8"	8'-2 5/8"	8'-10 3/8"	8'-10"	8'-5 1/4"	8'-1 1/8"	8'-11 5/8"
300'	8'-2 3/8"	7'-8 3/4"	7'-5 7/8"	8'-3 1/2"	8'-1 1/4"	7'-10 3/8"	7'-4 3/8"	8'-4 3/4"
400'	7'-10 1/8"	7'-5 3/8"	7'-1 5/8"	8'-0 1/8"	7'-9"	7'-7"	7'-0 1/8"	8'-1 3/8"
500'	7'-7 5/8"	7'-3 3/8"	6'-11 1/8"	7'-10 1/8"	7'-6 1/2"	7'-5"	6'-9 5/8"	7'-11 3/8"
600'	7'-5 7/8"	7'-2"	6'-9 3/8"	7'-8 3/4"	7'-4 3/4"	7'-3 5/8"	6'-7 7/8"	7'-10"
700'	7'-4 5/8"	7'-1"	6'-8 1/8"	7'-7 3/4"	7'-3 1/2"	7'-2 5/8"	6'-6 5/8"	7'-9"
800'	7'-3 7/8"	7'-0 3/8"	6'-7 3/8"	7'-7 1/8"	7'-2 3/4"	7'-2"	6'-5 7/8"	7'-8 3/8"
1000'	7'-2 5/8"	6'-11 3/8"	6'-6 1/8"	7'-6 1/8"	7'-1 1/2"	7'-1"	6'-4 5/8"	7'-7 3/8"
1200'	7'-1 3/4"	6'-10 5/8"	6'-5 1/4"	7'-5 3/8"	7'-0 5/8"	7'-0 1/4"	6'-3 3/4"	7'-6 5/8"
1400'	7'-1 1/8"	6'-10 1/8"	6'-4 5/8"	7'-4 7/8"	7'-0"	6'-11 3/4"	6'-3 1/8"	7'-6 1/8"
1600'	7'-0 5/8"	6'-9 3/4"	6'-4 1/8"	7'-4 1/2"	6'-11 1/2"	6'-11 3/8"	6'-2 5/8"	7'-5 3/4"
1800'	7'-0 1/4"	6'-9 1/2"	6'-3 3/4"	7'-4 1/4"	6'-11 1/8"	6'-11 1/8"	6'-2 1/4"	7'-5 1/2"
2000'	7'-0"	6'-9 1/4"	6'-3 1/2"	7'-4"	6'-10 7/8"	6'-10 7/8"	6'-2"	7'-5 1/4"
2500'	7'-0 5/8"	6'-8 7/8"	6'-4 1/8"	7'-3 5/8"	6'-11 1/2"	6'-10 1/2"	6'-2 5/8"	7'-4 7/8"
3000'	7'-0 1/8"	6'-8 5/8"	6'-3 5/8"	7'-3 3/8"	6'-11"	6'-10 1/4"	6'-2 1/8"	7'-4 5/8"
4000'	6'-11 1/2"	6'-8 1/4"	6'-3"	7'-3"	6'-10 3/8"	6'-9 7/8"	6'-1 1/2"	7'-4 1/4"
5000'	6'-11 1/8"	6'-8 1/8"	6'-2 5/8"	7'-2 7/8"	6'-10"	6'-9 3/4"	6'-1 1/8"	7'-4 1/8"
6000'	6'-10 3/4"	6'-7 7/8"	6'-2 1/4"	7'-2 5/8"	6'-9 5/8"	6'-9 1/2"	6'-0 3/4"	7'-3 7/8"
7000'	6'-10 5/8"	6'-7 7/8"	6'-2 1/8"	7'-2 5/8"	6'-9 1/2"	6'-9 1/2"	6'-0 5/8"	7'-3 7/8"
8000'	6'-10 1/2"	6'-7 3/4"	6'-2"	7'-2 1/2"	6'-9 3/8"	6'-9 3/8"	6'-0 1/2"	7'-3 3/4"
9000'	6'-10 3/8"	6'-7 3/4"	6'-1 7/8"	7'-2 1/2"				
10,000'	6'-10 1/4"	6'-7 5/8"	6'-1 3/4"	7'-2 3/8"				
15,000'	6'-10"	6'-7 1/2"	6'-1 1/2"	7'-2 1/4"				

S.E.	XT	MA	MT
2"	7/8"	6'-0"	6'-6 1/4"
3"	1 1/4"	5'-10 1/2"	6'-7 7/8"

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FIGURE 11.41

RADIUS	SUPERELEVATION=4"							
	As	T	A	Ts				
200'	8'-9 1/4"	8'-7 5/8"	8'-0 1/8"	9'-0 7/8"				
300'	8'-0 1/2"	8'-0 3/4"	7'-3 3/8"	8'-6"				
400'	7'-8 1/4"	7'-9 3/8"	6'-11 1/8"	8'-2 5/8"				
500'	7'-5 3/4"	7'-7 3/8"	6'-8 5/8"	8'-0 5/8"				
600'	7'-4"	7'-6"	6'-6 7/8"	7'-11 1/4"				
700'	7'-2 3/4"	7'-5"	6'-5 5/8"	7'-10 1/4"				
800'	7'-2"	7'-4 3/8"	6'-4 7/8"	7'-9 5/8"				
1000'	7'-0 3/4"	7'-3 3/8"	6'-3 5/8"	7'-8 5/8"				
1200'	6'-11 7/8"	7'-2 5/8"	6'-2 3/4"	7'-7 7/8"				
1400'	6'-11 1/4"	7'-2 1/8"	6'-2 1/8"	7'-7 3/8"				
1600'	6'-10 3/4"	7'-1 3/4"	6'-1 5/8"	7'-7"				
1800'	6'-10 3/8"	7'-1 1/2"	6'-1 1/4"	7'-6 3/4"				
2000'	6'-10 1/8"	7'-1 1/4"	6'-1"	7'-6 1/2"				
2500'	6'-10 3/4"	7'-0 7/8"	6'-1 5/8"	7'-6 1/8"				
3000'	6'-10 1/4"	7'-0 5/8"	6'-1 1/8"	7'-5 7/8"				
4000'	6'-9 5/8"	7'-0 1/4"	6'-0 1/2"	7'-5 1/2"				
5000'	6'-9 1/4"	7'-0 1/8"	6'-0 1/8"	7'-5 3/8"				
6000'	6'-8 7/8"	6'-11 7/8"	5'-11 3/4"	7'-5 1/8"				

S.E.	XT	MA	MT
4"	1 7/8"	5'-9 1/2"	6'-10 1/4"

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DOUBLE TRACK–ROCK TUNNEL
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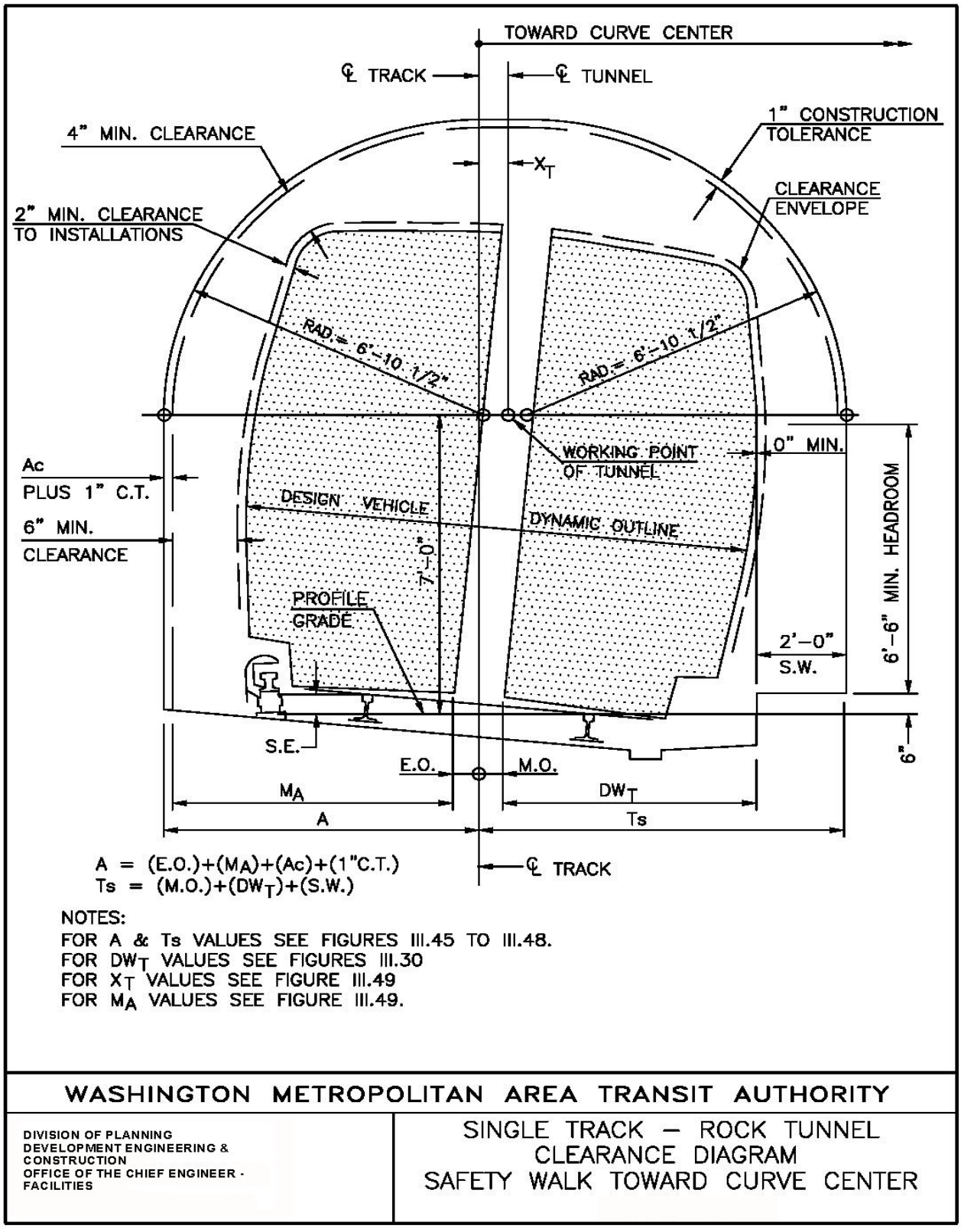
FIGURE 11.42



NOTES:
FOR A & Ts VALUES SEE FIGURES III.45 TO III.48.
FOR DW_T VALUES SEE FIGURES III.30
FOR X_T VALUES SEE FIGURE III.49
FOR M_A VALUES SEE FIGURE III.49.

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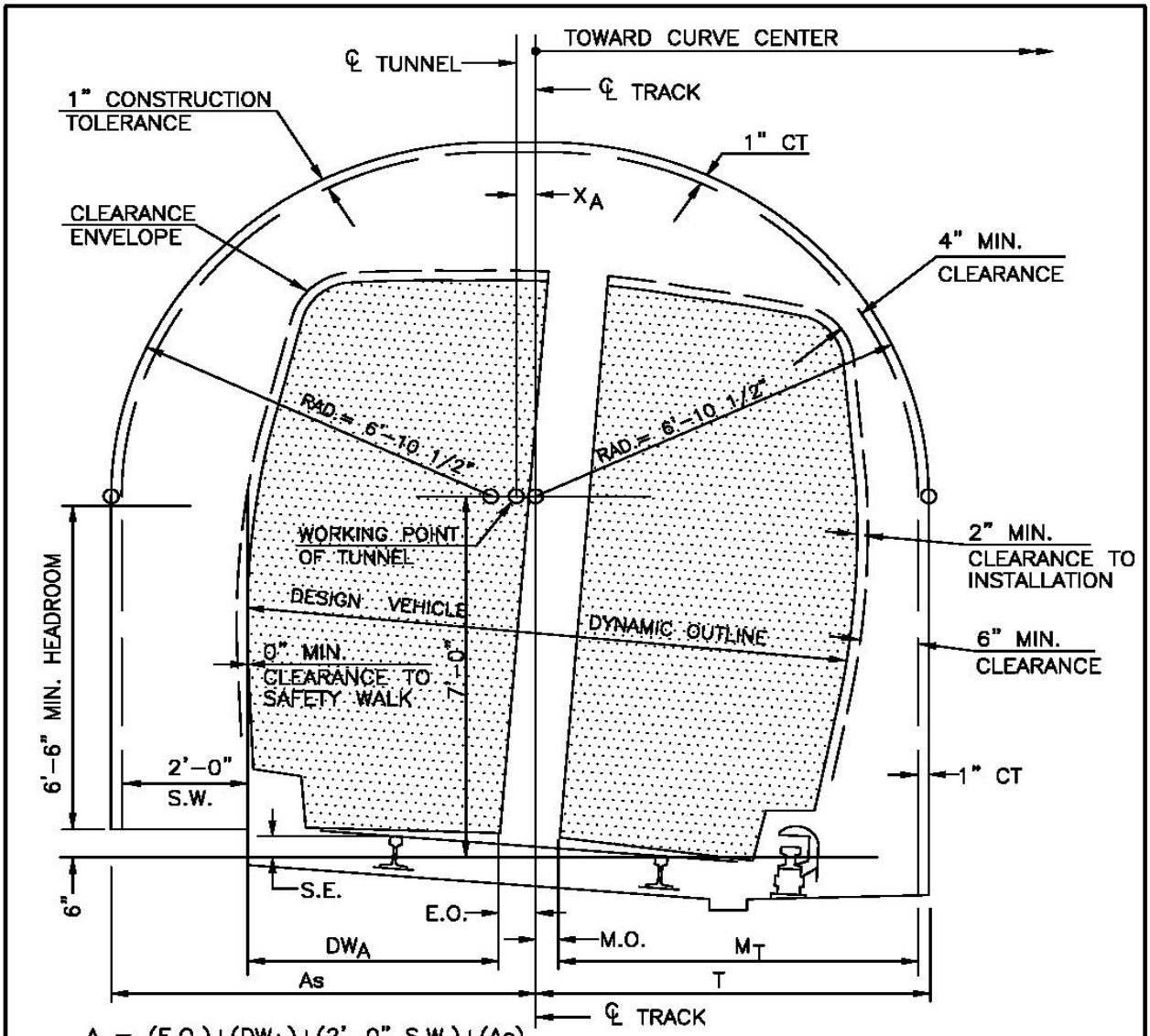
SINGLE TRACK – ROCK TUNNEL
CLEARANCE DIAGRAM
SAFETY WALK TOWARD CURVE CENTER

FIGURE 11.43



$A = (E.O.)+(DW_A)+(2'-0"\ S.W.)+(Ac)$

$T = (M.O.)+(M_T)+(1"C.T.)$

NOTES:

FOR As & T VALUES SEE FIGURES III.45 TO III.48
FOR DW_A VALUES SEE FIGURE III.31.
FOR X_A VALUES SEE FIGURE III.49
FOR M_T VALUES SEE FIGURE III.49

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SINGLE TRACK – ROCK TUNNEL
CLEARANCE DIAGRAM
SAFETY WALK AWAY FROM CURVE CENTER

FIGURE 11.44

RADIUS	SUPERELEVATION=0"				SUPERELEVATION=1"			
	As	T	A	Ts	As	T	A	Ts
500'	8'–3 3/4"	7'–0 3/8"	7'–1 5/8"	8'–1 3/4"	8'–2 3/4"	7'–2 1/8"	7'–0 7/8"	8'–3"
600'	8'–2"	6'–11"	6'–11 7/8"	8'–0 3/8"	8'–1"	7'–0 3/4"	6'–11 1/8"	8'–1 5/8"
700'	8'–0 3/4"	6'–10"	6'–10 5/8"	7'–11 3/8"	7'–11 3/4"	6'–11 3/4"	6'–9 7/8"	8'–0 5/8"
800'	8'–0"	6'–9 3/8"	6'–9 7/8"	7'–10 3/4"	7'–11"	6'–11 1/8"	6'–9 1/8"	8'–0"
1000'	7'–10 3/4"	6'–8 3/8"	6'–8 5/8"	7'–9 3/4"	7'–9 3/4"	6'–10 1/8"	6'–7 7/8"	7'–11"
1200'	7'–9 7/8"	6'–7 5/8"	6'–7 3/4"	7'–9"	7'–8 7/8"	6'–9 3/8"	6'–7"	7'–10 1/4"
1400'	7'–9 1/4"	6'–7 1/8"	6'–7 1/8"	7'–8 1/2"	7'–8 1/4"	6'–8 7/8"	6'–6 3/8"	7'–9 3/4"
1600'	7'–8 3/4"	6'–6 3/4"	6'–6 5/8"	7'–8 1/8"	7'–7 3/4"	6'–8 1/2"	6'–5 7/8"	7'–9 3/8"
1800'	7'–8 3/8"	6'–6 1/2"	6'–6 1/4"	7'–7 7/8"	7'–7 3/8"	6'–8 1/4"	6'–5 1/2"	7'–9 1/8"
2000'	7'–8 1/8"	6'–6 1/4"	6'–6"	7'–7 5/8"	7'–7 1/8"	6'–8"	6'–5 1/4"	7'–8 7/8"
2500'	7'–8 3/4"	6'–5 7/8"	6'–6 5/8"	7'–7 1/4"	7'–7 3/4"	6'–7 5/8"	6'–5 7/8"	7'–8 1/2"
3000'	7'–8 1/4"	6'–5 5/8"	6'–6 1/8"	7'–7"	7'–7 1/4"	6'–7 3/8"	6'–5 3/8"	7'–8 1/4"
4000'	7'–7 5/8"	6'–5 1/4"	6'–5 1/2"	7'–6 5/8"	7'–6 5/8"	6'–7"	6'–4 3/4"	7'–7 7/8"
5000'	7'–7 1/4"	6'–5 1/8"	6'–5 1/8"	7'–6 1/2"	7'–6 1/4"	6'–6 7/8"	6'–4 3/8"	7'–7 3/4"
6000'	7'–6 7/8"	6'–4 7/8"	6'–4 1/2"	7'–6 1/4"	7'–5 7/8"	6'–6 5/8"	6'–4"	7'–7 1/2"
7000'	7'–6 3/4"	6'–4 7/8"	6'–4 3/8"	7'–6 1/4"	7'–5 3/4"	6'–6 5/8"	6'–3 7/8"	7'–7 1/2"
8000'	7'–6 5/8"	6'–4 3/4"	6'–4 1/8"	7'–6 1/8"	7'–5 5/8"	6'–6 1/2"	6'–3 3/4"	7'–7 3/8"
9000'	7'–6 1/2"	6'–4 3/4"	6'–4"	7'–6 1/8"	7'–5 1/2"	6'–6 1/2"	6'–3 5/8"	7'–7 3/8"
10,000'	7'–6 1/2"	6'–4 1/2"	6'–3 3/4"	7'–6 1/8"	7'–5 3/8"	6'–6 3/8"	6'–3 1/2"	7'–7 1/4"
15,000'	7'–6 1/4"	6'–4 1/8"	6'–3 1/2"	7'–6 "	7'–5 1/8"	6'–6 1/4"	6'–3 1/4"	7'–7 1/8"
20,000'	7'–6 1/8"	6'–4 1/8"	6'–3 1/2"	7'–6"	7'–5 1/8"	6'–6 1/4"	6'–3 1/4"	7'–7 1/8"
25,000'	7'–6"	6'–3 3/4"	6'–3 1/2"	7'–6"	7'–4 7/8"	6'–6 1/8"	6'–3"	7'–7"
TANGENT	7'–6"	6'–3 1/2"	6'–3 1/2"	7'–6"				

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SINGLE TRACK–ROCK TUNNEL
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FIGURE 11.45

RADIUS	SUPERELEVATION=2"				SUPERELEVATION=3"			
	As	T	A	Ts	As	T	A	Ts
500'	8'–1 5/8"	7'–3 7/8"	6'–11 5/8"	8'–4 1/8"	8'–0 1/2"	7'–5 7/8"	6'–10 1/8"	8'–5 3/8"
600'	7'–11 7/8"	7'–2 1/2"	6'–9 7/8"	8'–2 3/4"	7'–10 3/4"	7'–4 1/2"	6'–8 3/8"	8'–4"
700'	7'–10 5/8"	7'–1 1/2"	6'–8 5/8"	8'–1 3/4"	7'–9 1/2"	7'–3 1/2"	6'–7 1/8"	8'–3"
800'	7'–9 7/8"	7'–0 7/8"	6'–7 7/8"	8'–1 1/8"	7'–8 3/4"	7'–2 7/8"	6'–6 3/8"	8'–2 3/8"
1000'	7'–8 5/8"	6'–11 7/8"	6'–6 5/8"	8'–0 1/8"	7'–7 1/2"	7'–1 7/8"	6'–5 1/8"	8'–1 3/8"
1200'	7'–7 3/4"	6'–11 1/8"	6'–5 3/4"	7'–11 3/8"	7'–6 5/8"	7'–1 1/8"	6'–4 1/4"	8'–0 5/8"
1400'	7'–7 1/8"	6'–10 5/8"	6'–5 1/8"	7'–10 7/8"	7'–6"	7'–0 5/8"	6'–3 5/8"	8'–0 1/8"
1600'	7'–6 5/8"	6'–10 1/4"	6'–4 5/8"	7'–10 1/2"	7'–5 1/2"	7'–0 1/4"	6'–3 1/8"	7'–11 3/4"
1800'	7'–6 1/4"	6'–10"	6'–4 1/4"	7'–10 1/4"	7'–5 1/8"	7'–0"	6'–2 3/4"	7'–11 1/2"
2000'	7'–6"	6'–9 3/4"	6'–4"	7'–10"	7'–4 7/8"	6'–11 3/4"	6'–2 1/2"	7'–11 1/4"
2500'	7'–6 5/8"	6'–9 3/8"	6'–4 5/8"	7'–9 5/8"	7'–5 1/2"	6'–11 3/8"	6'–3 1/8"	7'–10 7/8"
3000'	7'–6 1/8"	6'–9 1/8"	6'–4 1/8"	7'–9 3/8"	7'–5"	6'–11 1/8"	6'–2 5/8"	7'–10 5/8"
4000'	7'–5 1/2"	6'–8 3/4"	6'–3 1/2"	7'–9"	7'–4 3/8"	6'–10 3/4"	6'–2"	7'–10 1/4"
5000'	7'–5 1/8"	6'–8 5/8"	6'–3 1/8"	7'–8 7/8"	7'–4"	6'–10 5/8"	6'–1 5/8"	7'–10 1/8"
6000'	7'–4 3/4"	6'–8 3/8"	6'–2 3/4"	7'–8 5/8"	7'–3 5/8"	6'–10 3/8"	6'–1 1/4"	7'–9 7/8"
7000'	7'–4 5/8"	6'–8 3/8"	6'–2 5/8"	7'–8 5/8"	7'–3 1/2"	6'–10 3/8"	6'–1 1/8"	7'–9 7/8"
8000'	7'–4 1/2"	6'–8 1/4"	6'–2 1/2"	7'–8 1/2"	7'–3 3/8"	6'–10 1/4"	6'–1"	7'–9 3/4"
9000'	7'–4 3/8"	6'–8 1/4"	6'–2 3/8"	7'–8 1/2"				
10,000'	7'–4 1/4"	6'–8 1/8"	6'–2 1/4"	7'–8 3/8"				
15,000'	7'–4"	6'–8"	6'–2"	7'–8 1/4"				

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FIGURE 11.46

RADIUS	SUPERELEVATION=4"							
	As	T	A	Ts				
500'	7'-11 3/4"	7'-7 5/8"	6'-8 7/8"	8'-6 5/8"				
600'	7'-10"	7'-6 1/4"	6'-7 1/8"	8'-5 1/4"				
700'	7'-8 3/4"	7'-5 1/4"	6'-5 7/8"	8'-4 1/4"				
800'	7'-8"	7'-4 5/8"	6'-5 1/8"	8'-3 5/8"				
1000'	7'-6 3/4"	7'-3 5/8"	6'-3 7/8"	8'-2 5/8"				
1200'	7'-5 7/8"	7'-2 7/8"	6'-3"	8'-1 7/8"				
1400'	7'-5 1/4"	7'-2 3/8"	6'-2 3/8"	8'-1 3/8"				
1600'	7'-4 3/4"	7'-2"	6'-1 7/8"	8'-1"				
1800'	7'-4 3/8"	7'-1 3/4"	6'-1 1/2"	8'-0 3/4"				
2000'	7'-4 1/8"	7'-1 1/2"	6'-1 1/4"	8'-0 1/2"				
2500'	7'-4 3/4"	7'-1 1/8"	6'-1 7/8"	8'-0 1/8"				
3000'	7'-4 1/4"	7'-0 7/8"	6'-1 3/8"	7'-11 7/8"				
4000'	7'-3 5/8"	7'-0 1/2"	6'-0 3/4"	7'-11 1/2"				
5000'	7'-3 1/4"	7'-0 3/8"	6'-0 3/8"	7'-11 3/8"				
6000'	7'-2 7/8"	7'-0 1/8"	6'-0"	7'-11 1/8"				

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FIGURE 11.47

RADIUS	X_T VALUES SAFETY WALK TOWARD CURVE CENTER				
	0"	1"	2"	3"	4"
500'	6 1/8"	7 1/8"	8 1/4"	9 5/8"	10 7/8"
600'	6 1/4"	7 1/4"	8 1/2"	9 7/8"	11 1/8"
700'	6 3/8"	7 3/8"	8 5/8"	10"	11 1/4"
800'	6 1/2"	7 1/2"	8 5/8"	10"	11 1/4"
1000'	6 5/8"	7 5/8"	8 3/4"	10 1/8"	11 3/8"
1200'	6 5/8"	7 5/8"	8 7/8"	10 1/4"	11 1/2"
1400'	6 3/4"	7 3/4"	8 7/8"	10 1/4"	11 1/2"
1600'	6 3/4"	7 3/4"	9"	10 3/8"	11 5/8"
1800'	6 7/8"	7 7/8"	9"	10 3/8"	11 5/8"
2000'	6 7/8"	7 7/8"	9"	10 3/8"	11 5/8"
2500'	6 3/8"	7 3/8"	8 1/2"	9 7/8"	11 1/8"
3000'	6 1/2"	7 1/2"	8 5/8"	10"	11 1/4"
4000'	6 5/8"	7 5/8"	8 3/4"	10 1/8"	11 3/8"
5000'	6 3/4"	7 3/4"	8 7/8"	10 1/4"	11 1/2"
6000'	7"	7 3/4"	9"	10 3/8"	11 1/2"
7000'	7 1/8"	7 7/8"	9"	10 3/8"	
8000'	7 1/4"	7 7/8"	9"	10 3/8"	
9000'	7 1/4"	7 7/8"	9 1/8"		
10000'	7 3/8"	7 7/8"	9 1/8"		
15,000'	7 1/2"	8"	9 1/8"		
20,000'	7 1/2"	8"			
25,000'	7 1/2"	8"			
TANGENT	7 1/2"				

S.E.	0"	1"	2"	3"	4"
M_A	6'–2 1/2"	6'–1 3/4"	6'–0 1/2"	5'–11"	5'–9 3/4"

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FIGURE 11.48

RADIUS	X_A VALUES SAFETY WALK AWAY FROM CURVE CENTER				
	0"	1"	2"	3"	4"
500'	7 3/4"	6 3/8"	4 7/8"	3 3/8"	2 1/8"
600'	7 1/2"	6 1/8"	4 3/4"	3 1/8"	1 7/8"
700'	7 3/8"	6"	4 5/8"	3"	1 3/4"
800'	7 3/8"	6"	4 1/2"	3"	1 3/4"
1000'	7 1/4"	5 7/8"	4 3/8"	2 7/8"	1 5/8"
1200'	7 1/8"	5 3/4"	4 3/8"	2 3/4"	1 1/2"
1400'	7 1/8"	5 3/4"	4 1/4"	2 1/2"	1 1/2"
1600'	7"	5 5/8"	4 1/4"	2 5/8"	1 3/8"
1800'	7"	5 5/8"	4 1/8"	2 5/8"	1 3/8"
2000'	7"	5 5/8"	4 1/8"	2 5/8"	1 3/8"
2500'	7 1/2"	6 1/8"	4 5/8"	3 1/8"	1 7/8"
3000'	7 3/8"	6"	4 1/2"	3"	1 3/4"
4000'	7 1/4"	5 7/8"	4 3/8"	2 7/8"	1 5/8"
5000'	7 1/8"	5 3/4"	4 1/4"	2 3/4"	1 1/2"
6000'	7"	5 5/8"	4 1/4"	2 5/8"	1 3/8"
7000'	7"	5 5/8"	4 1/8"	2 5/8"	
8000'	6 7/8"	5 5/8"	4 1/8"	2 5/8"	
9000'	6 7/8"	5 1/2"	4 1/8"		
10000'	7"	5 1/2"	4 1/8"		
15,000'	7 1/8"	5 1/2"	4"		
20,000'	7 1/4"	5 1/2"			
25,000'	7 3/8"	5 3/8"			
TANGENT	7 1/2"				

S.E.	0"	1"	2"	3"	4"
M_T	6'-2 1/2"	6'-5"	6'-6 3/4"	6'-8 3/4"	6'-10 1/2"

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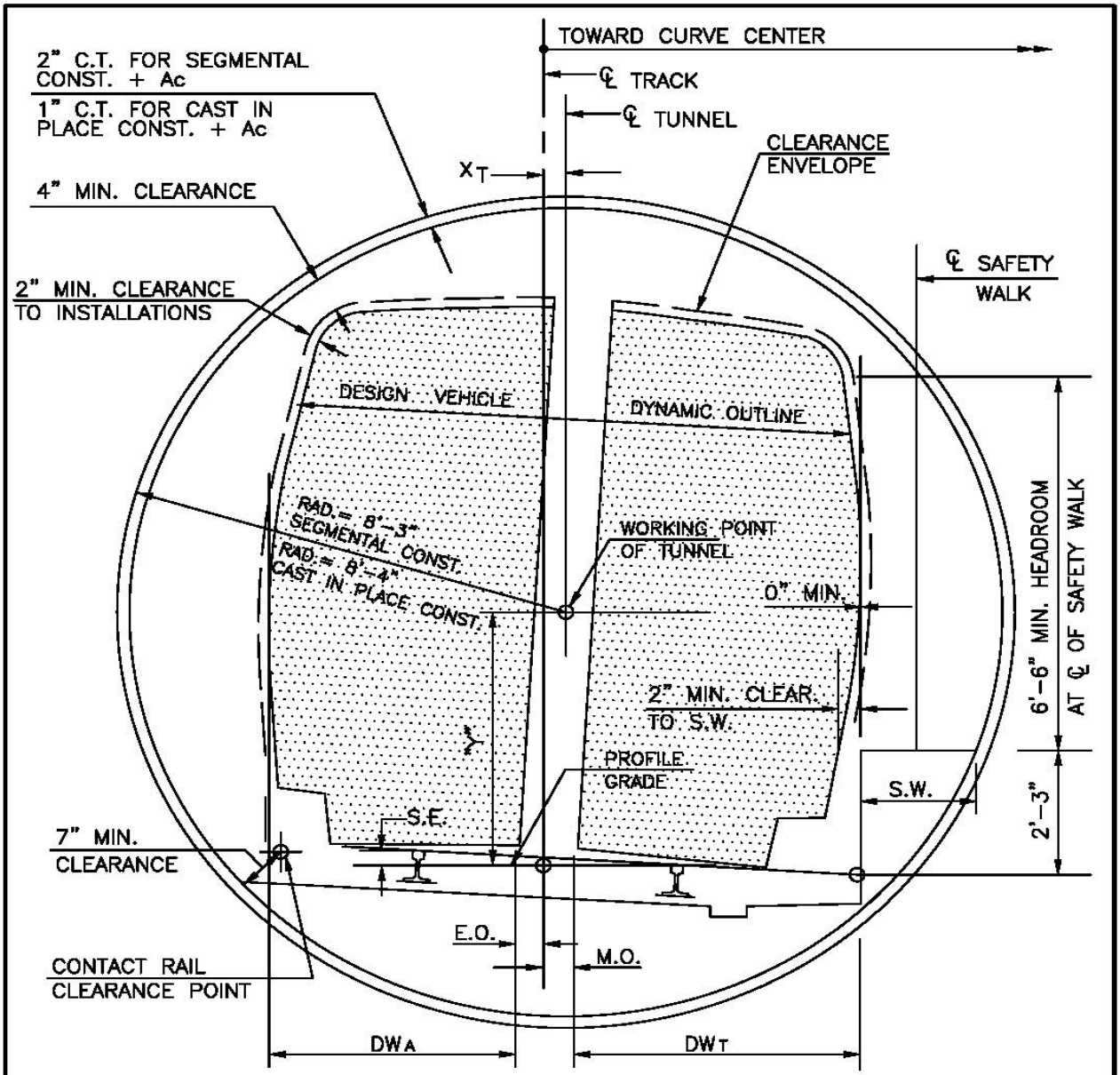
FIGURE 11.49



NOTES:
FOR X_T, Y, & S.W. VALUES SEE FIGURE III.52.
FOR DW_T & DW_A VALUES SEE FIGURES III.30 & III.31.

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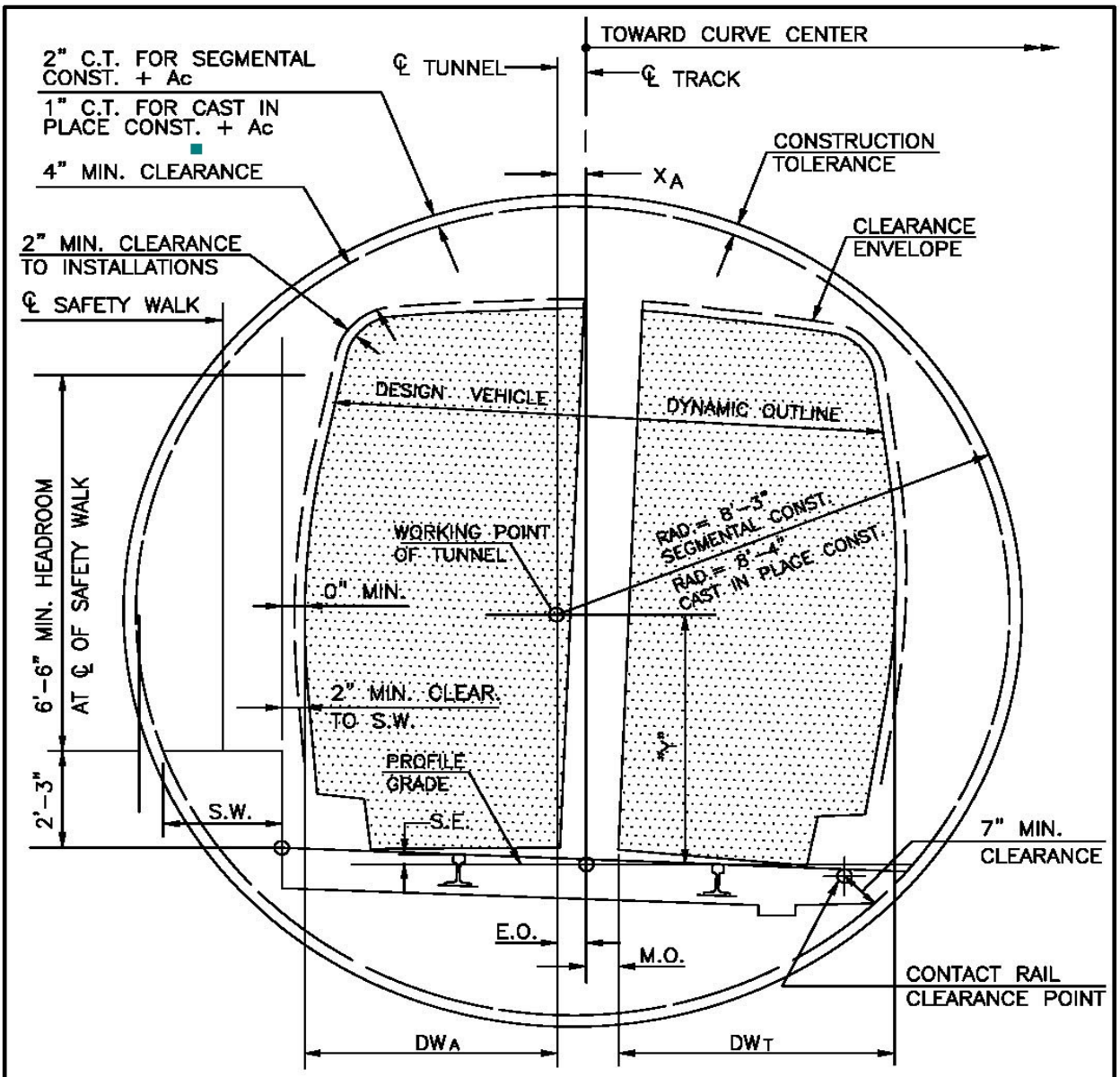
CIRCULAR TUNNEL
CLEARANCE DIAGRAM
SAFETY WALK TOWARD CURVE CENTER

FIGURE 11.50



NOTES:
FOR X_A,Y, & S.W. VALUES SEE FIGURE III.53.
FOR DW_T & DW_A VALUES SEE FIGURES III.30 & III.31.

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CIRCULAR TUNNEL
CLEARANCE DIAGRAM
SAFETY WALK AWAY FROM CURVE CENTER

FIGURE 11.51

SAFETY WALK TOWARD CURVE CENTER

RADIUS	SUPERELEVATION = 0"			SUPERELEVATION = 1"			SUPERELEVATION = 2"		
	X_T	Y	SW	X_T	Y	SW	X_T	Y	SW
700'	4 1/4"	5'-4"	1'-11"	5 7/8"	5'-4"	1'-10 5/8"	7 1/4"	5'-4"	1'-11"
900'	4 1/4"	5'-4"	2'-0"	5 7/8"	5'-4"	2'-0"	7 1/8"	5'-4"	2'-0"
1200'	3 1/2"	5'-4"	2'-0"	5 1/8"	5'-4"	2'-0"	6 3/8"	5'-4"	2'-0"
1600'	2 1/2"	5'-4"	2'-0"	4 1/4"	5'-4"	2'-0"	5 1/2"	5'-4"	2'-0"
2000'	2 1/8"	5'-4"	2'-0"	3 3/4"	5'-4"	2'-0"	5"	5'-4"	2'-0"
3000'	1 1/2"	5'-4"	2'-0"	3 1/8"	5'-4"	2'-0"	4 3/8"	5'-4"	2'-0"
5000'	1"	5'-4"	2'-0"	2 5/8"	5'-4"	2'-0"	3 7/8"	5'-4"	2'-0"
20,000'	1/4"	5'-4"	2'-0"	2"	5'-4"	2'-0"	3 1/4"	5'-4"	2'-0"
TANGENT	0"	5'-4"	2'-0"						

RADIUS	SUPERELEVATION = 3"			SUPERELEVATION = 4"		
	X_T	Y	SW	X_T	Y	SW
700'	8 7/8"	5'-4"	1'-11"	10 1/8"	5'-4"	1'-9 1/2"
900'	8 3/4"	5'-4"	2'-0"	9 7/8"	5'-4"	1'-11 1/2"
1200'	8"	5'-4"	2'-0"	9 5/8"	5'-4"	2'-0"
1600'	7 1/8"	5'-4"	2'-0"	8 5/8"	5'-4"	2'-0"
2000'	6 5/8"	5'-4"	2'-0"	8 3/8"	5'-4"	2'-0"
3000'	6 1/8"	5'-4"	2'-0"	7 5/8"	5'-4"	2'-0"
5000'	5 1/2"	5'-4"	2'-0"	7 1/8"	5'-4"	2'-0"
20,000'	4 7/8"	5'-4"	2'-0"	6 1/2"	5'-4"	2'-0"

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FIGURE 11.52

SAFETY WALK AWAY FROM CURVE CENTER

RADIUS	SUPERELEVATION = 0"			SUPERELEVATION = 1"			SUPERELEVATION = 2"		
	X_A	Y	SW	X_A	Y	SW	X_A	Y	SW
700'	4"	5'–4"	1'–9 1/2"	4 3/8"	5'–4"	2'–0"	2 1/2"	5'–4"	1'–11 1/2"
900'	4 1/4"	5'–4"	2'–0"	3 5/8"	5'–4"	2'–0"	2 1/2"	5'–4"	2'–0"
1200'	3 1/2"	5'–4"	2'–0"	2 3/8"	5'–4"	2'–0"	1 1/8"	5'–4"	2'–0"
1600'	2 5/8"	5'–4"	2'–0"	1 1/2"	5'–4"	2'–0"	1/4"	5'–4"	2'–0"
2000'	2"	5'–4"	2'–0"	1"	5'–4"	2'–0"	1/8"	5'–4"	2'–0"
3000'	1 1/2"	5'–4"	2'–0"	1/2"	5'–4"	2'–0"	0"	5'–4"	2'–0"
5000'	1"	5'–4"	2'–0"	0"	5'–4"	2'–0"	0"	5'–4"	2'–0"
20,000'	3/8"	5'–4"	2'–0"	0"	5'–4"	2'–0"	0"	5'–4"	2'–0"
TANGENT	0"	5'–4"	2'–0"						

RADIUS	SUPERELEVATION = 3"			SUPERELEVATION = 4"		
	X_A	Y	SW	X_A	Y	SW
700'	1/4"	5'–4"	1'–10 1/2"	0"	5'–4"	1'–10 1/2"
900'	1 1/8"	5'–4"	2'–0"	0"	5'–4"	2'–0"
1200'	3/8"	5'–4"	2'–0"	0"	5'–4"	2'–0"
1600'	0"	5'–4"	2'–0"	0"	5'–4"	2'–0"
2000'	0"	5'–4"	2'–0"	0"	5'–4"	2'–0"
3000'	0"	5'–4"	2'–0"	0"	5'–4"	2'–0"
5000'	0"	5'–4"	2'–0"	0"	5'–4"	2'–0"
20,000'	0"	5'–4"	2'–0"	0"	5'–4"	2'–0"

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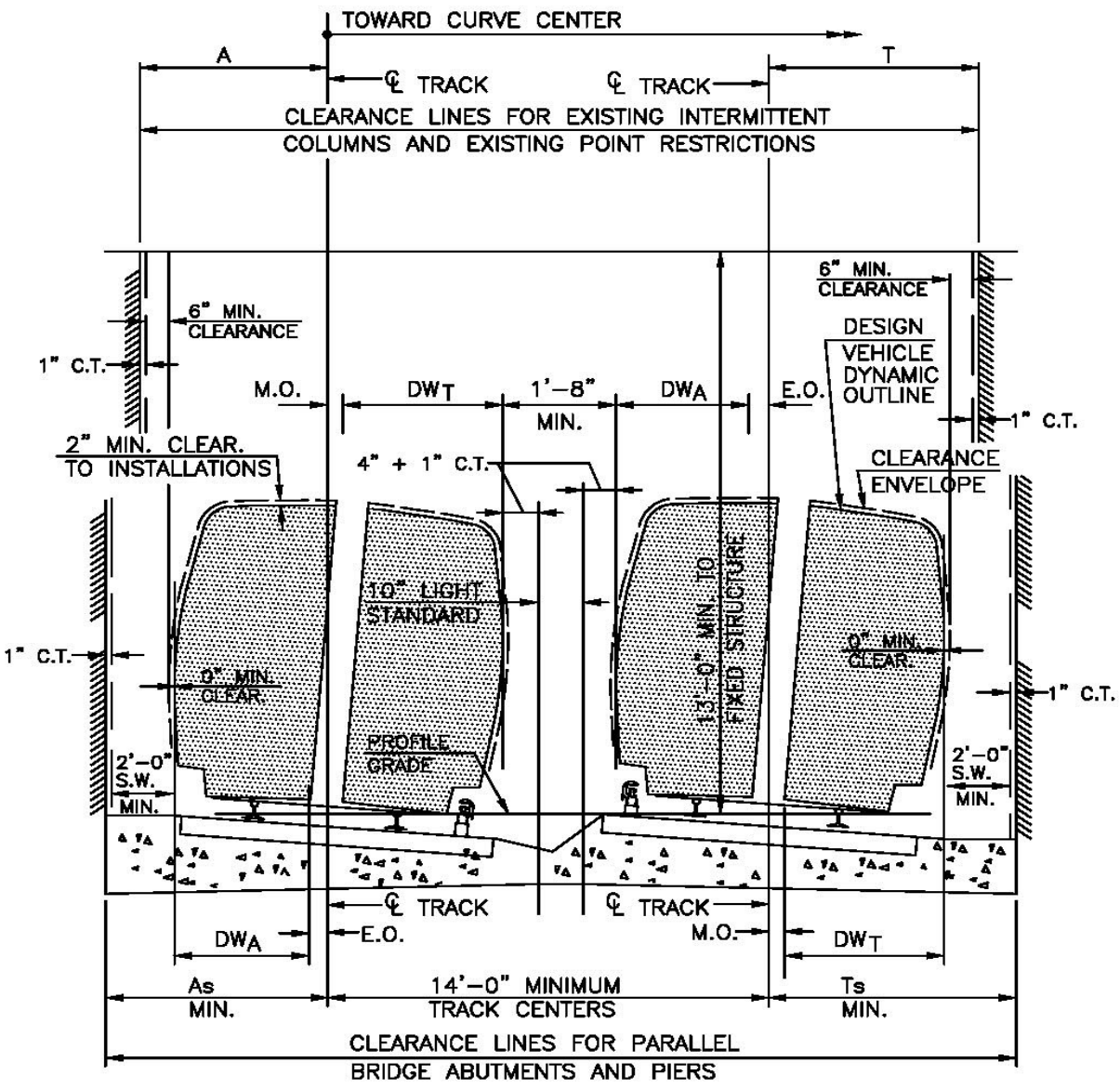
FIGURE 11.53



NOTES:
FOR A, As, T & Ts VALUES SEE FIGURES III.56 TO III.59.
FOR DW_T & DW_A VALUES SEE FIGURES III.30 & III.31.
FOR TRACK CENTERS SEE FIGURE III.55.

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SURFACE TRACK SECTION CLEARANCE DIAGRAM

FIGURE 11.54

RADIUS	TRACK CENTERS						
	SUPERELEVATION						
	0"	1"	2"	3"	4"	5"	6"
200'	16'–0"	16'–0 1/4"	16'–0 1/4"	16'–0 3/8"	16'–0 7/8"	16'–1 1/4"	16'–1 7/8"
300'	14'–10 1/4"	14'–10 1/2"	14'–10 1/2"	14'–10 5/8"	14'–11 1/8"	14'–11 1/2"	15'–0 1/8"
400'	14'–3 1/2"	14'–3 3/4"	14'–3 3/4"	14'–3 7/8"	14'–4 3/8"	14'–4 3/4"	14'–5 3/8"
500'	14'–0"	14'–0"	14'–0"	14'–0"	14'–0"	14'–0"	14'–1 3/8"
600'	14'–0"	14'–0"	14'–0"	14'–0"	14'–0"	14'–0"	14'–0"
TANGENT	14'–0"						

NOTE:
TRACK CENTERS INCLUDE MINIMUM 1'–8" DISTANCE BETWEEN DYNAMIC OUTLINES FOR INSTALLATION OF LIGHT STANDARDS.

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FIGURE 11.55

RADIUS	SUPERELEVATION=0"				SUPERELEVATION=1"			
	A	Ts (MIN.)	As (MIN.)	T	A	Ts (MIN.)	As (MIN.)	T
200'	7'-11"	9'-3"	9'-3"	7'-11"	7'-10"	9'-4 1/4"	9'-2"	8'-0 1/4"
300'	7'-4 1/8"	8'-8 1/8"	8'-8 1/8"	7'-4 1/8"	7'-3 1/8"	8'-9 3/8"	8'-7 1/8"	7'-5 3/8"
400'	7'-0 3/4"	8'-4 3/4"	8'-4 3/4"	7'-0 3/4"	6'-11 3/4"	8'-6"	8'-3 3/4"	7'-2"
500'	6'-10 3/4"	8'-2 3/4"	8'-2 3/4"	6'-10 3/4"	6'-9 3/4"	8'-4"	8'-1 3/4"	7'-0"
600'	6'-9 3/8"	8'-1 3/8"	8'-1 3/8"	6'-9 3/8"	6'-8 3/8"	8'-2 5/8"	8'-0 3/8"	6'-10 5/8"
700'	6'-8 3/8"	8'-0 3/8"	8'-0 3/8"	6'-8 3/8"	6'-7 3/8"	8'-1 5/8"	7'-11 3/8"	6'-9 5/8"
800'	6'-7 3/4"	7'-11 3/4"	7'-11 3/4"	6'-7 3/4"	6'-6 3/4"	8'-1"	7'-10 3/4"	6'-9"
1000'	6'-6 3/4"	7'-10 3/4"	7'-10 3/4"	6'-6 3/4"	6'-5 3/4"	8'-0"	7'-9 3/4"	6'-8"
1200'	6'-6"	7'-10"	7'-10"	6'-6"	6'-5"	7'-11 1/4"	7'-9"	6'-7 1/4"
1400'	6'-5 1/2"	7'-9 1/2"	7'-9 1/2"	6'-5 1/2"	6'-4 1/2"	7'-10 3/4"	7'-8 1/2"	6'-6 3/4"
1600'	6'-5 1/8"	7'-9 1/8"	7'-9 1/8"	6'-5 1/8"	6'-4 1/8"	7'-10 3/8"	7'-8 1/8"	6'-6 3/8"
1800'	6'-4 7/8"	7'-8 7/8"	7'-8 7/8"	6'-4 7/8"	6'-3 7/8"	7'-10 1/8"	7'-7 7/8"	6'-6 1/8"
2000'	6'-4 5/8"	7'-8 5/8"	7'-8 5/8"	6'-4 5/8"	6'-3 5/8"	7'-9 7/8"	7'-7 5/8"	6'-5 7/8"
2500'	6'-4 1/4"	7'-8 1/4"	7'-8 1/4"	6'-4 1/4"	6'-3 1/4"	7'-9 1/2"	7'-7 1/4"	6'-5 1/2"
3000'	6'-4"	7'-8"	7'-8"	6'-4"	6'-3"	7'-9 1/4"	7'-7"	6'-5 1/4"
4000'	6'-3 5/8"	7'-7 5/8"	7'-7 5/8"	6'-3 5/8"	6'-2 5/8"	7'-8 7/8"	7'-6 5/8"	6'-4 7/8"
5000'	6'-3 1/2"	7'-7 1/2"	7'-7 1/2"	6'-3 1/2"	6'-2 1/2"	7'-8 3/4"	7'-6 1/2"	6'-4 3/4"
6000'	6'-3 1/4"	7'-7 1/4"	7'-7 1/4"	6'-3 1/4"	6'-2 1/4"	7'-8 1/2"	7'-6 1/4"	6'-4 1/2"
7000'	6'-3 1/4"	7'-7 1/4"	7'-7 1/4"	6'-3 1/4"	6'-2 1/4"	7'-8 1/2"	7'-6 1/4"	6'-4 1/2"
8000'	6'-3 1/8"	7'-7 1/8"	7'-7 1/8"	6'-3 1/8"	6'-2 1/8"	7'-8 3/8"	7'-6 1/8"	6'-4 3/8"
9000'	6'-3 1/8"	7'-7 1/8"	7'-7 1/8"	6'-3 1/8"	6'-2 1/8"	7'-8 3/8"	7'-6 1/8"	6'-4 3/8"
10,000'	6'-3"	7'-7"	7'-7"	6'-3"	6'-2"	7'-8 1/4"	7'-6"	6'-4 1/4"
15,000'	6'-2 7/8"	7'-6 7/8"	7'-6 7/8"	6'-2 7/8"	6'-1 7/8"	7'-8 1/8"	7'-5 7/8"	6'-4 1/8"
25,000'	6'-2 3/4"	7'-6 3/4"	7'-6 3/4"	6'-2 3/4"	6'-1 3/4"	7'-8"	7'-5 3/4"	6'-4"
TANGENT	6'-2 5/8"	7'-6 5/8"	7'-6 5/8"	6'-2 5/8"				

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FIGURE 11.56

RADIUS	SUPERELEVATION=2"				SUPERELEVATION=3"			
	A	Ts (MIN.)	As (MIN.)	T	A	Ts (MIN.)	As (MIN.)	T
200'	7'–8 7/8"	9'–5 3/8"	9'–0 7/8"	8'–1 3/8"	7'–7 3/4"	9'–6 5/8"	8'–11 3/4"	8'–2 5/8"
300'	7'–2"	8'–10 1/2"	8'–6"	7'–6 1/2"	7'–0 7/8"	8'–11 3/4"	8'–4 7/8"	7'–7 3/4"
400'	6'–10 5/8"	8'–7 1/8"	8'–2 5/8"	7'–3 1/8"	6'–9 1/2"	8'–8 3/8"	8'–1 1/2"	7'–4 3/8"
500'	6'–8 5/8"	8'–5 1/8"	8'–0 5/8"	7'–1 1/8"	6'–7 1/2"	8'–6 3/8"	7'–11 1/2"	7'–2 3/8"
600'	6'–7 1/4"	8'–3 3/4"	7'–11 1/4"	6'–11 3/4"	6'–6 1/8"	8'–5"	7'–10 1/8"	7'–1"
700'	6'–6 1/4"	8'–2 3/4"	7'–10 1/4"	6'–10 3/4"	6'–5 1/8"	8'–4"	7'–9 1/8"	7'–0"
800'	6'–5 5/8"	8'–2 1/8"	7'–9 5/8"	6'–10 1/8"	6'–4 1/2"	8'–3 3/8"	7'–8 1/2"	6'–11 3/8"
1000'	6'–4 5/8"	8'–1 1/8"	7'–8 5/8"	6'–9 1/8"	6'–3 1/2"	8'–2 3/8"	7'–7 1/2"	6'–10 3/8"
1200'	6'–3 7/8"	8'–0 3/8"	7'–7 7/8"	6'–8 3/8"	6'–2 3/4"	8'–1 5/8"	7'–6 3/4"	6'–9 5/8"
1400'	6'–3 3/8"	7'–11 7/8"	7'–7 3/8"	6'–7 7/8"	6'–2 1/4"	8'–1 1/8"	7'–6 1/4"	6'–9 1/8"
1600'	6'–3"	7'–11 1/2"	7'–7"	6'–7 1/2"	6'–1 7/8"	8'–0 3/4"	7'–5 7/8"	6'–8 3/4"
1800'	6'–2 3/4"	7'–11 1/4"	7'–6 3/4"	7'–7 1/4"	6'–1 5/8"	8'–0 1/2"	7'–5 5/8"	6'–8 1/2"
2000'	6'–2 1/2"	7'–11"	7'–6 1/2"	6'–7"	6'–1 3/8"	8'–0 1/4"	7'–5 3/8"	6'–8 1/4"
2500'	6'–2 1/8"	7'–10 5/8"	7'–6 1/8"	6'–6 5/8"	6'–1"	7'–11 7/8"	7'–5"	6'–7 7/8"
3000'	6'–1 7/8"	7'–10 3/8"	7'–5 7/8"	6'–6 3/8"	6'–0 3/4"	7'–11 5/8"	7'–4 3/4"	6'–7 5/8"
4000'	6'–1 1/2"	7'–10"	7'–5 1/2"	6'–6"	6'–0 3/8"	7'–11 1/4"	7'–4 3/8"	6'–7 1/4"
5000'	6'–1 3/8"	7'–9 7/8"	7'–5 3/8"	6'–5 7/8"	6'–0 1/4"	7'–11 1/8"	7'–4 1/4"	6'–7 1/8"
6000'	6'–1 1/8"	7'–9 5/8"	7'–5 1/8"	6'–5 5/8"	6'–0"	7'–10 7/8"	7'–4"	6'–6 7/8"
7000'	6'–1 1/8"	7'–9 5/8"	7'–5 1/8"	6'–5 5/8"	6'–0"	7'–10 7/8"	7'–4"	6'–6 7/8"
8000'	6'–1"	7'–9 1/2"	7'–5"	6'–5 1/2"	5'–11 7/8"	7'–10 3/4"	7'–3 7/8"	6'–6 3/4"
9000'	6'–1"	7'–9 1/2"	7'–5"	6'–5 1/2"				
10,000'	6'–0 7/8"	7'–9 3/8"	7'–4 7/8"	6'–5 3/8"				
15,000'	6'–0 3/4"	7'–9 1/4"	7'–4 3/4"	6'–5 1/4"				

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FIGURE 11.57

RADIUS	SUPERELEVATION=4"				SUPERELEVATION=5"			
	A	Ts (MIN.)	As (MIN.)	T	A	Ts (MIN.)	As (MIN.)	T
200'	7'–7"	9'–7 7/8"	8'–11"	8'–3 7/8"	7'–6 1/4"	9'–9"	8'–10 1/4"	8'–5"
300'	7'–0 1/8"	9'–1"	8'–4 1/8"	7'–9"	6'–11 3/8"	9'–2 1/8"	8'–3 3/8"	7'–10 1/8"
400'	6'–8 3/4"	8'–9 5/8"	8'–0 3/4"	7'–5 5/8"	6'–8"	8'–10 3/4"	8'–0"	7'–6 3/4"
500'	6'–6 3/4"	8'–7 5/8"	7'–10 3/4"	7'–3 5/8"	6'–6"	8'–8 3/4"	7'–10"	7'–4 3/4"
600'	6'–5 3/8"	8'–6 1/4"	7'–9 3/8"	7'–2 1/4"	6'–4 5/8"	8'–7 3/8"	7'–8 5/8"	7'–3 3/8"
700'	6'–4 3/8"	8'–5 1/4"	7'–8 3/8"	7'–1 1/4"	6'–3 5/8"	8'–6 3/8"	7'–7 5/8"	7'–2 3/8"
800'	6'–3 3/4"	8'–4 5/8"	7'–7 3/4"	7'–0 5/8"	6'–3"	8'–5 3/4"	7'–7"	7'–1 3/4"
1000'	6'–2 3/4"	8'–3 5/8"	7'–6 3/4"	6'–11 5/8"	6'–2"	8'–4 3/4"	7'–6"	7'–0 3/4"
1200'	6'–2"	8'–2 7/8"	7'–6"	6'–10 7/8"	6'–1 1/4"	8'–4"	7'–5 1/4"	7'–0"
1400'	6'–1 1/2"	8'–2 3/8"	7'–5 1/2"	6'–10 3/8"	6'–0 3/4"	8'–3 1/2"	7'–4 3/4"	6'–11 1/2"
1600'	6'–1 1/8"	8'–2"	7'–5 1/8"	6'–10"	6'–0 3/8"	8'–3 1/8"	7'–4 3/8"	6'–11 1/8"
1800'	6'–0 7/8"	8'–1 3/4"	7'–4 7/8"	6'–9 3/4"	6'–0 1/8"	8'–2 7/8"	7'–4 1/8"	6'–10 7/8"
2000'	6'–0 5/8"	8'–1 1/2"	7'–4 5/8"	6'–9 1/2"	5'–11 7/8"	8'–2 5/8"	7'–3 7/8"	6'–10 5/8"
2500'	6'–0 1/4"	8'–1 1/8"	7'–4 1/4"	6'–9 1/8"	5'–11 1/2"	8'–2 1/4"	7'–3 1/2"	6'–10 1/4"
3000'	6'–0"	8'–0 7/8"	7'–4"	6'–8 7/8"	5'–11 1/4"	8'–2"	7'–3 1/4"	6'–10"
4000'	5'–11 5/8"	8'–0 1/2"	7'–3 5/8"	6'–8 1/2"	5'–10 7/8"	8'–1 5/8"	7'–2 7/8"	6'–9 5/8"
5000'	5'–11 1/2"	8'–0 3/8"	7'–3 1/2"	6'–8 3/8"	5'–10 3/4"	8'–1 1/2"	7'–2 3/4"	6'–9 1/2"
6000'	5'–11 1/4"	8'–0 1/8"	7'–3 1/4"	6'–8 1/8"				

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FIGURE 11.58

RADIUS	SUPERELEVATION=6"							
	A	Ts (MIN.)	As (MIN.)	T				
200'	7'-5 5/8"	9'-10 1/4"	8'-9 5/8"	8'-6 1/4"				
300'	6'-10 3/4"	9'-3 3/8"	8'-2 3/4"	7'-11 3/8"				
400'	6'-7 3/8"	9'-0"	7'-11 3/8"	7'-8"				
500'	6'-5 3/8"	8'-10"	7'-9 3/8"	7'-6"				
600'	6'-4"	8'-8 5/8"	7'-8"	7'-4 5/8"				
700'	6'-3"	8'-7 5/8"	7'-7"	7'-3 5/8"				
800'	6'-2 3/8"	8'-7"	7'-6 3/8"	7'-3"				
1000'	6'-1 3/8"	8'-6"	7'-5 3/8"	7'-2"				
1200'	6'-0 5/8"	8'-5 1/4"	7'-4 5/8"	7'-1 1/4"				
1400'	6'-0 1/8"	8'-4 3/4"	7'-4 1/8"	7'-0 3/4"				
1600'	5'-11 3/4"	8'-4 3/8"	7'-3 3/4"	7'-0 3/8"				
1800'	5'-11 1/2"	8'-4 1/8"	7'-3 1/2"	7'-0 1/8"				
2000'	5'-11 1/4"	8'-3 7/8"	7'-3 1/4"	6'-11 7/8"				
2500'	5'-10 7/8"	8'-3 1/2"	7'-2 7/8"	6'-11 1/2"				
3000'	5'-10 5/8"	8'-3 1/4"	7'-2 5/8"	6'-11 1/4"				
4000'	5'-10 1/4"	8'-2 7/8"	7'-2 1/4"	6'-10 7/8"				

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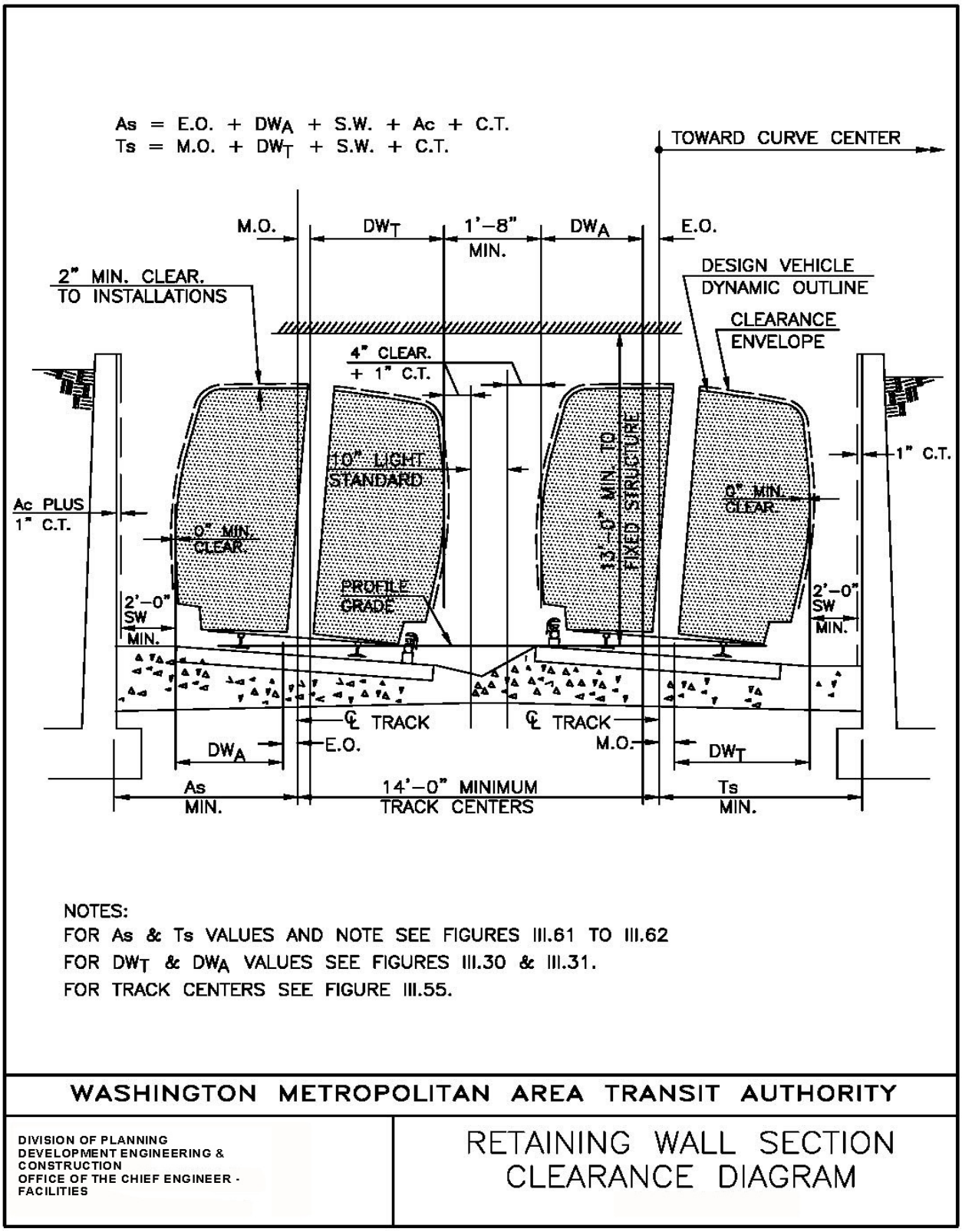
FIGURE 11.59



NOTES:
FOR As & Ts VALUES AND NOTE SEE FIGURES III.61 TO III.62
FOR DW_T & DW_A VALUES SEE FIGURES III.30 & III.31.
FOR TRACK CENTERS SEE FIGURE III.55.

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RETAINING WALL SECTION CLEARANCE DIAGRAM

FIGURE 11.60

RADIUS	S.E.=0"		S.E.=1"		S.E.=2"		S.E.=3"	
	As (MIN.)	Ts (MIN.)	As (MIN.)	Ts (MIN.)	As (MIN.)	Ts (MIN.)	As (MIN.)	Ts (MIN.)
200'	9'-8 1/4"	9'-3"	9'-7 1/4"	9'-4 1/4"	9'-6 1/8"	9'-5 3/8"	9'-5"	9'-6 5/8"
300'	8'-11 1/2"	8'-8 1/8"	8'-10 1/2"	8'-9 3/8"	8'-9 3/8"	8'-10 1/2"	8'-8 1/4"	8'-11 3/4"
400'	8'-7 1/4"	8'-4 3/4"	8'-6 1/4"	8'-6"	8'-5 1/8"	8'-7 1/8"	8'-4"	8'-8 3/8"
500'	8'-4 3/4"	8'-2 3/4"	8'-3 3/4"	8'-4"	8'-2 5/8"	8'-5 1/8"	8'-1 1/2"	8'-6 3/8"
600'	8'-3"	8'-1 3/8"	8'-2"	8'-2 5/8"	8'-0 7/8"	8'-3 3/4"	7'-11 3/4"	8'-5"
700'	8'-1 3/4"	8'-0 3/8"	8'-0 3/4"	8'-1 5/8"	7'-11 5/8"	8'-2 3/4"	7'-10 1/2"	8'-4"
800'	8'-1"	7'-11 3/4"	8'-0"	8'-1"	7'-10 7/8"	8'-2 1/8"	7'-9 3/4"	8'-3 3/8"
1000'	7'-11 3/4"	7'-10 3/4"	7'-10 3/4"	8'-0"	7'-9 5/8"	8'-1 1/8"	7'-8 1/2"	8'-2 3/8"
1200'	7'-10 7/8"	7'-10"	7'-9 7/8"	7'-11 1/4"	7'-8 3/4"	8'-0 3/8"	7'-7 5/8"	8'-1 5/8"
1400'	7'-10 1/4"	7'-9 1/2"	7'-9 1/4"	7'-10 3/4"	7'-8 1/8"	7'-11 7/8"	7'-7"	8'-1 1/8"
1600'	7'-9 3/4"	7'-9 1/8"	7'-8 3/4"	7'-10 3/8"	7'-7 5/8"	7'-11 1/2"	7'-6 1/2"	8'-0 3/4"
1800'	7'-9 3/8"	7'-8 7/8"	7'-8 3/8"	7'-10 1/8"	7'-7 1/4"	7'-11 1/4"	7'-6 1/8"	8'-0 1/2"
2000'	7'-9 1/8"	7'-8 5/8"	7'-8 1/8"	7'-9 7/8"	7'-7"	7'-11"	7'-5 7/8"	8'-0 1/4"
2500'	7'-9 3/4"	7'-8 1/4"	7'-8 3/4"	7'-9 1/2"	7'-7 5/8"	7'-10 5/8"	7'-6 1/2"	7'-11 7/8"
3000'	7'-9 1/4"	7'-8"	7'-8 1/4"	7'-9 1/4"	7'-7 1/8"	7'-10 3/8"	7'-6"	7'-11 5/8"
4000'	7'-8 5/8"	7'-7 5/8"	7'-7 5/8"	7'-8 7/8"	7'-6 1/2"	7'-10"	7'-5 3/8"	7'-11 1/4"
5000'	7'-8 1/4"	7'-7 1/2"	7'-7 1/4"	7'-8 3/4"	7'-6 1/8"	7'-9 7/8"	7'-5"	7'-11 1/8"
6000'	7'-7 7/8"	7'-7 1/4"	7'-6 7/8"	7'-7 1/2"	7'-5 3/4"	7'-9 5/8"	7'-4 5/8"	7'-10 7/8"
7000'	7'-7 3/4"	7'-7 1/4"	7'-6 3/4"	7'-7 1/2"	7'-5 5/8"	7'-9 5/8"	7'-4 1/2"	7'-10 7/8"
8000'	7'-7 5/8"	7'-7 1/8"	7'-6 5/8"	7'-8 3/8"	7'-5 1/2"	7'-9 1/2"	7'-4 3/8"	7'-10 3/4"
9000'	7'-7 1/2"	7'-7 1/8"	7'-6 1/2"	7'-8 3/8"	7'-5 3/8"	7'-9 1/2"		
10,000'	7'-7 3/8"	7'-7"	7'-6 3/8"	7'-8 1/4"	7'-5 1/4"	7'-9 3/8"		
15,000'	7'-7 1/8"	7'-6 7/8"	7'-6 1/8"	7'-8 1/8"	7'-5"	7'-9 1/4"		
25,000'	7'-6 7/8"	7'-6 3/4"	7'-5 7/8"	7'-8"				
TANGENT	7'-6 5/8"	7'-6 5/8"						

NOTE: THE MINIMUM CLEARANCE BETWEEN ℄ OF TRACK AND FACE OF WALL SHALL BE 8'-6" IF A CLOSED DRAINAGE SYSTEM IS INSTALLED BETWEEN THE TRACK AND THE WALL.

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FIGURE 11.61

RADIUS	S.E.=4"		S.E.=5"		S.E.=6"			
	As (MIN.)	Ts (MIN.)	As (MIN.)	Ts (MIN.)	As (MIN.)	Ts (MIN.)		
200'	9'-4 1/4"	9'-7 7/8"	9'-3 1/2"	9'-9"	9'-2 7/8"	9'-10 1/4"		
300'	8'-7 1/2"	9'-1"	8'-6 3/4"	9'-2 1/8"	8'-6 1/8"	9'-3 3/8"		
400'	8'-3 1/4"	8'-9 5/8"	8'-2 1/2"	8'-10 3/4"	8'-1 7/8"	9'-0"		
500'	8'-0 3/4"	8'-7 5/8"	8'-0"	8'-8 3/4"	7'-11 3/8"	8'-10"		
600'	7'-11"	8'-6 1/4"	7'-10 1/4"	8'-7 3/8"	7'-9 5/8"	8'-8 5/8"		
700'	7'-9 3/4"	8'-5 1/4"	7'-9"	8'-6 3/8"	7'-8 3/8"	8'-7 5/8"		
800'	7'-9"	8'-4 5/8"	7'-8 1/4"	8'-5 3/4"	7'-7 5/8"	8'-7"		
1000'	7'-7 3/4"	8'-3 5/8"	7'-7"	8'-4 3/4"	7'-6 3/8"	8'-6"		
1200'	7'-6 7/8"	8'-2 7/8"	7'-6 1/8"	8'-4"	7'-5 1/2"	8'-5 1/4"		
1400'	7'-6 1/4"	8'-2 3/8"	7'-5 1/2"	8'-3 1/2"	7'-4 7/8"	8'-4 3/4"		
1600'	7'-5 3/4"	8'-2"	7'-5"	8'-3 1/8"	7'-4 3/8"	8'-4 3/8"		
1800'	7'-5 3/8"	8'-1 3/4"	7'-4 5/8"	8'-2 7/8"	7'-4"	8'-4 1/8"		
2000'	7'-5 1/8"	8'-1 1/2"	7'-4 3/8"	8'-2 5/8"	7'-3 3/4"	8'-3 7/8"		
2500'	7'-5 3/4"	8'-1 1/8"	7'-5"	8'-2 1/4"	7'-4 3/8"	8'-3 1/2"		
3000'	7'-5 1/4"	8'-0 7/8"	7'-4 1/2"	8'-2"	7'-3 7/8"	8'-3 1/4"		
4000'	7'-4 5/8"	8'-0 1/2"	7'-3 7/8"	8'-1 5/8"	7'-3 1/4"	8'-2 7/8"		
5000'	7'-4 1/4"	8'-0 3/8"	7'-3 1/2"	8'-1 1/2"				
6000'	7'-3 7/8"	8'-0 1/8"						

NOTE: THE MINIMUM CLEARANCE BETWEEN ℄ OF TRACK AND FACE OF WALL SHALL BE 8'-6" IF A CLOSED DRAINAGE SYSTEM IS INSTALLED BETWEEN THE TRACK AND THE WALL.

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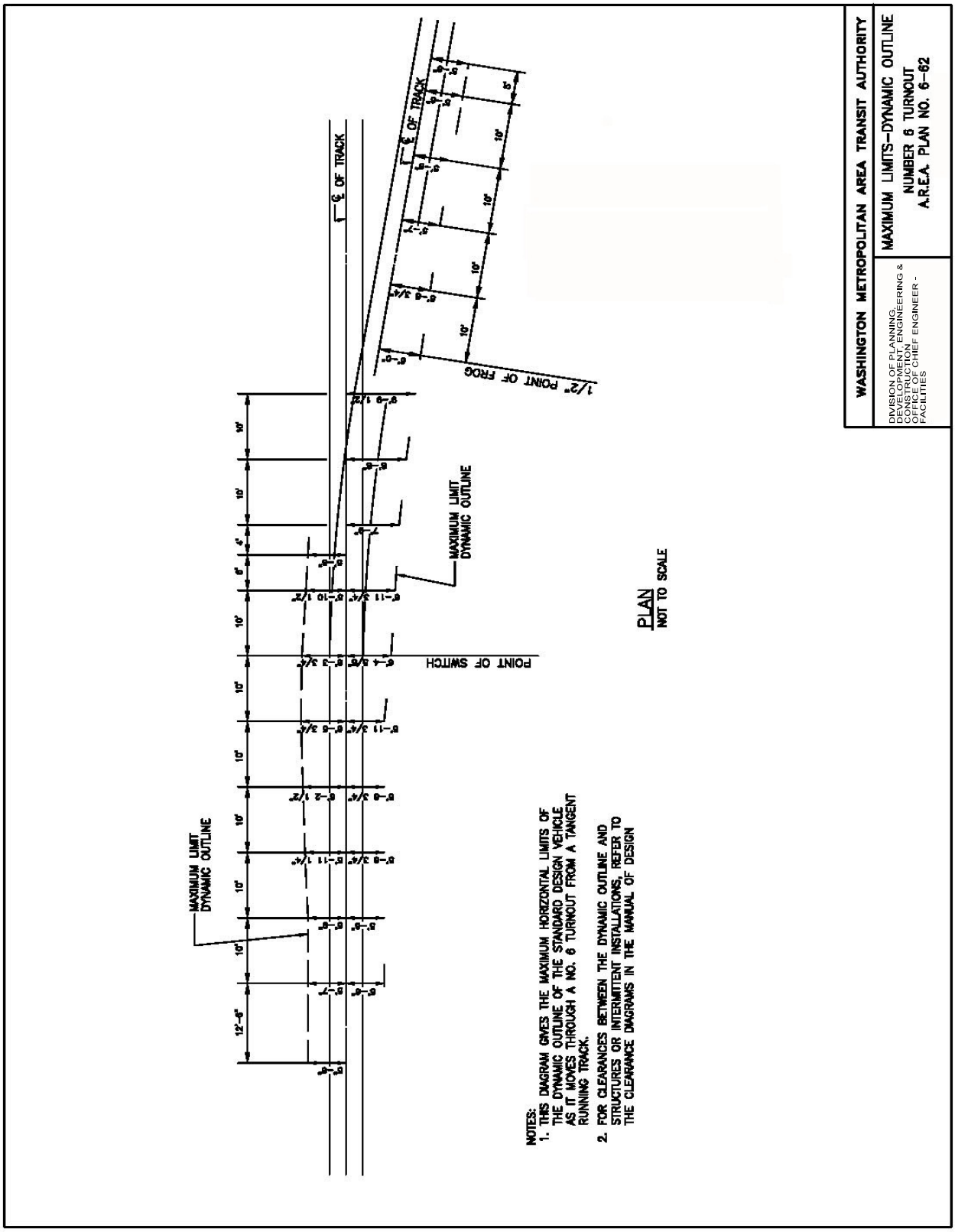
FIGURE 11.62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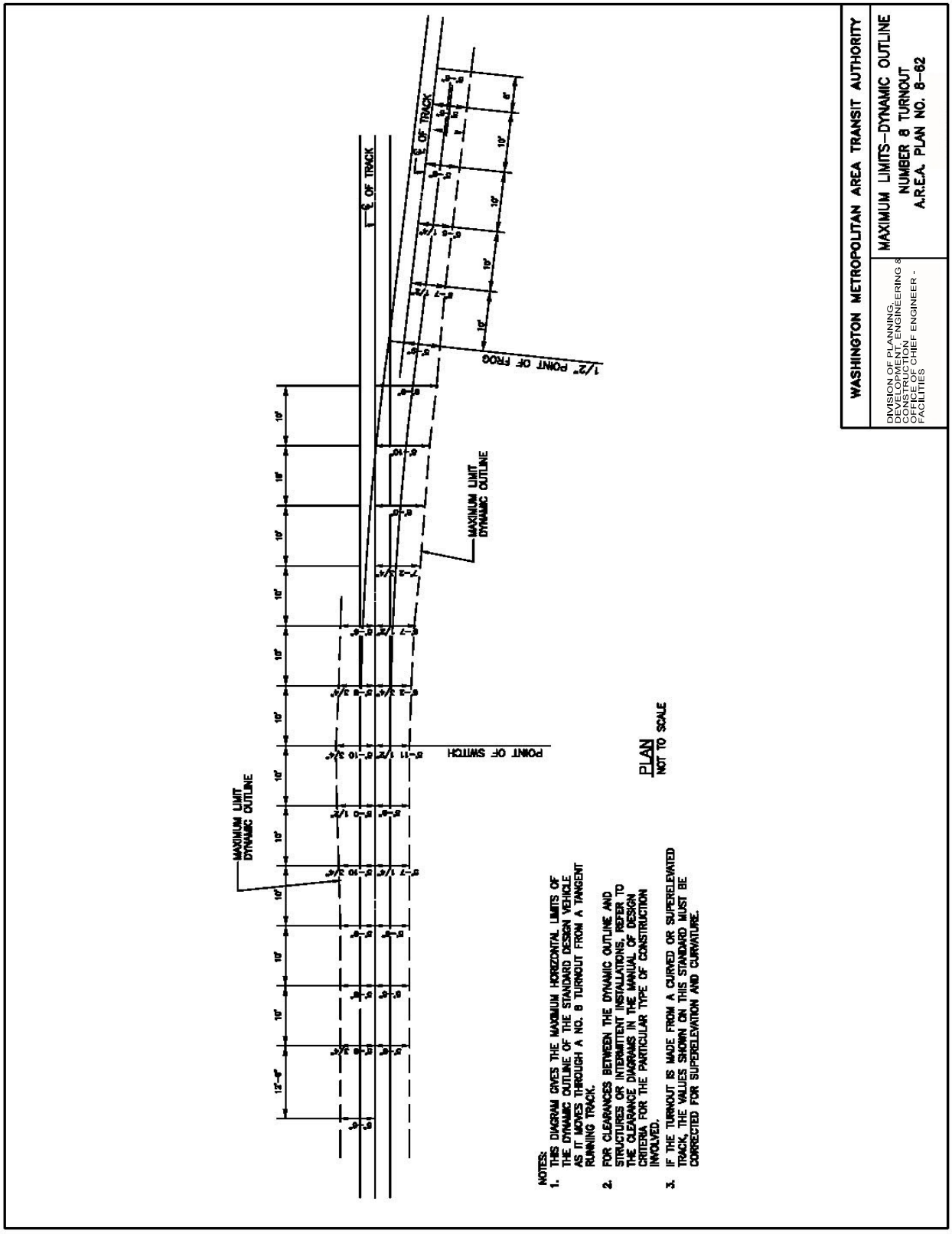
MAXIMUM LIMITS-DYNAMIC OUTLINE
NUMBER 6 TURNOUT
A.R.E.A. PLAN NO. 6-62
PLAN
NOT TO SCALE
MAXIMUM LIMIT DYNAMIC OUTLINE
MAXIMUM LIMIT DYNAMIC OUTLINE
℄ OF TRACK
℄ OF TRACK
1/2" POINT OF FROG
POINT OF SWITCH
NOTES:
1. THIS DIAGRAM GIVES THE MAXIMUM HORIZONTAL LIMITS OF THE DYNAMIC OUTLINE OF THE STANDARD DESIGN VEHICLE AS IT MOVES THROUGH A NO. 6 TURNOUT FROM A TANGENT RUNNING TRACK.
2. FOR CLEARANCES BETWEEN THE DYNAMIC OUTLINE AND STRUCTURES OR INTERMITTENT INSTALLATIONS, REFER TO THE CLEARANCE DIAGRAMS IN THE MANUAL OF DESIGN

FIGURE 11.63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MAXIMUM LIMITS–DYNAMIC OUTLINE
NUMBER 8 TURNOUT
A.R.E.A. PLAN NO. 8–62
DIVISION OF PLANNING, DEVELOPMENT, ENGINEERING & CONSTRUCTION
OFFICE OF CHIEF ENGINEER - FACILITIES
MAXIMUM LIMIT DYNAMIC OUTLINE
MAXIMUM LIMIT DYNAMIC OUTLINE
POINT OF SWITCH
1/2" POINT OF FROG
℄ OF TRACK
℄ OF TRACK
PLAN
NOT TO SCALE
NOTES:
1. THIS DIAGRAM GIVES THE MAXIMUM HORIZONTAL LIMITS OF THE DYNAMIC OUTLINE OF THE STANDARD DESIGN VEHICLE AS IT MOVES THROUGH A NO. 8 TURNOUT FROM A TANGENT RUNNING TRACK.
2. FOR CLEARANCES BETWEEN THE DYNAMIC OUTLINE AND STRUCTURES OR INTERMITTENT INSTALLATIONS, REFER TO THE CLEARANCE DIAGRAMS IN THE MANUAL OF DESIGN CRITERIA FOR THE PARTICULAR TYPE OF CONSTRUCTION INVOLVED.
3. IF THE TURNOUT IS MADE FROM A CURVED OR SUPERELEVATED TRACK, THE VALUES SHOWN ON THIS STANDARD MUST BE CORRECTED FOR SUPERELEVATION AND CURVATURE.

FIGURE 11.64

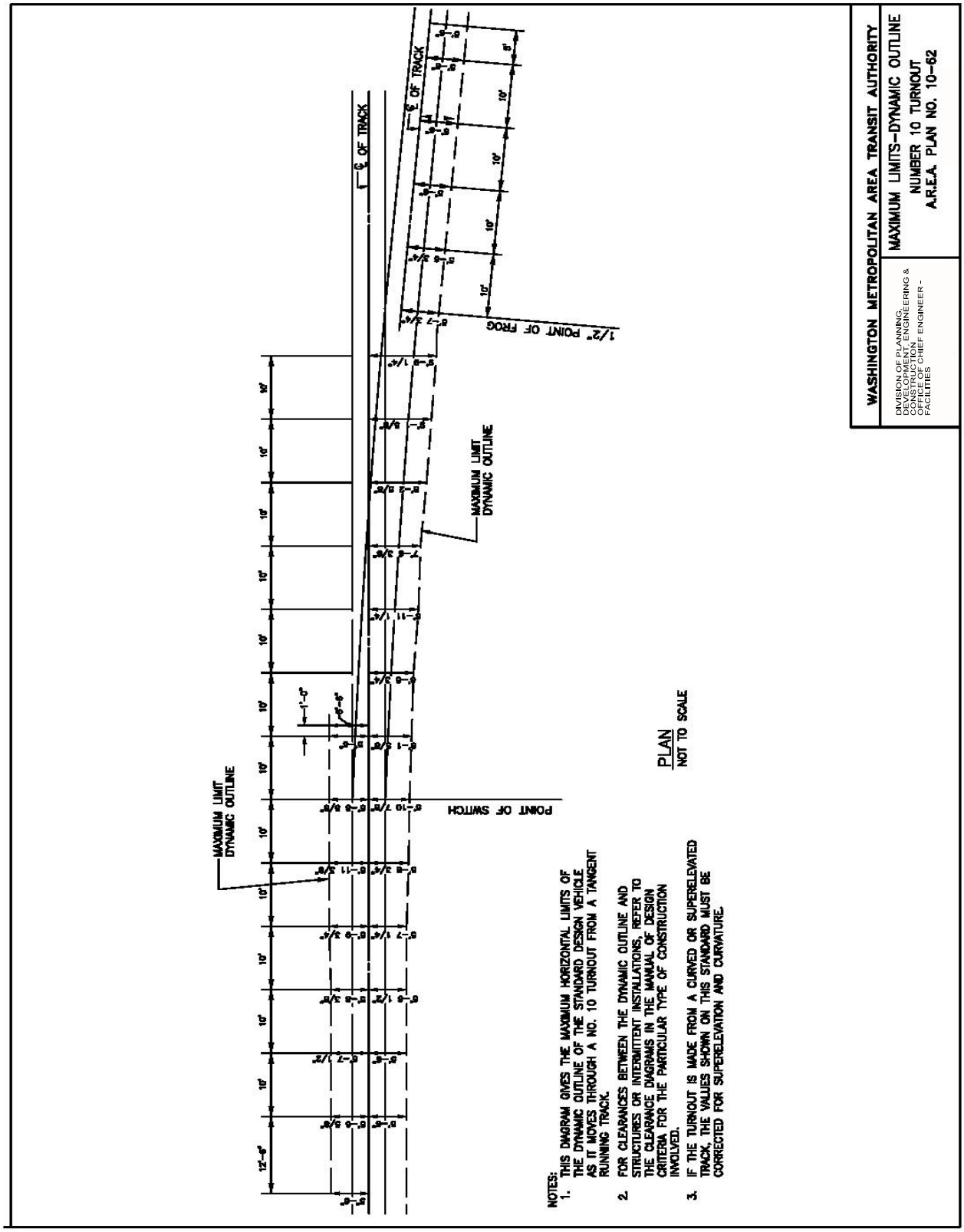

WASHINGTON METROPOLITAN AREA TRANSIT AUTHORITY
DIVISION OF PLANNING, DEVELOPMENT, ENGINEERING & CONSTRUCTION - OFFICE OF CHIEF ENGINEER - FACILITIES
MAXIMUM LIMITS-DYNAMIC OUTLINE
NUMBER 10 TURNOUT
A.R.E.A. PLAN NO. 10-62
℄ OF TRACK
℄ OF TRACK
1/2" POINT OF FROG
MAXIMUM LIMIT DYNAMIC OUTLINE
MAXIMUM LIMIT DYNAMIC OUTLINE
POINT OF SWITCH
PLAN
NOT TO SCALE
NOTES:
1. THIS DIAGRAM GIVES THE MAXIMUM HORIZONTAL LIMITS OF THE DYNAMIC OUTLINE OF THE STANDARD DESIGN VEHICLE AS IT MOVES THROUGH A NO. 10 TURNOUT FROM A TANGENT RUNNING TRACK.
2. FOR CLEARANCES BETWEEN THE DYNAMIC OUTLINE AND STRUCTURES OR INTERMITTENT INSTALLATIONS, REFER TO THE CLEARANCE DIAGRAMS IN THE MANUAL OF DESIGN CRITERIA FOR THE PARTICULAR TYPE OF CONSTRUCTION INVOLVED.
3. IF THE TURNOUT IS MADE FROM A CURVED OR SUPERELEVATED TRACK, THE VALUES SHOWN ON THIS STANDARD MUST BE CORRECTED FOR SUPERELEVATION AND CURVATURE.

FIGURE 11.65

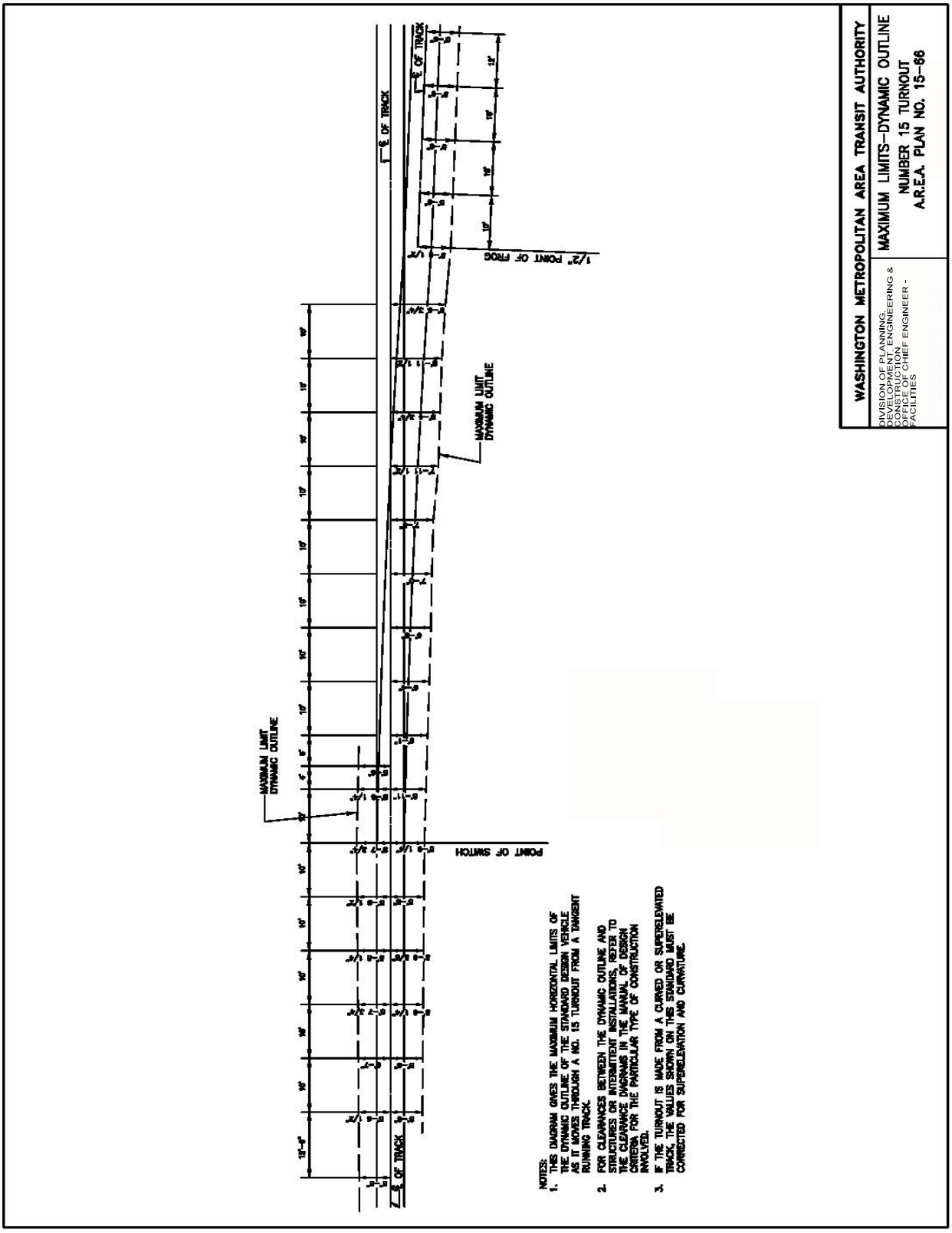
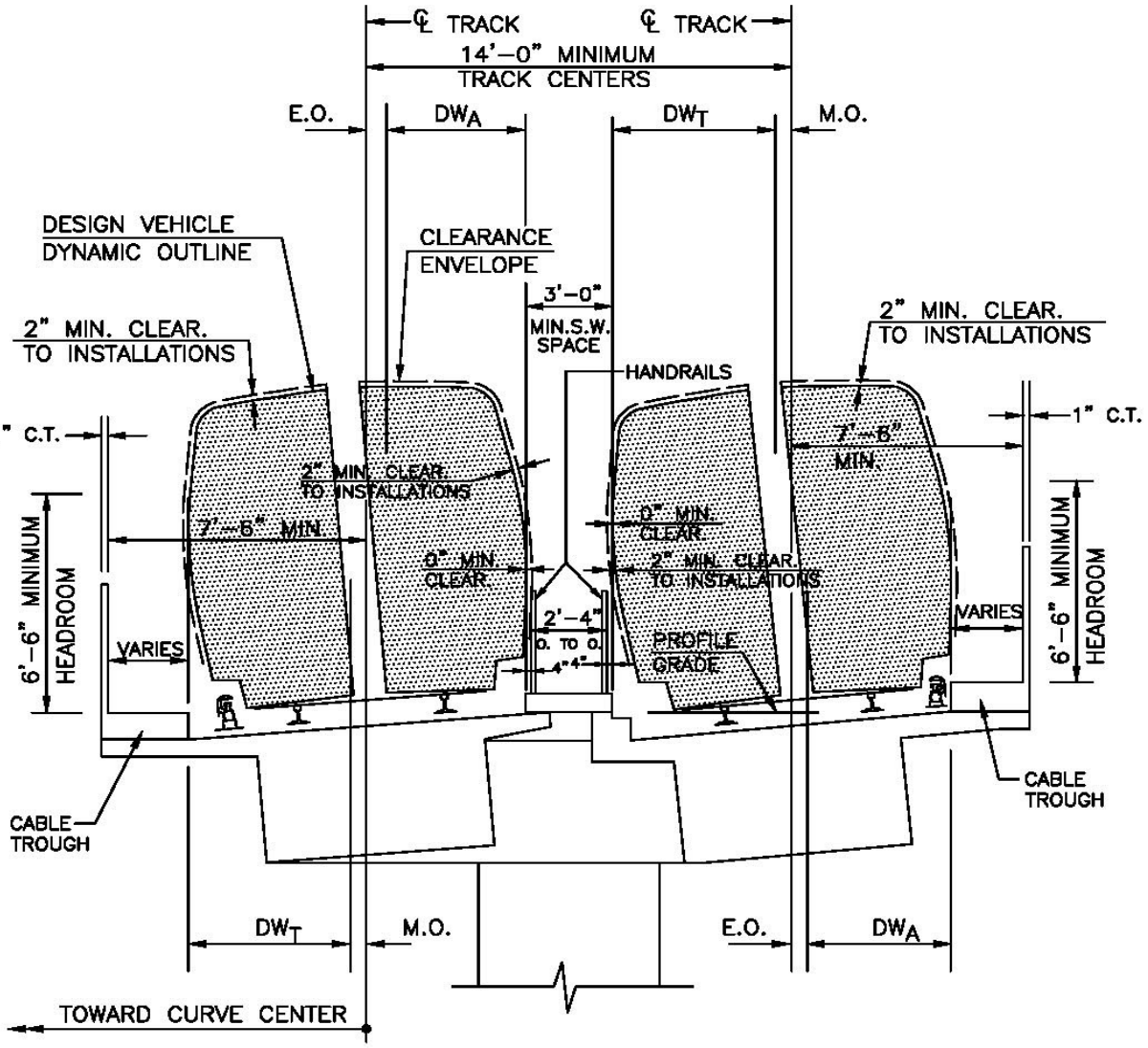

WASHINGTON METROPOLITAN AREA TRANSIT AUTHORITY
DIVISION OF PLANNING, DEVELOPMENT, ENGINEERING & CONSTRUCTION OFFICE OF CHIEF ENGINEER - FACILITIES
MAXIMUM LIMITS—DYNAMIC OUTLINE
NUMBER 15 TURNOUT
A.R.E.A. PLAN NO. 15-66
MAXIMUM LIMIT DYNAMIC OUTLINE
MAXIMUM LIMIT DYNAMIC OUTLINE
℄ OF TRACK
℄ OF TRACK
℄ OF TRACK
1/2" POINT OF FROG
POINT OF SWITCH
NOTES:
1. THIS DIAGRAM GIVES THE MAXIMUM HORIZONTAL LIMITS OF THE DYNAMIC OUTLINE OF THE STANDARD DESIGN VEHICLE AS IT MOVES THROUGH A NO. 15 TURNOUT FROM A TANGENT RUNNING TRACK.
2. FOR CLEARANCES BETWEEN THE DYNAMIC OUTLINE AND STRUCTURES OR INTERMITTENT INSTALLATIONS, REFER TO THE CLEARANCE DIAGRAMS IN THE MANUAL OF DESIGN CRITERIA FOR THE PARTICULAR TYPE OF CONSTRUCTION INVOLVED.
3. IF THE TURNOUT IS MADE FROM A CURVED OR SUPERELEVATED TRACK, THE VALUES SHOWN ON THIS STANDARD MUST BE CORRECTED FOR SUPERELEVATION AND CURVATURE.

FIGURE 11.66



NOTES:
FOR TRACK CENTERS SEE FIGURES III.68.
FOR DW_T & DW_A VALUES SEE FIGURES III.30 & III.31.

WASHINGTON METROPOLITAN AREA TRANSIT AUTHORITY

DIVISION OF PLANNING
DEVELOPMENT ENGINEERING & CONSTRUCTION
OFFICE OF THE CHIEF ENGINEER - FACILITIES

AERIAL STRUCTURE
DOUBLE TRACK SECTION
CLEARANCE DIAGRAM

FIGURE 11.67

RADIUS	TRACK CENTERS						
	SUPERELEVATION						
	0"	1"	2"	3"	4"	5"	6"
500'	15'–3 1/2"	15'–3 3/4"	15'–3 3/4"	15'–3 7/8"	15'–4 3/8"	15'–4 3/4"	15'–5 3/8"
600'	15'–0 3/4"	15'–1"	15'–1"	15'–1 1/8"	15'–1 5/8"	15'– 2"	15'–2 5/8"
700'	14'–10 3/4"	14'–11"	14'–11"	14'–11 1/8"	14'–11 5/8"	15'–0"	15'–0 5/8"
800'	14'–9 1/2"	14'–9 3/4"	14'–9 3/4"	14'–9 7/8"	14'–10 3/8"	14'–10 3/4"	14'–11 3/8"
1000'	14'–7 1/2"	14'–7 3/4"	14'–7 3/4"	14'–7 7/8"	14'–8 3/8"	14'–8 3/4"	14'–9 3/8"
1200'	14'–6"	14'–6 1/4"	14'–6 1/4"	14'–6 3/8"	14'–6 7/8"	14'–7 1/4"	14'–7 7/8"
1400'	14'–5"	14'–5 1/4"	14'–5 1/4"	14'–5 3/8"	14'–5 7/8"	14'–6 1/4"	14'–6 7/8"
1600'	14'–4 1/4"	14'–4 1/2"	14'–4 1/2"	14'–4 5/8"	14'–5 1/8"	14'–5 1/2"	14'–6 1/8"
1800'	14'–3 3/4"	14'–4"	14'–4"	14'–4 1/8"	14'–4 5/8"	14'–5"	14'–5 5/8"
2000'	14'–3 1/4"	14'–3 1/2"	14'–3 1/2"	14'–3 5/8"	14'–4 1/8"	14'–4 1/2"	14'–5 1/8"
2500'	14'–2 1/2"	14'–2 3/4"	14'–2 3/4"	14'–2 7/8"	14'–3 3/8"	14'–3 3/4"	14'–4 3/8"
3000'	14'–2"	14'–2 1/4"	14'–2 1/4"	14'–2 3/8"	14'–2 7/8"	14'–3 1/4"	14'–3 7/8"
4000'	14'–1 1/4"	14'–1 1/2"	14'–1 1/2"	14'–1 5/8"	14'–2 1/8"	14'–2 1/2"	14'–3 1/8"
5000'	14'–0 3/4"	14'–1 1/4"	14'–1 1/4"	14'–1 3/8"	14'–1 7/8"	14'–2 1/4"	
6000'	14'–0 1/2"	14'–0 3/4"	14'–0 3/4"	14'–0 7/8"	14'–1 3/8"		
7000'	14'–0 1/4"	14'–0 1/2"	14'–0 1/2"	14'–0 5/8"			
8000'	14'–0"	14'–0 1/4"	14'–0 1/4"	14'–0 3/8"			
9000'	14'–0"	14'–0"	14'–0"				
10,000'	14'–0"	14'–0"	14'–0"				
15,000'	14'–0"	14'–0"	14'–0"				
20,000'	14'–0"	14'–0"					
25,000'	14'–0"	14'–0"					
TANGENT	14'–0"						

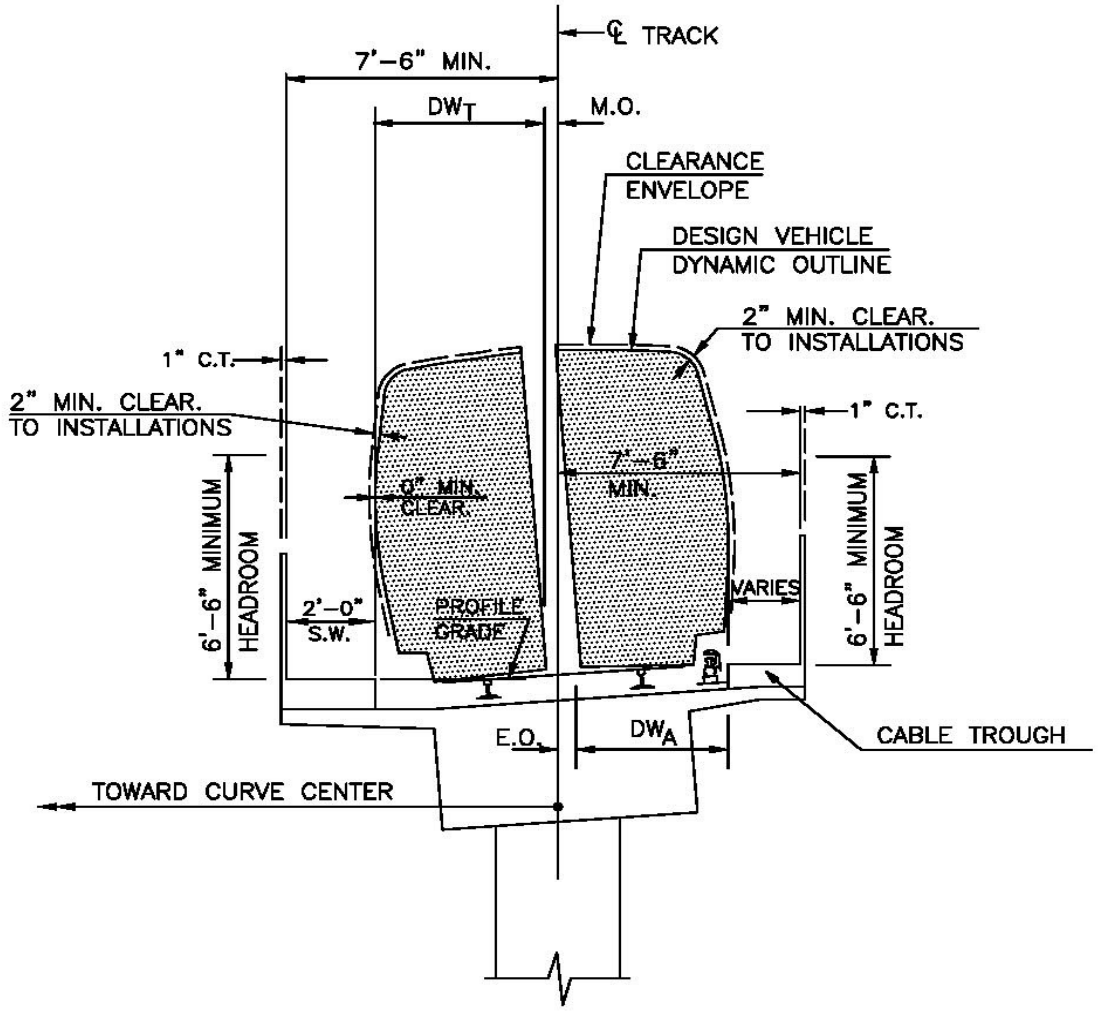
NOTE:
TRACK CENTERS INCLUDE MINIMUM 3'–0" DISTANCE BETWEEN DYNAMIC OUTLINES.

WASHINGTON METROPOLITAN AREA TRANSIT AUTHORITY

DIVISION OF PLANNING
DEVELOPMENT ENGINEERING & CONSTRUCTION
OFFICE OF THE CHIEF ENGINEER - FACILITIES

AERIAL STRUCTURE–DOUBLE TRACK
DESIGN TABLES

FIGURE 11.68



NOTES:

FOR DW_T & DW_A VALUES SEE FIGURES III.30 & III.31.

WASHINGTON METROPOLITAN AREA TRANSIT AUTHORITY

DIVISION OF PLANNING
DEVELOPMENT ENGINEERING & CONSTRUCTION
OFFICE OF THE CHIEF ENGINEER - FACILITIES

AERIAL STRUCTURE
SINGLE TRACK SECTION
CLEARANCE DIAGRAM

FIGURE 11.69

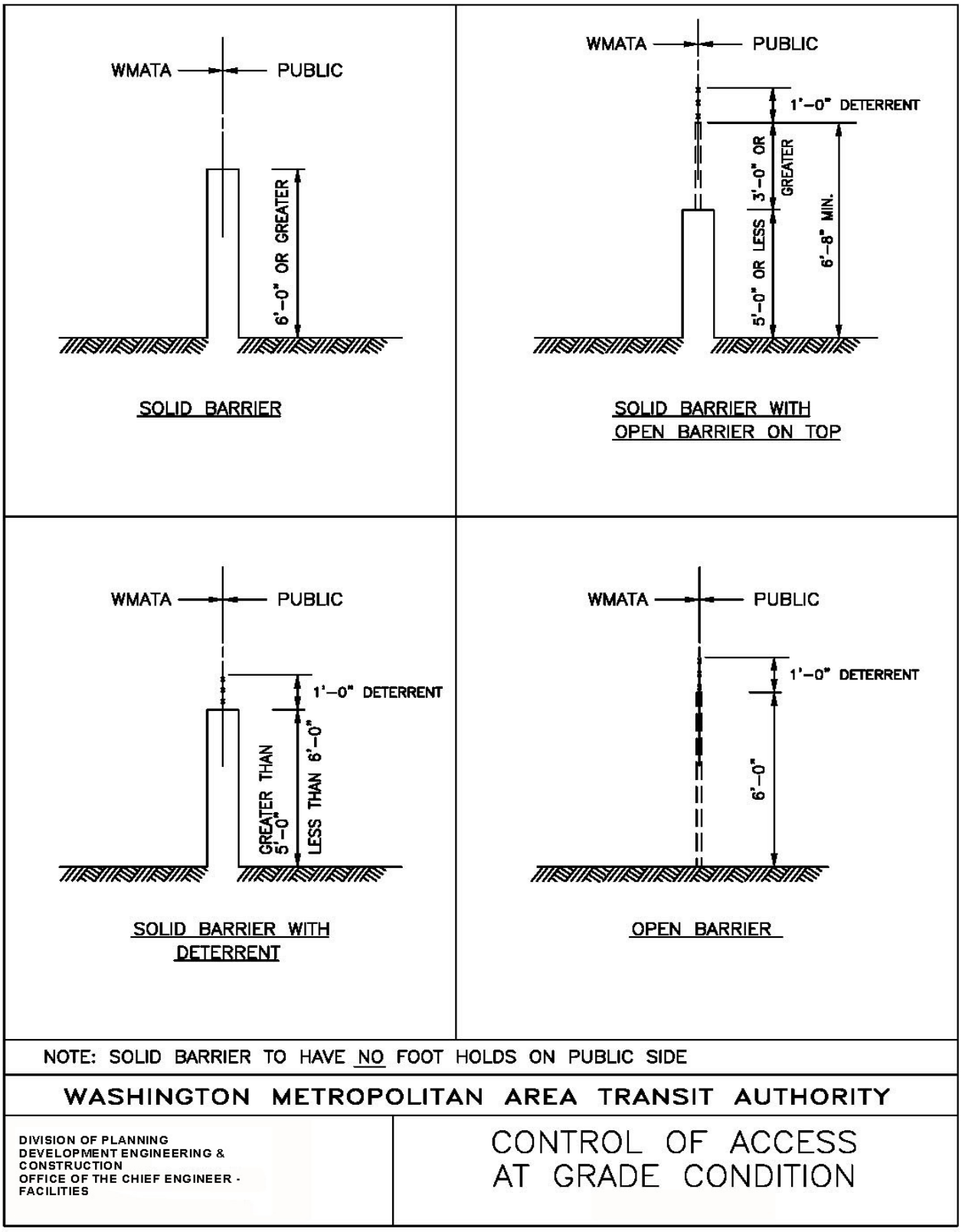

WMATA
PUBLIC
6'-0" OR GREATER
SOLID BARRIER
WMATA
PUBLIC
1'-0" DETERRENT
3'-0" OR GREATER
5'-0" OR LESS
6'-8" MIN.
SOLID BARRIER WITH OPEN BARRIER ON TOP
WMATA
PUBLIC
1'-0" DETERRENT
GREATER THAN 5'-0"
LESS THAN 6'-0"
SOLID BARRIER WITH DETERRENT
WMATA
PUBLIC
1'-0" DETERRENT
6'-0"
OPEN BARRIER
NOTE: SOLID BARRIER TO HAVE NO FOOT HOLDS ON PUBLIC SIDE
WASHINGTON METROPOLITAN AREA TRANSIT AUTHORITY
DIVISION OF PLANNING
DEVELOPMENT ENGINEERING & CONSTRUCTION
OFFICE OF THE CHIEF ENGINEER - FACILITIES
CONTROL OF ACCESS AT GRADE CONDITION

FIGURE 11.70

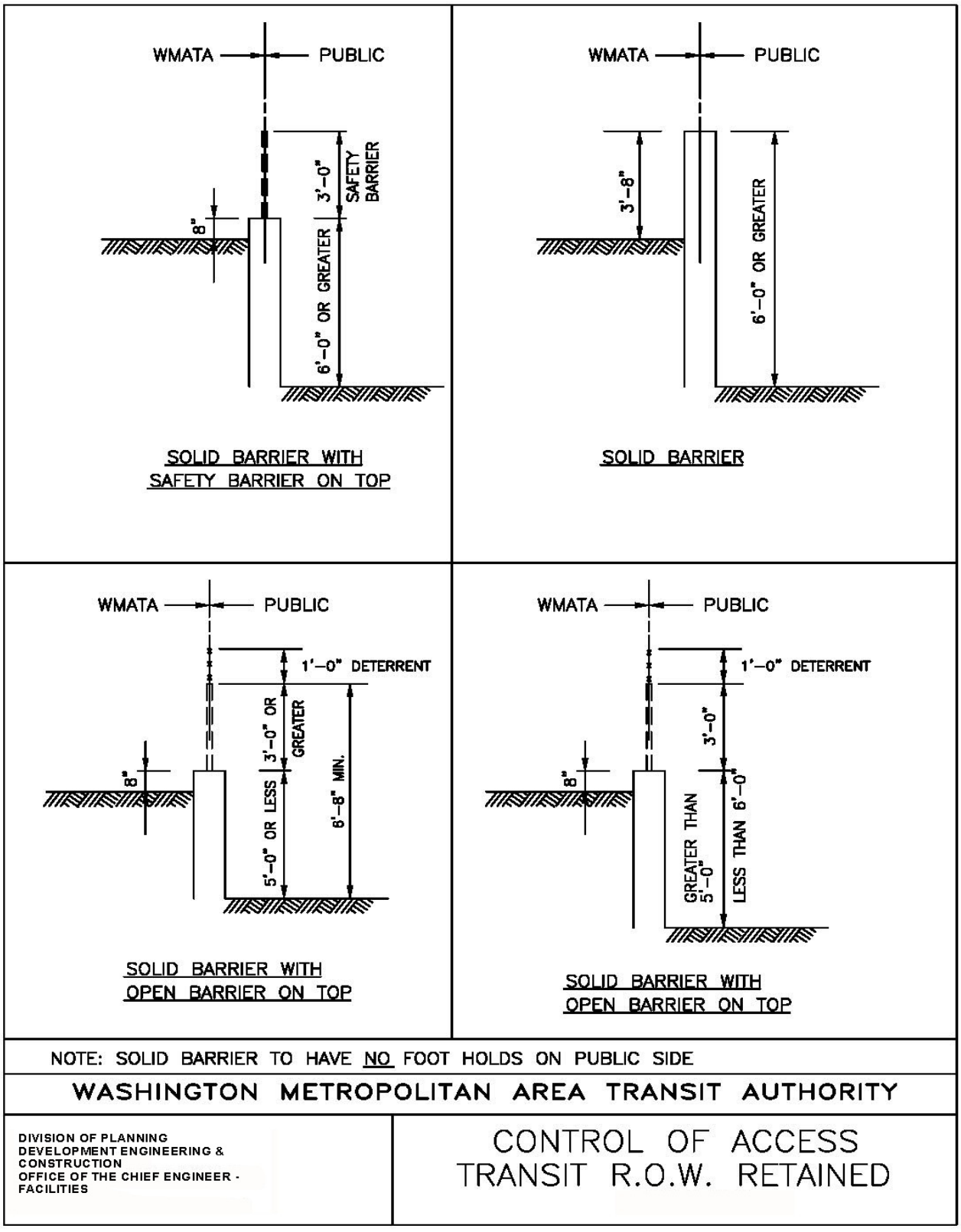

WMATA
PUBLIC
3'-0" SAFETY BARRIER
8"
6'-0" OR GREATER
SOLID BARRIER WITH SAFETY BARRIER ON TOP
WMATA
PUBLIC
3'-8"
6'-0" OR GREATER
SOLID BARRIER
WMATA
PUBLIC
1'-0" DETERRENT
3'-0" OR GREATER
8"
5'-0" OR LESS
8'-8" MIN.
SOLID BARRIER WITH OPEN BARRIER ON TOP
WMATA
PUBLIC
1'-0" DETERRENT
3'-0"
8"
GREATER THAN 5'-0"
LESS THAN 6'-0"
SOLID BARRIER WITH OPEN BARRIER ON TOP
NOTE: SOLID BARRIER TO HAVE NO FOOT HOLDS ON PUBLIC SIDE
WASHINGTON METROPOLITAN AREA TRANSIT AUTHORITY
DIVISION OF PLANNING
DEVELOPMENT ENGINEERING & CONSTRUCTION
OFFICE OF THE CHIEF ENGINEER - FACILITIES
CONTROL OF ACCESS
TRANSIT R.O.W. RETAINED

FIGURE 11.71

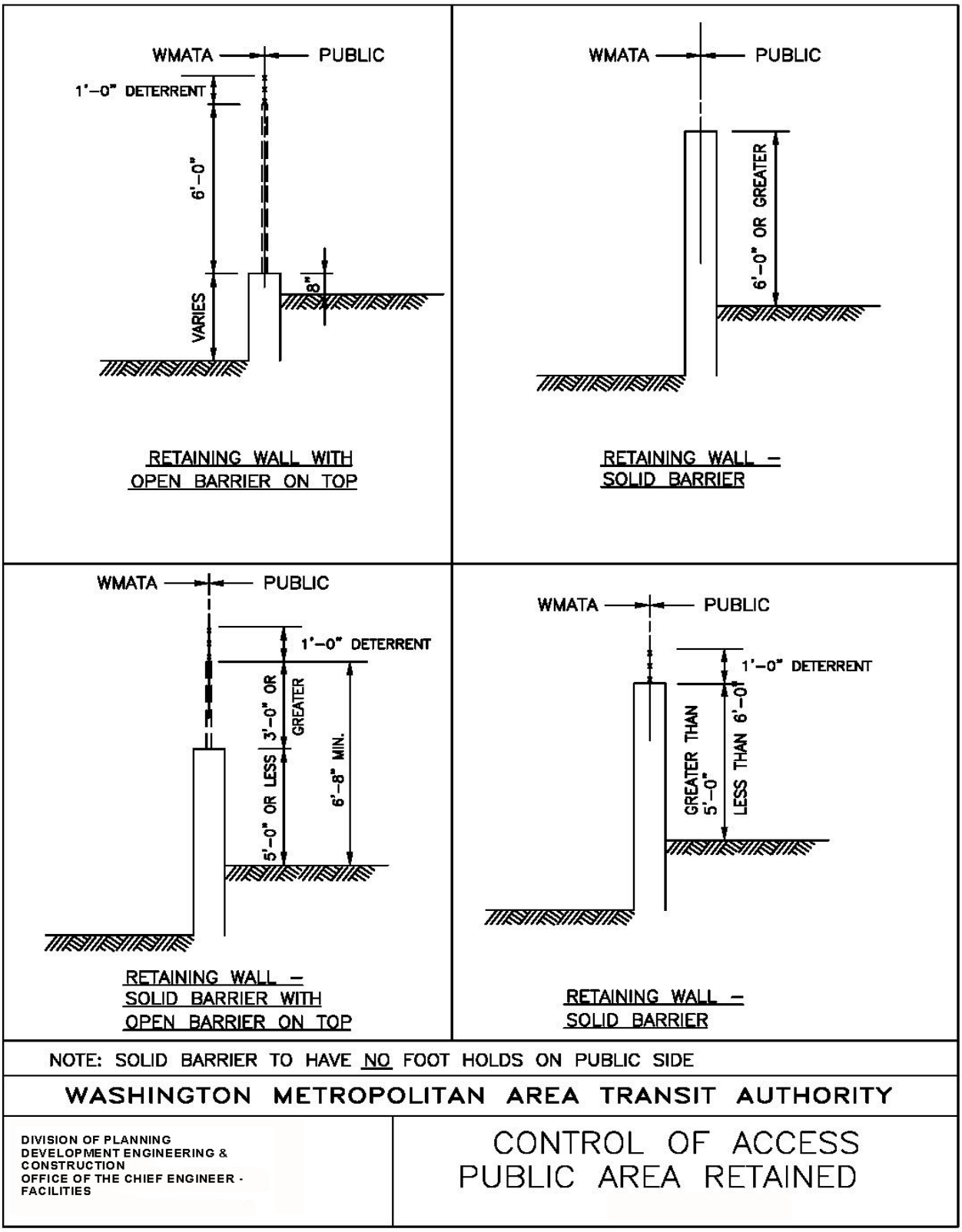

WMATA
PUBLIC
1'–0" DETERRENT
6'–0"
VARIES
8"
RETAINING WALL WITH OPEN BARRIER ON TOP
WMATA
PUBLIC
6'–0" OR GREATER
RETAINING WALL – SOLID BARRIER
WMATA
PUBLIC
1'–0" DETERRENT
3'–0" OR GREATER
5'–0" OR LESS
6'–8" MIN.
RETAINING WALL – SOLID BARRIER WITH OPEN BARRIER ON TOP
WMATA
PUBLIC
1'–0" DETERRENT
GREATER THAN 5'–0"
LESS THAN 6'–0"
RETAINING WALL – SOLID BARRIER
NOTE: SOLID BARRIER TO HAVE NO FOOT HOLDS ON PUBLIC SIDE
WASHINGTON METROPOLITAN AREA TRANSIT AUTHORITY
DIVISION OF PLANNING
DEVELOPMENT ENGINEERING & CONSTRUCTION
OFFICE OF THE CHIEF ENGINEER - FACILITIES
CONTROL OF ACCESS
PUBLIC AREA RETAINED

FIGURE 11.72

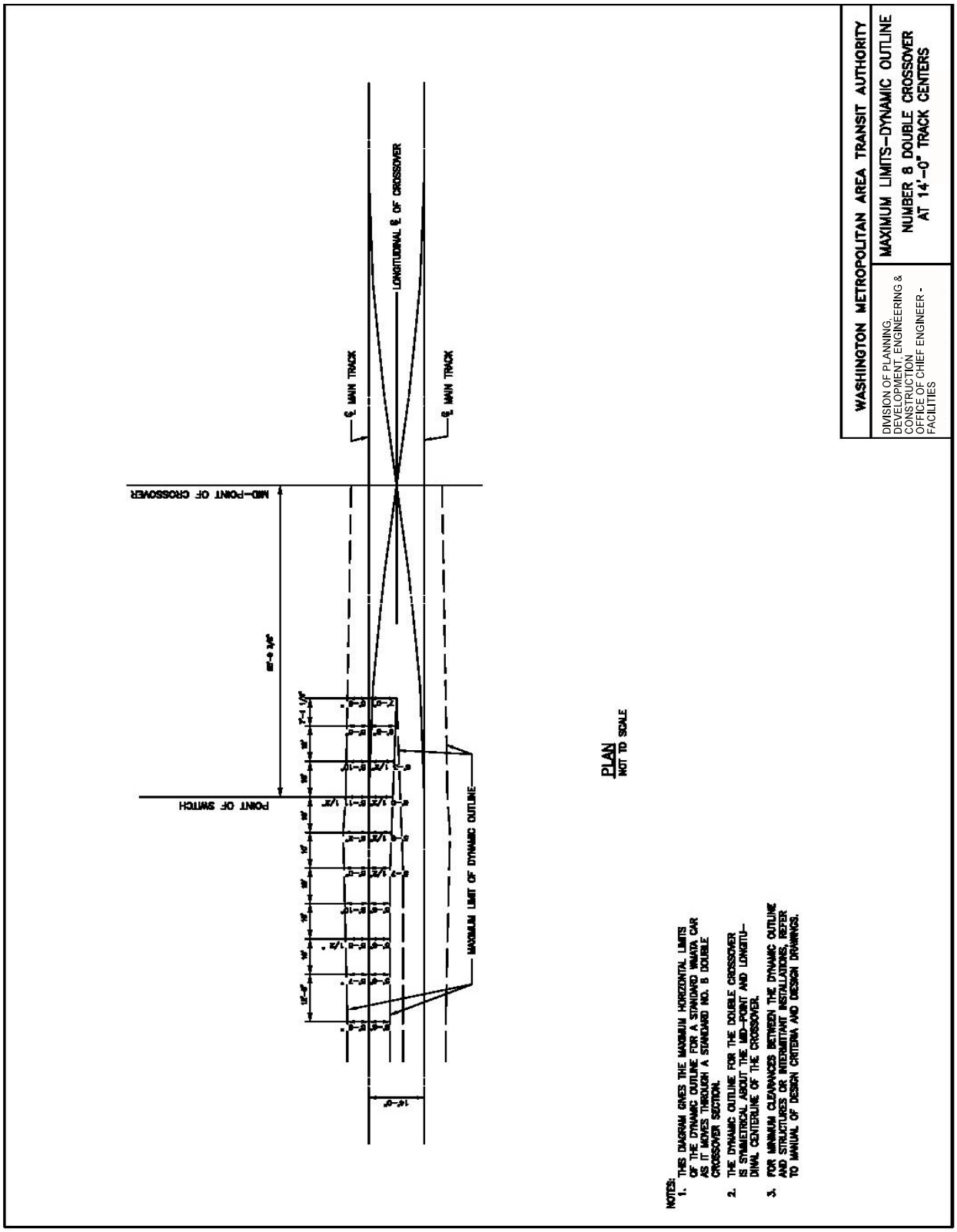

WASHINGTON METROPOLITAN AREA TRANSIT AUTHORITY
DIVISION OF PLANNING, DEVELOPMENT, ENGINEERING & CONSTRUCTION
OFFICE OF CHIEF ENGINEER - FACILITIES
MAXIMUM LIMITS-DYNAMIC OUTLINE
NUMBER 8 DOUBLE CROSSOVER
AT 14'-0" TRACK CENTERS
℄ MAIN TRACK
LONGITUDINAL ℄ OF CROSSOVER
℄ MAIN TRACK
MID-POINT OF CROSSOVER
POINT OF SWITCH
MAXIMUM LIMIT OF DYNAMIC OUTLINE
PLAN
NOT TO SCALE
NOTES:
1. THIS DIAGRAM GIVES THE MAXIMUM HORIZONTAL LIMITS OF THE DYNAMIC OUTLINE FOR A STANDARD WMATA CAR AS IT MOVES THROUGH A STANDARD NO. 8 DOUBLE CROSSOVER SECTION.
2. THE DYNAMIC OUTLINE FOR THE DOUBLE CROSSOVER IS SYMMETRICAL ABOUT THE MID-POINT AND LONGITUDINAL CENTERLINE OF THE CROSSOVER.
3. FOR MINIMUM CLEARANCES BETWEEN THE DYNAMIC OUTLINE AND STRUCTURES OR INTERMITTANT INSTALLATIONS, REFER TO MANUAL OF DESIGN CRITERIA AND DESIGN DRAWINGS.

FIGURE 11.73

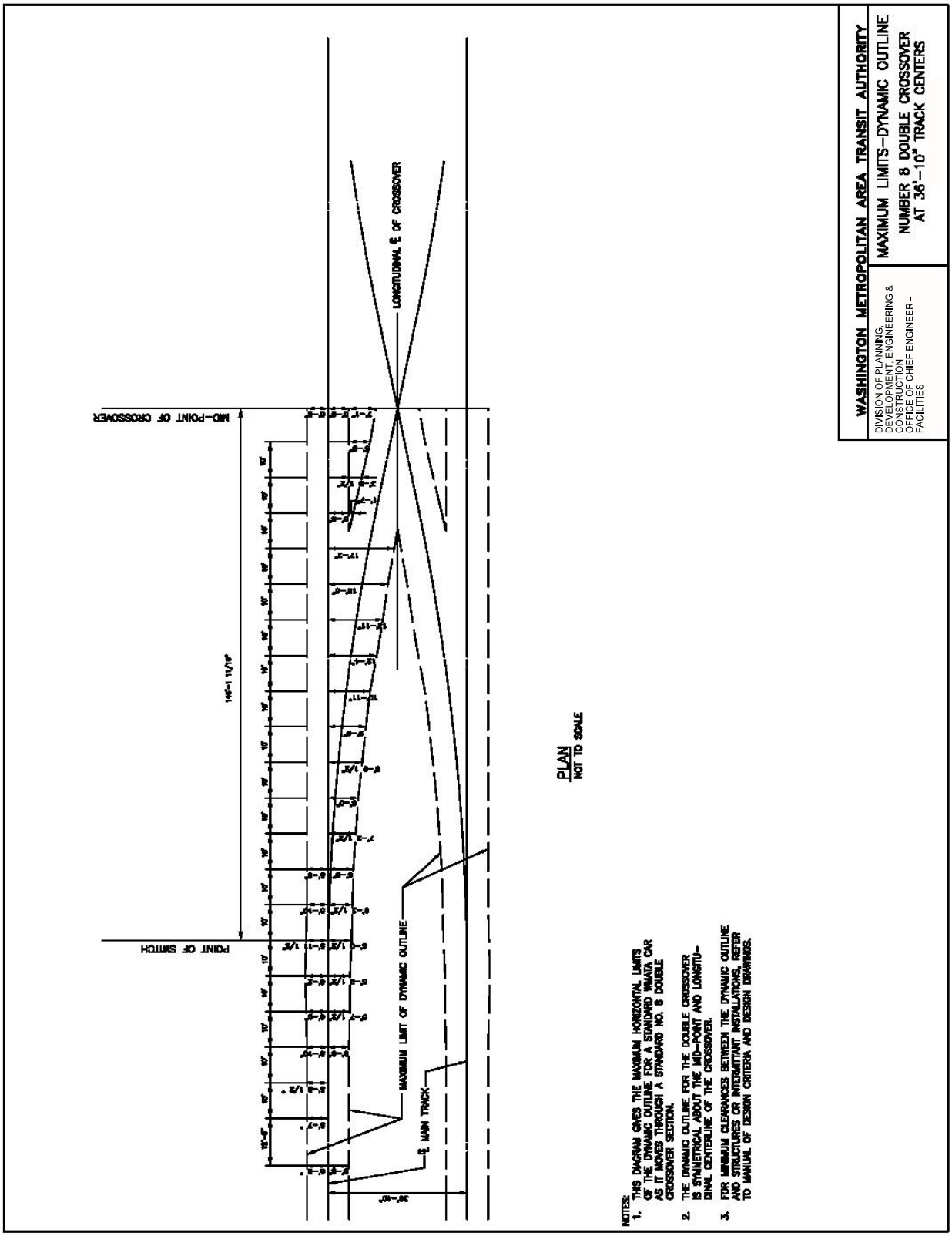

WASHINGTON METROPOLITAN AREA TRANSIT AUTHORITY
DIVISION OF PLANNING, DEVELOPMENT, ENGINEERING & CONSTRUCTION
OFFICE OF CHIEF ENGINEER - FACILITIES
MAXIMUM LIMITS-DYNAMIC OUTLINE
NUMBER 8 DOUBLE CROSSOVER
AT 36'-10" TRACK CENTERS
LONGITUDINAL ℄ OF CROSSOVER
MID-POINT OF CROSSOVER
POINT OF SWITCH
145'-1 11/16"
MAXIMUM LIMIT OF DYNAMIC OUTLINE
℄ MAIN TRACK
36'-10"
PLAN
NOT TO SCALE
NOTES:
1. THIS DIAGRAM GIVES THE MAXIMUM HORIZONTAL LIMITS OF THE DYNAMIC OUTLINE FOR A STANDARD WMATA CAR AS IT MOVES THROUGH A STANDARD NO. 8 DOUBLE CROSSOVER SECTION.
2. THE DYNAMIC OUTLINE FOR THE DOUBLE CROSSOVER IS SYMMETRICAL ABOUT THE MID-POINT AND LONGITUDINAL CENTERLINE OF THE CROSSOVER.
3. FOR MINIMUM CLEARANCES BETWEEN THE DYNAMIC OUTLINE AND STRUCTURES OR INTERMITTANT INSTALLATIONS, REFER TO MANUAL OF DESIGN CRITERIA AND DESIGN DRAWINGS.

FIGURE 11.74

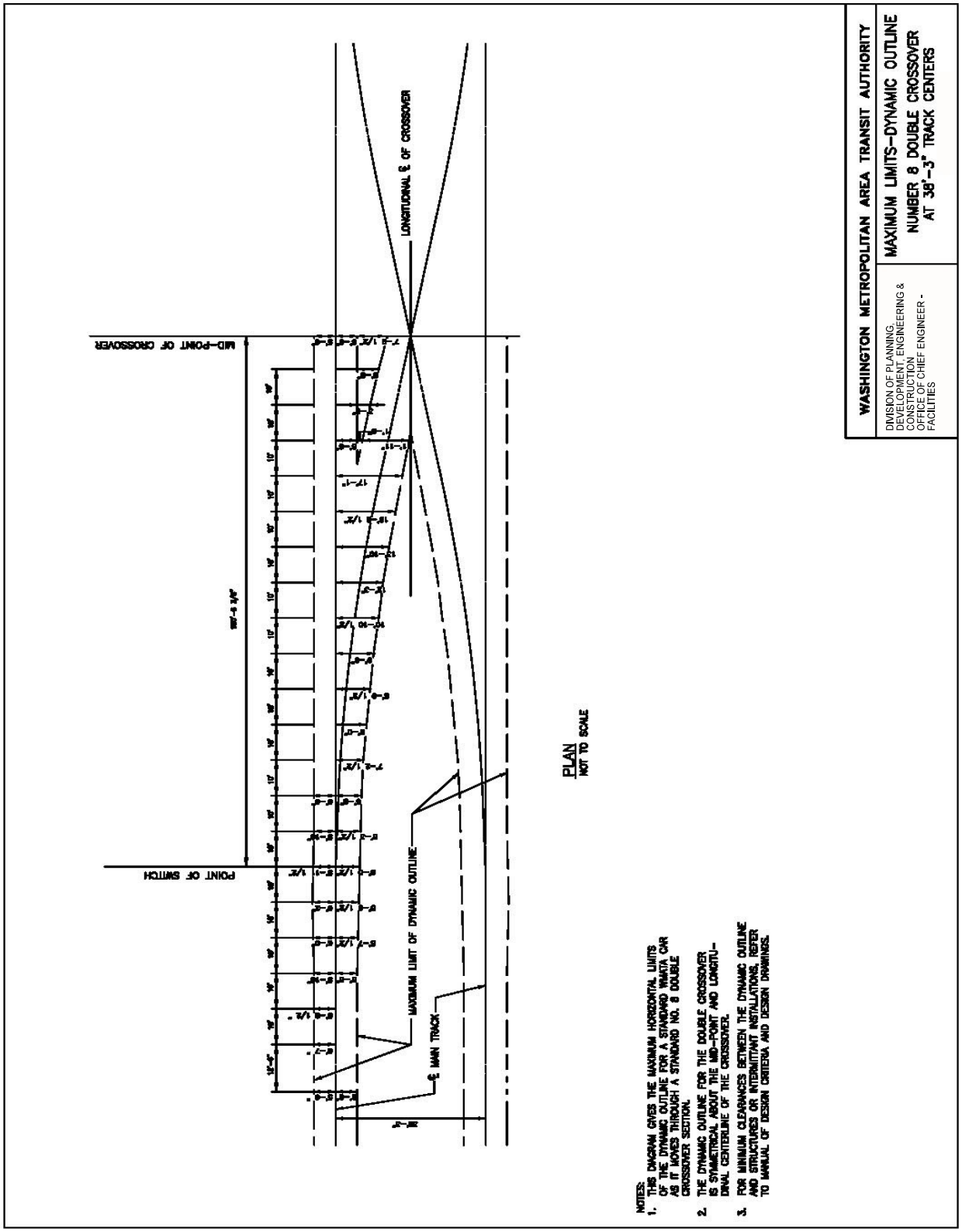

WASHINGTON METROPOLITAN AREA TRANSIT AUTHORITY
DIVISION OF PLANNING, DEVELOPMENT, ENGINEERING & CONSTRUCTION
OFFICE OF CHIEF ENGINEER - FACILITIES
MAXIMUM LIMITS-DYNAMIC OUTLINE
NUMBER 8 DOUBLE CROSSOVER
AT 38'-3" TRACK CENTERS
LONGITUDINAL ℄ OF CROSSOVER
MID-POINT OF CROSSOVER
POINT OF SWITCH
MAXIMUM LIMIT OF DYNAMIC OUTLINE
℄ MAIN TRACK
PLAN
NOT TO SCALE
NOTES:
1. THIS DIAGRAM GIVES THE MAXIMUM HORIZONTAL LIMITS OF THE DYNAMIC OUTLINE FOR A STANDARD WMATA CAR AS IT MOVES THROUGH A STANDARD NO. 8 DOUBLE CROSSOVER SECTION.
2. THE DYNAMIC OUTLINE FOR THE DOUBLE CROSSOVER IS SYMMETRICAL ABOUT THE MID-POINT AND LONGITUDINAL CENTERLINE OF THE CROSSOVER.
3. FOR MINIMUM CLEARANCES BETWEEN THE DYNAMIC OUTLINE AND STRUCTURES OR INTERMITTANT INSTALLATIONS, REFER TO MANUAL OF DESIGN CRITERIA AND DESIGN DRAWINGS.

FIGURE 11.75

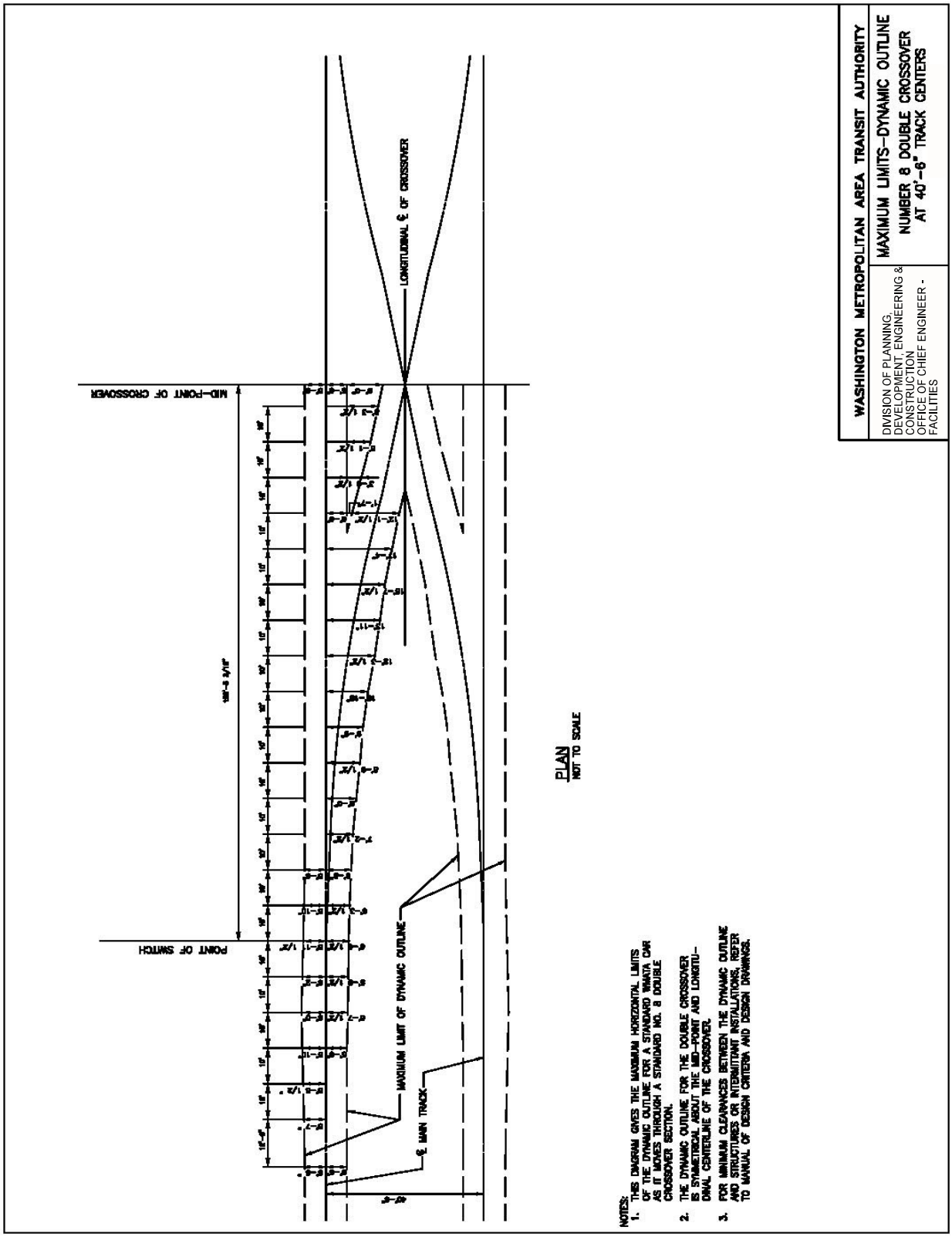

WASHINGTON METROPOLITAN AREA TRANSIT AUTHORITY
DIVISION OF PLANNING, DEVELOPMENT, ENGINEERING & CONSTRUCTION
OFFICE OF CHIEF ENGINEER - FACILITIES
MAXIMUM LIMITS-DYNAMIC OUTLINE
NUMBER 8 DOUBLE CROSSOVER
AT 40'-6" TRACK CENTERS
LONGITUDINAL ℄ OF CROSSOVER
MID-POINT OF CROSSOVER
POINT OF SWITCH
MAXIMUM LIMIT OF DYNAMIC OUTLINE
℄ MAIN TRACK
PLAN
NOT TO SCALE
NOTES:
1. THIS DIAGRAM GIVES THE MAXIMUM HORIZONTAL LIMITS OF THE DYNAMIC OUTLINE FOR A STANDARD WMATA CAR AS IT MOVES THROUGH A STANDARD NO. 8 DOUBLE CROSSOVER SECTION.
2. THE DYNAMIC OUTLINE FOR THE DOUBLE CROSSOVER IS SYMMETRICAL ABOUT THE MID-POINT AND LONGITUDINAL CENTERLINE OF THE CROSSOVER.
3. FOR MINIMUM CLEARANCES BETWEEN THE DYNAMIC OUTLINE AND STRUCTURES OR INTERMITTANT INSTALLATIONS, REFER TO MANUAL OF DESIGN CRITERIA AND DESIGN DRAWINGS.

FIGURE 11.76

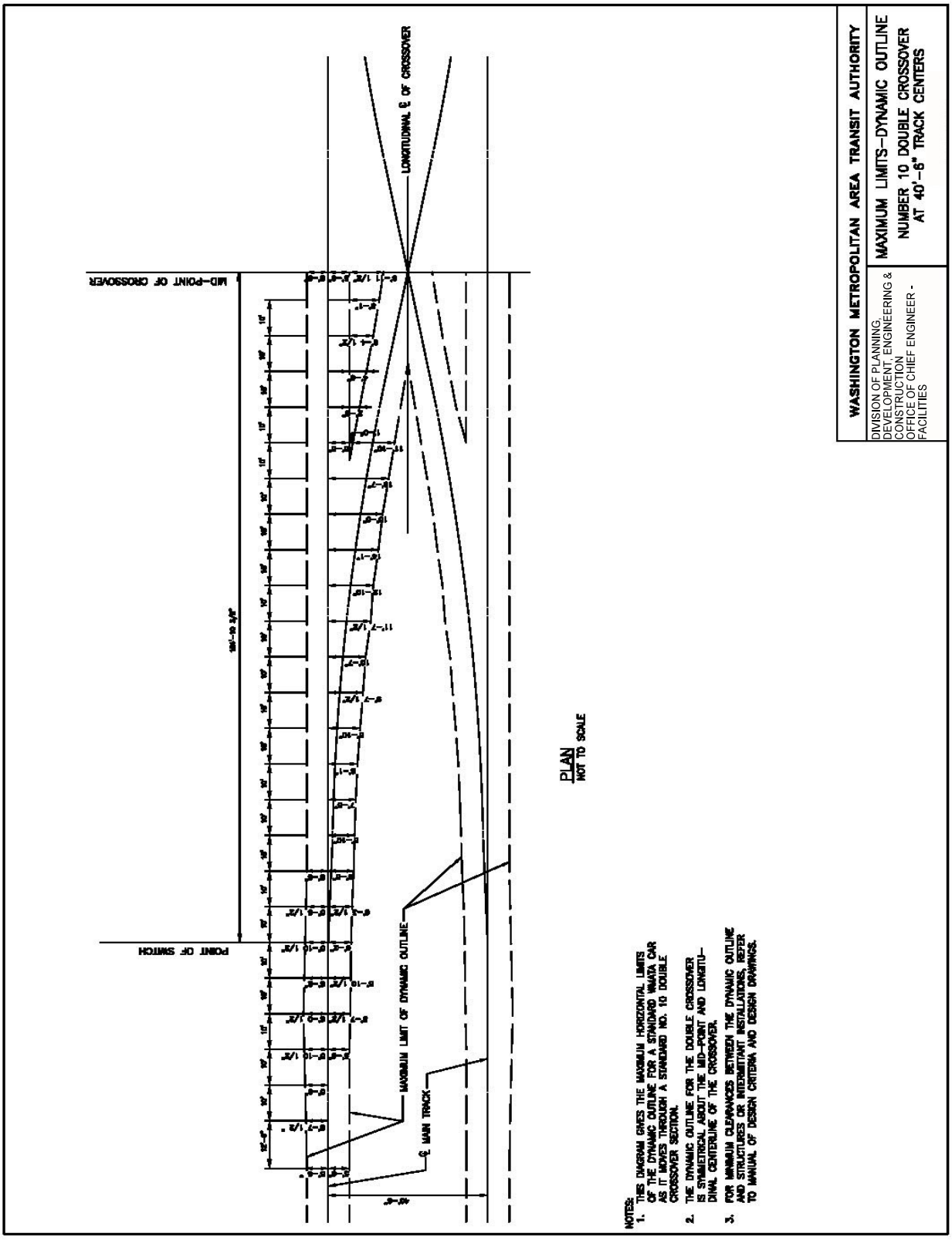

WASHINGTON METROPOLITAN AREA TRANSIT AUTHORITY
DIVISION OF PLANNING, DEVELOPMENT, ENGINEERING & CONSTRUCTION
OFFICE OF CHIEF ENGINEER - FACILITIES
MAXIMUM LIMITS–DYNAMIC OUTLINE
NUMBER 10 DOUBLE CROSSOVER
AT 40'-6" TRACK CENTERS
LONGITUDINAL ℄ OF CROSSOVER
MID-POINT OF CROSSOVER
POINT OF SWITCH
MAXIMUM LIMIT OF DYNAMIC OUTLINE
℄ MAIN TRACK
PLAN
NOT TO SCALE
NOTES:
1. THIS DIAGRAM GIVES THE MAXIMUM HORIZONTAL LIMITS OF THE DYNAMIC OUTLINE FOR A STANDARD WMATA CAR AS IT MOVES THROUGH A STANDARD NO. 10 DOUBLE CROSSOVER SECTION.
2. THE DYNAMIC OUTLINE FOR THE DOUBLE CROSSOVER IS SYMMETRICAL ABOUT THE MID-POINT AND LONGITUDINAL CENTERLINE OF THE CROSSOVER.
3. FOR MINIMUM CLEARANCES BETWEEN THE DYNAMIC OUTLINE AND STRUCTURES OR INTERMITTANT INSTALLATIONS, REFER TO MANUAL OF DESIGN CRITERIA AND DESIGN DRAWINGS.

FIGURE 11.77

SECTION 12 UTILITIES

12 .1 GENERAL

These criteria shall govern the maintenance, support, relocation, restoration and re-construction of utilities encountered or affected by WMATA construction of the rail transit system, and the restoration of pavement disturbed by such construction. In the design of the of the proposed work, due consideration shall be given to the needs of the transit system, the requirements and obligations of the utility organizations, traffic requirements, the service needs of abutting properties and policies established by WMATA.

12 .2 POLICY

WMATA is directed under Section 68 of Public Law 89-774 to reimburse utility companies for the cost of relocations as follows:

"Notwithstanding the provisions of Section 67 of this Article XV, any highway or other public facility or any Facilities of a public utility company which will be Dislocated by reason of a project deemed necessary by the Board to effectuate the authorized purposes of this Title shall be relocated if such facilities are devoted to a public use, and the reasonable cost of Relocation, if substitute Facilities are necessary, shall be paid by the Board from any of its monies."

12 .2.1 By definition utilities include facilities belonging to governmental agencies, public utility corporations and private parties, including service lines to adjoining properties.

12 .2.2 Utilities encountered or close enough to be affected by transit construction shall be:

12 .2.2.1 Supported and maintained complete in place during construction and continued in service following completion of transit facilities,

12 .2.2.2 Temporarily relocated and maintained, then, upon completion of transit facilities, restored to service,

12 .2.2.3 Temporarily relocated and maintained, then, upon completion of transit facilities, replaced by a new utility, or

12 .2.2.4 Permanently relocated to a new location beyond the immediate limits of transit construction.

Utility service to abutting properties shall not be interrupted and, if temporarily relocated, shall be restored upon completion of work. Replacements for any existing utilities, including governmental facilities and pavements shall be designed to provide service essentially equal to that offered by the existing installations.

12 .2.3 Betterments are enhancements to relocated facilities such as upgrades in materials. Increases in diameter of pipe, number of conduits in a duct bank, width of pavement for pavement restoration and the like are considered to be Betterments. Betterments shall not be included in the project design until the additional cost of the betterment(s) is funded by the utility. A signed contract on the reimbursement shall be in hand and formally approved by WMATA.

All designs involving maintenance, support, relocation, or other utility work shall be in accordance with the requirements of the affected Utility entities. The Designer shall submit utility designs to the concerned corporation or agency for final review and approval.

Record elevation of all utilities shall be corrected to datum of the U. S. Coast and Geodetic System. Pertinent utility elevations and locations shall be checked by field survey, and where critical to design, by digging test pits at such locations as may be approved by WMATA.

Designers shall consider plans developed or being developed by others in adjoining sections to ensure that the overall utilities systems will be comparable to those existing before start of construction and that the systems will be compatible with the transit system.

For all sections within the District of Columbia which involve cut-and-cover construction of line and/or station segments, the Designer shall determine the requirements for replacing in-kind utilities affected by Metro construction and define where additional utilities will be required prior to the release of the construction permit for general re-paving in the construction area. If these additional facilities can be agreed upon as Betterments to be constructed by the Metro contractor, their alignment and construction shall be designed by the Designer and included in the contract documents. If these additional utilities are to be built by the utility owner, their alignment shall be defined on the composite utilities plans with the notation "NIC".

12 .3 UTILITIES SUBSIDENCE ANALYSIS

In areas of potential subsidence above earth tunnels, the design handling of selected critical utilities shall be based upon a comprehensive analysis of anticipated settlement, structural integrity, and essential need of utility continuity. The specific utilities which are to receive this analysis will be identified in the Section Designer's Scope of Services. The comprehensive analysis shall be accomplished as follows:

12 .3.1 The subsidence potential will be evaluated and quantified. Available information will be extracted from the geotechnical report. Additional subsurface investigation shall be requested as necessary.

12 .3.2 Assess the structural capability of the utility structure including a joint physical inspection with utility owners to assure agreement with respect to present condition. Document condition of the facility by taking photographs and recording location and extent of cracks, settlements, distortion of section, and other pertinent data.

12 .3.3 Examine the feasibility and estimated cost of alternative forms of handling such as grouting (cement or chemical), underpinning, later repair, replacement, etc. Pre-coordinate the acceptability of outages or calculated risks with the utility owner.

12 .3.4 Provide specific recommendations including instrumentation to measure and assure that such settlement remains within the predetermined allowable limits.

12 .4 WETLANDS AND WATERS OF THE UNITED STATES

12 .4.1 Definition: The U.S. Army Corps of Engineers (Federal Register 1982) and the Environmental Protection Agency (Federal Register 1980) jointly define wetlands as:

"Those areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs and similar areas."

Wetlands are a subset of "Waters of the United States" which include deep-water aquatic habitats and special aquatic sites as well as wetlands. Waters of the United States are defined in the Federal Register 1982 as:

The territorial seas with respect to the discharge of fill material.

Coastal and inland waters, lakes, rivers, and streams that are navigable waters of the United States, including their adjacent wetlands.

Tributaries to navigable waters of the United States, including adjacent wetlands.

Interstate waters and their tributaries, including adjacent wetlands.

All other waters of the United States that are not a part of a tributary system to interstate waters or navigable waters of the United States, such as isolated wetlands and lakes, intermittent streams, prairie potholes, and other waters, the degradation or destruction of which could affect interstate commerce.

Wetlands and Waters of the U.S. in the project area shall be field delineated using the three parameter approach, as outlined in the Corps of Engineers' Wetlands Delineation Manual, or any other method that the Corps requires. The three parameter approach requires positive evidence of hydrophytic vegetation, hydric soils, and wetland vegetation for determining that an area is a wetland.

12 .4.2 Coordination

Cumulative wetland impacts associated with an entire route extension are to be coordinated as one package with the Corps of Engineers. WMATA will select one of the Section Designers to perform the coordination; the other Section Designers will provide all information necessary to assist in this coordination.

For projects in the District of Columbia and Maryland coordination must be made with the Baltimore District of the Corps of Engineers. For projects in Virginia, coordination must be made with the Norfolk District.

A Section 404 Permit, as required by the Clean Water Act, (33 U.S.C. 1344), shall be acquired. The objective of the Act is to maintain and restore the chemical, physical and biological integrity of the waters of the United States. The Corps of Engineers is authorized to issue permits for the discharge of dredged or fill material into waters of the United States, including wetlands.

12 .4.3 Mitigation

The Metro facilities should be located to avoid, minimize and mitigate wetlands impacts. Mitigation can take the form of:

12 .4.3.1 on-site restoration of wetlands disturbed during construction,
12 .4.3.2 on-site restoration of wetlands that are not in good condition,

12 .4.3.3 off-site restoration of wetlands that are not in good condition, or
12 .4.3.4 on-site or off-site wetland creation

The Corps of Engineers will determine the type of mitigation required and the mitigation ratio, i.e. 1:1, 2:1, etc.

12 .5 FLOOD PLAINS

12 .5.1 General: Where pertinent, the design of Metro shall include protection against a 700,000 cfs flood of the Potomac River as generally outlined in "Report on the Effect of Potomac River Floods on Metro," as prepared by DeLeuw, Cather & Company dated November 21, 1969.

The design of Metro shall take into consideration the protection of the system against local flooding resulting from stream overflows and surface flooding based upon the jurisdictional rainfall intensity for the 100-year storm (or the U.S. Weather Service 100-year intensity if such not adopted and published by the jurisdiction). Clearance of 4'-4" between top of rail and flood level is desirable and 3'-0" is minimum unless an exception is approved. The Designer shall submit findings and recommendations to the WMATA for approval while in the preliminary stages of work. Final design shall not be undertaken prior to such approval.

Flood protection shall involve station entrances, vent and fan shafts, power substations, chiller plants and any other facilities and openings into the system, such as electric conduits or other pipes.

12 .5.2 Floodplain Development

Where the Metro lines, the station complexes, ancillary structures, or parking lots will encroach upon any stream channel or overbank area designated as a floodplain, the design shall take into account all ordinances and criteria governing development in floodplains of the appropriate jurisdictional agency. Requirements may include, but shall not necessarily be limited to, the design of provisions for the maintenance of floodwater storage capacity; the preparation of comparative floodwater surface profiles; and the presentation of definitive studies to the agency and at public hearings.

12 .5.3 Criteria

The Designer will perform all 100-year floodplain analyses required by the approving agency for the project.

12 .5.3.1 District of Columbia

12 .5.3.1.1 Soil Resources Management Division
2100 Martin Luther King Jr. Ave SE
Washington, D.C. 20020
202-645-6059

12 .5.3.2 Virginia

12 .5.3.3 Maryland

12 .5.3.3.1 Montgomery County
Dept. of Environmental Protection

301-217-6321
Department of Permitting Services
255 Hungerford Drive
2nd Floor, Station 8
Rockville, Maryland 20850-4159
301-219-6300

12 .5.3.3.2 City of Rockville
Community Planning and Development Services
111 Maryland Avenue, 2nd Floor
Rockville, Maryland 20850
301-309-3200

12 .5.3.3.3 Prince George's County
Department of Environmental Resources
Engineering Plans Review Section
9400 Peppercorn Place
Largo, Maryland 20774
301-883-5905

12 .5.3.3.4 Maryland State Highway Administration
Department of Natural Resources
Waterway Resources
410-974-2918

12 .6 TREE CONSERVATION

12 .6.1 Definitions

Afforestation is the establishment of a tree cover in an area from which it has always or very long been absent, or the planting of open areas which are not presently in forest cover.

Forest or Woodland means a biological community dominated by trees or other woody plants covering an area of 10,000 square feet or more. This also includes forests that have been cut, but not cleared.

Forest Management Plans are prepared by a registered professional forester for timber management.

12 .6.1.1 Mitigation is the off-setting of forest values lost due to development and/or construction activities by replanting woodlands or other agreed upon means.

12 .6.1.2 Reforestation means the replanting of trees on recently forested land.

12 .6.1.3 Specimen tree means a particularly impressive or unusual example of a species due to its size, shape, age, or any trait that epitomizes the character of the species.

12 .6.2 The Designer shall perform all field delineations and plans required by the approving agency, if any, for the project.

12 .6.2.1 District of Columbia

12 .6.2.2 Virginia

12 .6.2.2.1 Arlington County
12 .6.2.2.2 Fairfax County
12 .6.2.2.3 City of Alexandria

12 .6.2.3 Maryland
12 .6.2.3.1 Montgomery County
12 .6.2.3.2 City of Rockville
12 .6.2.3.3 Prince George's County

A Forest Stand Delineation plan and Tree Conservation plan need to be submitted to the Maryland-National Capital Park and Planning Commission, Natural Resources Division.

12 .7 ARCHEOLOGICAL/HISTORIC PRESERVATION

The Designer shall perform all necessary research and records check to determine if any sites of archeological or historic significance will be impacted during the construction of the proposed Metro facilities. The Designer shall submit a report of findings to WMATA for review.

12 .8 SEWERS AND DRAINAGE

12 .8.1 General

All maintenance, relocation, restoration, and construction of sewers and drainage facilities shall be in strict conformance with the current specifications and practices of the concerned agencies in the affected jurisdictions. All plans must be approved by the appropriate utility agency.

Construction of sewer laterals to abutting properties shall comply in every respect with all applicable area codes.

12 .8.2 Design Criteria - General

Necessary replacements of existing sewers and appurtenances shall provide services equivalent to those of existing facilities.

Service to adjoining properties shall be maintained by supporting in place, by providing alternate temporary facilities or by diverting to other points.

Adequate closed flumes shall be provided to handle flows of sewers temporarily removed.

No surface drainage from adjoining areas shall be connected to the subway system track drains.

12 .8.3 Sanitary Sewers

12 .8.3.1 District of Columbia:

12 .8.3.1.1 In the District of Columbia the Plumbing Code of the Washington Metropolitan Area, as prepared by the Metropolitan Washington Council of Governments, supplemented by the 1967 Plumbing Code of the District of Columbia, shall be adhered to.

12 .8.3.2 Maryland

12 .8.3.2.1 Montgomery County - The Washington Suburban Sanitary Commission Standards shall apply to all sanitary sewers in Montgomery County. Plans must be prepared to meet their requirements as well as those of WMATA. The composite utility plans can be used as a base sheet in preparing the sanitary sewer plans. A supplementary WSSC title block will need to be added to the drawing.

The Plumbing and Gas Fitting Regulations of the Washington Suburban Sanitary Commission will apply.

12 .8.3.2.2 Prince George's County - The Washington Suburban Sanitary Commission Standards shall apply to all sanitary sewers in Prince George's County. Plans must be prepared to meet their requirements as well as those of WMATA. The composite utility plans can be used as a base sheet in preparing the sanitary sewer plans. A supplementary WSSC title block will need to be added to the drawing.

The Plumbing and Gas Fitting Regulations of the Washington Suburban Sanitary Commission will apply.

12 .8.3.3 Virginia

12 .8.3.3.1 Arlington County - In Arlington County, Virginia, the Plumbing Code of the Washington Metropolitan Area, as prepared by the Metropolitan Washington Council of Governments, supplemented by the amendments adopted by Arlington County, effective January 1, 1968, shall be adhered to.

12 .8.3.3.2 Fairfax County - The Plumbing Code of Fairfax County shall be complied within Fairfax County.

12 .8.3.3.3 City of Alexandria - The Plumbing Code of the City of Alexandria shall apply in the City of Alexandria.

12 .8.3.4 Storm Sewers

12 .8.3.4.1 District of Columbia

When the rational formula is used for design, rainfall intensity shall be based on a 15-year design storm. In critical locations, such as drainage pockets where flooding would result in heavy damage, 25-year storm shall be used.

12 .8.3.4.2 Maryland

12 .8.3.4.2.1 Maryland State Highway Administration (MSHA) - Where storm sewers are under the jurisdiction of the MSHA, replacement shall be in kind and shall comply with the latest MSHA standard drawings and specifications, and hydraulic criteria based on the classification of the roadway.

12 .8.3.4.2.2 Montgomery County - The Montgomery County Department of Public Works has responsibility for the storm drainage systems in

Montgomery County, exclusive of state roads. The County-adopted drainage design criteria is applicable. Montgomery County Standards are to be used for applicable storm facilities, exclusive of state roads.

12 .8.3.4.2.3 Prince George's County - The Prince George's County Department of Environmental Resources, Watershed Protection Branch, has responsibility for the storm drainage systems in that County, exclusive of state roads. County Standards are to be used for applicable storm facilities, exclusive of state roads.

12 .8.3.4.2.4 City of Rockville - Plumbing and Gas Fitting Regulations of the Washington Suburban Sanitary Commission apply in Rockville, Maryland, but the permit will be granted by the city.

12 .8.3.4.3 Virginia

12 .8.3.4.3.1 Virginia Department of Transportation - Where storm sewers are under the jurisdiction of the Virginia Department of Highways the replacement of these facilities shall be in kind and shall comply with the Virginia Department of Highways' standard drawings and specifications.

12 .8.3.4.3.2 Arlington County - Storm sewers in Arlington County will comply with all criteria of that County.

12 .8.3.4.3.3 Fairfax County - Storm sewers in Fairfax County will comply with the criteria in the Fairfax County Public Facilities Manual.

12 .8.3.4.3.4 City of Alexandria - Any elevations shown on drawings received from Alexandria must be verified in the field as being correct. Many elevations on the city drawings are of varying datum planes. Due to lack of records, utilities within the property of CSX Railroad will require field location. All entry onto CSX property must be cleared with the CSX Railroad.

12 .8.3.5 Combined Sewers

12 .8.3.5.1 District of Columbia Combined sewers are only in the District of Columbia. Close coordination must be made with WASUA when work is to be performed on combined sewers.

12 .9 STORMWATER MANAGEMENT

Maryland Water Resources Administration, under the Department of Natural Resources, has adopted new regulations under a chapter entitled COMAR 26.17.02 STORMWATER MANAGEMENT with an effective date of July 16, 2000 (RE: MD. R. Doc. No. 83-R-151-F). The regulations require that all land development have an approved stormwater management plan from the approving agency. A grading or building permit may not be issued for a property unless a stormwater management plan has been approved. The minimum requirements for stormwater management are:

Montgomery and Prince George's Counties and their incorporated municipalities require that the post-development peak discharges for a 2- and 10-year frequency storm event be maintained at a level equal to or less than the respective 2- and 10-year pre-

development peak discharge rates, through stormwater management techniques that control the volume, timing, and rate of runoff. Alternative minimum control requirements may be adopted subject to Administration approval. The Administration shall require a demonstration that alternative requirements will control flood damages, accelerated stream erosion, water quality, and sedimentation, including if necessary, comprehensive watershed studies.

If detention or retention structures are used, they must be in accordance with the Administration regulations for off-site structures, velocity dissipation, downstream analysis, and small ponds.

An operation and maintenance plan shall be required as a condition of stormwater management plan approval.

12 .10 WATER QUALITY

12 .10.1 General

Urbanization has had adverse consequences on streams due to an increase in flooding, streambank erosion and pollutant export. Pollutants include sediment, nutrients (e.g. nitrogen and phosphorus), bacteria, a depletion of dissolved oxygen, oil and grease, trace metals (including arsenic, chromium, copper, mercury, nickel, lead, zinc), toxic chemicals (including paint thinners and pesticides) and chlorides. Removal of these urban pollutants from stormwater runoff is important to protect the downstream wildlife. A series of Best Management Practices (BMPs) have been developed which not only control non-point source pollution from urban areas but also provide effective stormwater management.

12 .10.2 Methods

12 .10.2.1 Extended Detention Ponds - An extended detention pond is dry before a storm event. A portion of the total runoff, called the first flush, (frequently ½" to 1" per acre) is released at a rate that will detain it for about 24 hours. Pollutants are removed from the runoff by settling. A wetland marsh should be created in the bottom of an extended detention pond, wherever possible, to help remove pollutants that cannot be removed by conventional settling.

12 .10.2.2 Wet Ponds - Wet ponds, also known as retention ponds, are an effective means of removing sediment, nutrients, and trace metals. They require a steady source of water and may be a high maintenance item. They require a relatively impermeable soil for the bottom and sides.

12 .10.2.3 Infiltration Trenches - Infiltration trenches are designed to remove soluble and particulate pollutants but not to trap coarse sediments. Grass buffers must be installed to capture coarse sediment before it enters the trench. Trenches can provide groundwater recharge, low flow augmentation and localized streambank erosion control. They are only feasible when soils are permeable and the watertable and bedrock are well below the bottom of the trench.

12 .10.2.4 Infiltration Basins - Infiltration basins are effective in removing soluble and particulate pollutants but not to trap coarse sediments. Coarse sediment should generally be removed before it enters the basin. Basins can provide groundwater recharge, low flow augmentation and localized streambank

erosion control. They are only feasible when soils are permeable and the watertable and bedrock are well below the bottom of the trench.

12 .10.2.5 Water quality inlets - also known as oil/grit separators, are designed to remove sediment and hydrocarbon loadings from parking lot runoff before they are conveyed to the storm drainage network.

12 .10.3 Criteria

The Designer will perform all analyses required by the approving agency for the project.

12 .11 WATER

12 .11.1 Codes and Standards

All maintenance, relocation, restoration, and construction of water mains and appurtenances shall be in strict conformance with the current specifications and practices of the agencies concerned.

Construction of water services to abutting properties shall comply in every respect with applicable area codes as follows:

In the District of Columbia and Arlington County, Virginia, the Plumbing Code of the Washington Metropolitan Area, as prepared by the Metropolitan Washington Council of Governments, supplemented by the following:

12 .11.1.1 The 1967 Plumbing Code of the District of Columbia

12 .11.1.1.1 Amendments adopted by Arlington County, effective January 1, 1968.

12 .11.1.2 In Montgomery and Prince George's Counties, Maryland, the Plumbing and Gas Fitting Regulations of the Washington Suburban Sanitary Commission.

12 .11.1.3 Plumbing and Gas Fitting Regulations of the Washington Suburban Sanitary Commission also apply in the City of Rockville.

12 .11.1.4 The Plumbing Code of Fairfax County shall apply in Fairfax County.

12 .11.1.5 The Plumbing Code of the City of Alexandria shall apply in the City of Alexandria.

12 .11.2 Design Criteria - District of Columbia

12 .11.2.1 All designs shall be according to WASUA standards.
12 .11.2.2 No water main or fire hydrant shall be taken out of service without prior approval of the affected utility owner.

12 .11.3 Design Criteria - Virginia

12 .11.3.1 Arlington County

12 .11.3.1.1 Arlington County standards shall apply in all instances for water mains in areas controlled by the county, and for service mains in park areas.

12 .11.3.1.2 In the event Metro construction requires adjustment or reconstruction of 30" diameter and smaller water mains serving the Pentagon Building and National Airport, pipe shall conform to that of existing installation and work shall meet the requirements of the Washington Aqueduct, 5000 MacArthur Boulevard, N.W., Washington, D. C.

12 .11.3.2 City of Alexandria - Where possible, the jurisdiction's water provider will perform the construction or reconstruction of all water mains within the area of the Metro System prior to the Metro Contractor's entry on the job. If it becomes necessary for the Metro Contractor to perform any work on the water facility, prior approval must be obtained from Alexandria Water Company.

12 .11.3.3 Fairfax County - The jurisdiction's water provider has responsibility for all water facilities in the areas of Fairfax County.

Where possible, all construction or reconstruction of water mains caused by Metro excavation shall be performed by the Fairfax Water Authority's Contractor. If the Metro Contractor is required to perform any work on the water facilities in the county, prior approval must be obtained from jurisdiction's water provider

12 .11.4 Design Criteria - Maryland

12 .11.4.1 Montgomery County

12 .11.4.1.1 The Washington Suburban Sanitary Commission Standards shall apply to all water mains and appurtenances in Montgomery County.

12 .11.4.1.2 City of Rockville

The Washington Suburban Sanitary Commission Standards shall apply for water facilities in the City of Rockville.

12 .11.4.2 Prince George's County

The Washington Suburban Sanitary Commission's Standards shall apply to all water mains and appurtenances in Prince George's County.

12 .12 NATURAL GAS

12 .12.1 Codes and Standards

All work throughout the Metro system (including park areas in Virginia and Pentagon Grounds) on or adjacent to gas lines shall comply with standards of the Washington Gas Company and the Gas Transmission and Distribution Standards of the American Society of Mechanical Engineers.

12 .12.2 Design Criteria - General

Construction of temporary gas mains and replacement of cast iron mains may be performed by the Washington Gas Company, by a contractor under contract to the gas company or by the Authority's contractor, as provided for in the Master Agreement between the gas company and the Authority. Consideration shall be given as to the most efficient of these options for this project.

The Designer will inform the Washington Gas Company where the design for the transit system will affect the company's facilities.

12 .13 ELECTRIC

12 .13.1 Codes and Standards

All support, maintenance, relocation and restoration of electric lines throughout the Metro system shall be in strict conformance with current practices of the Potomac Electric Power Company or the Dominion Virginia Power, Baltimore Gas and Electric Company, the requirements of the Electrical Code of the concerned jurisdictions and agencies, and the National Electric Safety Code.

12 .13.2 Design Criteria - General

General Design shall be based on the following:

Maintain electric facilities complete in place providing that the support system can satisfactorily retain the line/grade of the facility and retention of the duct structures is practical within the limitations contained herein. Support of vitrified clay and asbestos cement ducts must necessarily be independent of the Metro decking system and in no way exposed to the vibration of same. Due to the fragility of these vitrified clay and asbestos-cement ducts and their susceptibility to damage from movement, misalignment and vibration, any such ducts maintained complete in place will be subject to critical inspection (preferably by mandrel test in any available open ducts) before acceptance as a permanent structure.

As dictated by space limitations or cost, relocate electric facilities to areas outside the limits of Metro excavation and its system of trench support.

Temporarily support electric facilities to be maintained in service until such time as replacement facilities shall be provided, either within or beyond the limits of Metro excavation. Remove existing duct structures and manholes where cables in these facilities are to be kept in service during and after construction of Metro. Provide temporary split duct systems and manholes to serve the same utility function as existing facilities with respect to accessibility, manhole size, required number of ducts and structure protection for equipment, cable and men. The number of temporary ducts will be minimized by coordination with the utility to assure utilization of maximum temporary capacity without unnecessary spare ducts.

Split duct when encased for permanent retention shall represent a straight-rigid conduit line as is practical without bends or curves. Generally, split duct will only be acceptable for retained facilities up to a minimum of four ducts housing secondary, street light, and/or traffic signal cables.

Pipe lines carrying high-voltage lines shall be supported during construction. Upon completion of work, pipes shall be permanently supported on compacted backfill and surrounded by thermally acceptable sand.

Consult with the owners of electric facilities in the preparation of designs, plans, and specifications to assure that the method of handling facilities is the most economical, consistent with needs of Metro, and service requirements. Additional factors to be considered shall include limitations that may be imposed by decking and excavation support systems and the type and material of facilities involved.

When circumstances justify, relocated or maintained utilities may be permanently supported on concrete posts tied to the roof of the Metro structure. Each such posting, however, must be separately approved by the Authority.

12 .13.3 The Utility Will:

12 .13.3.1 Perform all cable work, including removal of existing cable.

12 .13.3.2 Furnish cast iron manhole frames and covers, precast manhole roofs, gratings, pulling-in-irons and inserts for installation to be made by the Contractor.

12 .13.4 WMATA Contractor Shall:

12 .13.4.1 Where required, maintain and support duct banks, manholes and vaults.

12 .13.4.2 Install and support temporary split ducts, manholes and vaults when existing facilities cannot be maintained.

12 .13.4.3 Where required, construct new ducts (including split duct to be retained), manholes and vaults.

12 .13.4.4 Provide concrete foundation beneath facilities maintained in place or constructed on compacted fill.

12 .13.4.5 Furnish all conduit (split or whole), spacers, couplings and end bells.

12 .13.4.6 Furnish concrete encasement around all permanent duct systems including split duct being retained.

12 .13.4.7 Exercise caution when working in the vicinity of and installing support systems for pipe-type cables. The supporting system shall be designed to mechanically support these pipes, but also to protect the "Somastic" coating around pipes from puncture and vibrational damage.

12 .13.4.8 Provide special backfill around pipe conduit carrying high voltage cable.

12 .14 TELEPHONE

12 .14.1 Codes and Standards

All maintenance, relocation, and support of telephone lines throughout the Metro system (including park areas in Virginia and the Pentagon grounds) shall be in strict conformance with current practices of the affected telephone companies.

12 .14.2 Design Criteria - General

Design shall indicate which telephone lines are to be maintained complete in place; which ducts are to be removed; cables temporarily supported and, upon completion of work, replaced by a new system of ducts and cables; and any rerouting or new construction. Abandoned lines and those to be abandoned shall also be indicated.

12 .15 TELEGRAPH

12 .15.1 Standards

All restoration of **TELEGRAPH** lines shall provide service essentially equal to that offered by the existing installations. No Betterments shall be included unless formally approved by WMATA.

12 .15.2 Design Criteria - General

Design shall include manholes of same size as now exist. Concrete may be used instead of brick. Pipes and conduits shall be temporarily supported and, upon completion of work, placed on compacted backfill.

12 .16 OVERHEAD UTILITY LINES

12 .16.1 Abandonment, relocation, restoration, and extension of overhead utility lines, poles, and appurtenances, including service lines to adjoining properties, will be performed by the owners in accordance with laws and regulations of the concerned jurisdiction, owners' standards, and the National Electrical Safety Code.

12 .16.2 Protection and support of overhead utility lines, including poles, appurtenances, and services shall be provided by the Metro Contractor.

12 .16.3 Poles supporting overhead facilities may be owned by one party and shared with others under mutual agreement. Utilities in this common use arrangement are:

12 .16.3.1 Electric Cables
12 .16.3.2 Telephone Cables
12 .16.3.3 Cable Television
12 .16.3.4 TELEGRAPH Lines
12 .16.3.5 Railroad Communication Lines
12 .16.3.6 Police, Fire Alarm, and other Government Lines
12 .16.3.7 Street Lights and Traffic Signals

12 .16.4 The Designer shall coordinate his efforts with those of the owners to assure that Metro plans include designs mutually acceptable to the owners and the Authority.

12 .16.5 Overhead utility work will normally be accomplished by the utility involved at no cost to the Contractor. Any additional work performed by the owner for the convenience of the Contractor shall be arranged by the Contractor at no expense to the Authority.

12 .16.6 Plans shall denote general type of service provided by overhead lines in accordance with the symbology of Standard Drawing ST-U-14.

12 .16.7 Certain jurisdictions have restricted the use of overhead lines in specific areas. The Designer shall reflect these requirements in project design.

12 .16.8 Clearances shall be in accordance with jurisdictional codes and standards adopted by the utilities involved, and those specified in the National Electrical Safety Code shall be considered the minimum requirement with respect to Metro right-of-way crossings and structures.

12 .16.9 The Designer shall evaluate the need for relocation of existing overhead high-voltage electric lines, including transmission lines, due to hazards from Metro

construction or train operations. Findings and recommendations shall be submitted to WMATA for approval before including any such work in Metro contract documents

12 .17 UTILITIES MARKERS

The presence of utility lines, including drains and culverts, crossing right-of-way below at-grade and embankment sections of Metro, shall be indicated on the site by markers placed at the points where the centerline of the utilities intersect the boundaries of the right-of-way. Markers shall identify each utility, its owner, Metro route, and survey station and depth, as shown on Standard Drawing ST-U-66.

Typically, markers shall be placed just inside of Metro fences, with the face of targets parallel with and facing the adjoining track. They shall not encroach on safety walks, clearance areas, ditches, and service roads.

When circumstances prevent markers being placed on the centerline of the utility, they shall be placed as close thereto as practicable with the direction and offset from marker to utility indicated as shown on Standard Drawing ST-U-66.

The depth of utilities shall be indicated on marker targets to the nearest 0.5'. Whether the marker is on the centerline of the utility or offset therefrom, the depth shall be that from the surface above the installation to the top of the facility.

Style of lettering and numerals on target face shall be Helvetica-Medium.

No markers shall be placed for Metro-owned facilities parallel with or within clearance areas of those crossing rights-of-way and having readily visible manholes and inlets.

12 .18 UTILITIES CROSSINGS OF METRO

12 .18.1 Codes and Standards

All pipeline and conduit crossings beneath at-grade embankment and trench sections and lead and yard tracks of Metro shall be encased in a larger pipe or conduit in accordance with the applicable provisions of Chapter 1, Part 5 of the “Manual of Railway Engineering” of the American Railway Engineering Association, and current practices of the owners of the concerned crossings.

All pipeline and conduit crossings, including access for service thereto, shall meet the requirements of "A Policy on the Accommodation of Utilities on Freeway Rights-of-Way" by AASHTO, latest edition.

Where Metro tracks are parallel with or contiguous to tracks of any of the several railroads operating in the Washington Metropolitan Area, and a utility installation may necessitate crossing the rights-of-way of Metro and railroad, the utility and casement pipe on Metro property shall be compatible with the portion on railroad property.

Appropriate mitigation measures for stray current will be implemented.

12 .18.2 Design Criteria

Casement pipes shall be provided for all pipelines carrying oil, gas petroleum products, other flammable or volatile substances, steam, water or other non-flammable substances under pressure. Electric duct, telephone conduit, gravity flow sewer and drain crossings will not require encasement where the strength of the facility is capable of withstanding Metro loading.

Casement pipes shall include seals and vents, as set forth in the above reference manual. Where Metro is contiguous to railroad tracks and pipelines and casement pipes are continuous beneath both track installations, seals and vents shall be provided at the ends of the continuous system. The Designer shall coordinate his design with the concerned railroad.

The top of casement pipe crossing Metro shall be a minimum of 6.5' below top of rail. The presence of Metro drainage pipes, power cables, and communication lines, or coordination with contiguous railroads may require that this dimension be increased.

Where Metro might be constructed above utilities to be retained in service, the facilities shall be uncovered and encased prior to placing track or, if more economical, replaced by a new system with a jacked casement pipe.

12 .19 SOIL EROSION AND SEDIMENT CONTROL

12 .19.1 General

It is the policy of WMATA to comply with all jurisdictional requirements

12 .19.2 District of Columbia

All construction is to be designed in accordance with the “District of Columbia Erosion and Sediment Control Handbook”, latest edition.

12 .19.3 Maryland

The “Maryland Standards and Specifications for Soil Erosion and Sediment Control” (latest edition) as published by the Maryland Water Resources Administration is to be adhered to during the preparation of the plans.

12 .19.3.1 Montgomery County - The Montgomery Soil Conservation District or the Maryland Department of the Environment is to approve all soil erosion and sediment control plans.

12 .19.3.2 Prince George’s County - The Prince George’s Soil Conservation District or the Maryland Department of the Environment is to approve all soil erosion and sediment control plans.

12 .19.3.3 Maryland State Highway Administration - The Maryland Department of the Environment is to approve all soil erosion and sediment control plans.

12 .19.4 Virginia

All construction is to be designed in accordance with the “Virginia Erosion and Sediment Control Handbook,” latest edition.

12 .19.4.1 Arlington County

12 .19.4.2 Fairfax County

Fairfax County has adopted an ordinance which requires that measures of a temporary or permanent nature shall be applied at all phases of construction to alleviate the harmful or damaging effects of erosion and sedimentation during and after development. Measures for control of erosion and sedimentation meeting County requirements shall be included on the plans when these are submitted for review. To assist designers, the County has published an Erosion-Siltation Control Handbook.

12 .19.4.3 City of Alexandria
12 .19.4.4 Virginia Department of Highways

12 .20 FIRE ALARM AND POLICE COMMUNICATION SYSTEMS

12 .20.1 Codes and Standards - There are no codes or standards. Except for required protection and support of cables and restoration of ducts by subway contractor, all work in the District of Columbia will be performed by the Traffic and Electrical Services Division, Department of Highways and Traffic. Maryland and Virginia areas have no such specialized facilities.

12 .20.2 Design Criteria - General

In the District of Columbia cables are located in ducts of the Verizon Telephone Co. and, to a limited extent, in ducts belonging to the District. Work by the District will be at no cost to the Contractor unless otherwise indicated on drawings and/or specifications.

Maryland and Virginia areas utilize normal telephone lines. There are no separate facilities.

12 .21 PARKS

12 .21.1 Codes and Standards

All relocation and restoration of underground utility lines, water mains, sewers, drains, catch basins, sprinkler systems, lights, pavements and other improvements shall be in accordance with requirements of the several governmental agencies and utility corporations as stipulated elsewhere in these criteria.

12 .21.2 Design Criteria - General

Design for the various facilities shall be submitted to the National Park Service by the Designer for final approval.

Application to the National Park Service for a permit to construct in park areas shall be submitted by WMATA.

12 .22 U.S. CAPITOL GROUNDS

12 .22.1 Codes and Standards

All relocation and restoration of underground utility lines, water mains, sewers, drains, catch basins, sprinkler systems, lights, pavements and other improvements

shall be in accordance with requirements stipulated elsewhere in these criteria for the several governmental agencies and utility corporations.

12 .22.2 Design Criteria - General

Should location of transit facilities necessitate cutting of sidewalks with exposed aggregate surface, restoration shall be made in kind.

Designs for the various facilities will be submitted to the Architect of the Capitol by the Designer for final approval.

Application to the Architect of the Capitol for a permit to construct in the Capitol Grounds will be submitted by WMATA.

12 .23 U.S. STEAM TUNNELS AND PIPES

12 .23.1 Codes and Standards

All work in the District of Columbia and in Arlington (the Pentagon) shall comply with the practices and standards of the General Services Administration.

12 .24 VAULTS

12 .24.1 Codes and Standards

All remodeling, abandonment or other work involving private vaults extending from adjoining buildings into public space shall be in strict accordance with rules, regulations and practices which, in the District of Columbia, shall include the D.C. Building Code, the D.C. Electrical Code, the D.C. Plumbing Code and the National Electrical Safety Code, and applicable codes in other jurisdictions.

12 .24.2 Design Criteria

Determination shall be made as to which vaults will be affected by transit construction. Details shall show portion of each vault to be excavated; new walls required to permit continued use of vaults outside of construction limits; new walls to accomplish complete abandonment of vaults, where required; the work required to restore vaults, including delivery chutes and freight elevators and the area available for permanent occupancy by the original owner upon completion of transit facilities.

The Designer shall also determine what goods or facilities must be removed from vault; how deliveries will be made to properties when existing vault entrances are required to be abandoned; and the time required to take each of the above enumerated steps. This information shall be forwarded to WMATA to arrange for permission to occupy the vault and make the necessary alterations. This information should be forwarded at earliest practicable date so that WMATA may take prompt action and avoid possibility of construction being delayed.

12 .25 PAVING RESTORATION

12 .25.1 Codes and Standards

All pavement restoration in public streets shall be in strict conformance with the current specifications and practices of the several jurisdictions and agencies involved.

12 .25.2 Design Criteria - General

Restored pavements shall be of materials and conform to widths prevailing prior to transit construction. No street, sidewalk or alley widening shall be included.

In the District of Columbia 8" granite curbs shall be used for all restoration and construction of arterial or through streets in accordance with the Master Agreement with the DC Department of Highways & Traffic. Existing 8" granite curbs, when removed, shall be stored and protected until reused. Existing 6" granite curbs, when removed, shall be disposed of and not reused. Additional curb required shall be furnished by the contractor.

Any catch basins disturbed or removed shall be replaced in kind, except that 15" minimum diameter pipe shall be used for any new connection. In jurisdictions other than the District of Columbia, replacements shall be in kind and in accordance with regulations and established policies of the concerned agency.

Designs shall be submitted for owners' final approval by the Designer.

12 .26 PARKING METERS RESTORATION

12 .26.1 Codes and Standards

Does not apply, since work will not involve new meters, only removal and restoration of existing facilities.

12 .26.2 Design Criteria - General

The affected agencies within their jurisdictions will remove and restore meter heads; the contractor shall remove, store and reinstall posts, depending upon parking restrictions during Metro construction and upon interference with Metro construction. Work by the agencies will be at no cost to the contractor unless otherwise indicated on drawings and/or specifications.

12 .27 PASSENGER CAR AND BUS PAVEMENTS

12 .27.1 General

This criteria applies to the design of all paved areas which are to be constructed on Metro station property as part of the rail rapid transit system. Metro parking facilities shall also comply with the Americans with Disabilities Act Accessibility Guidelines (ADAAG). Where this criteria differs from jurisdictional codes and standards, waivers shall be sought or differences resolved during design. For additional related information, refer to the Standard Drawings.

12 .27.1.1 Lane Widths See Chaper 2, Station Site and Access Planning Manual

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12 .27.1.2 Roadway Geometric Design:See Chaper 2, Station Site and Access Planning Manual.

12 .27.2 Soils Investigations

At the request of the Designer, subject to the contractual conditions, WMATA will provide soils tests in those areas which are designated for paving and will provide the soils information which is necessary for pavement design (including classification, ground water conditions, and properties).

12 .27.3 Passenger Car Areas

This criteria includes areas designated for passenger cars only, such as certain entrance and access roads, "Kiss-and-Ride" parking areas, and all other passenger car parking areas.

12 .27.3.1 Grades: See Chaper 2, Station Site and Access Planning Manual .

12 .27.3.2 Drainage:

Design shall be based on a 10-year storm and shall be coordinated with jurisdictional requirements. Pavements shall be sloped to drain to gutter, swales, and inlets, preventing ponding in foot traffic areas and where passengers enter or leave cars. Inlets shall be sized and placed to limit gutter flows to 4-foot spread at crosswalks, 6 feet where adjacent to sidewalks, and 8 feet at all other places.

12 .27.3.3 Soils:

CBR of natural subgrade and improved soil areas should be estimated from the available soil test data. The pavement sections presented on the Civil Standard Drawings have been designed for a subgrade strength of CBR-9. If the local soil conditions do not meet this strength requirement, the Section Designer shall either devise a construction method to improve the soil subgrade to CBR-9 or provide new pavement design.

12 .27.3.4 Pavement:

Design shall be based upon a 20-year design period, initial daily two-direction traffic of 1000 cars, a Design Traffic number between 10 and 50, and Asphalt Institute Design Charts (including handbooks MS-4 and MS-1). The minimum total pavement thickness shall be as shown on the Civil Standard Drawings. Motorcycle parking areas shall be paved with reinforced portland cement concrete.

12 .27.3.5 Parking Spaces:

Standard park-and-ride parking space widths shall be given in See Chaper 2, Station Site and Access Planning Manual

Standard kiss-and-ride parking space widths shall be given in See Chaper 2, Station Site and Access Planning Manual.

Accessible parking spaces for the physically challenged shall be given in See Chaper 2, Station Site and Access Planning Manual.

Drive aisles in kiss-and-ride facilities shall be given in See Chaper 2, Station Site and Access Planning Manual.

Motorcycle parking spaces shall be given in See Chaper 2, Station Site and Access Planning Manual,

12 .28 ENTRANCE/EXIT ROADWAYS AND BUS AREAS

This criteria applies to bus stalls, exclusive bus entrance or exit roads, entrance or exit roads used jointly by buses and passenger cars, and other areas where bus traffic can be expected. If the passenger car area is not clearly separated from that provided for bus traffic, utilize the bus design requirements.

12 .28.1 Grades:

See See Chaper 2, Station Site and Access Planning Manual.

12 .28.2 Drainage:

Design shall be based on a 10-year storm and shall be coordinated with the requirements of local jurisdictions. Pavement shall be sloped to drain away from passenger loading areas.

12 .28.3 Soils:

12 .28.3.1 CBR of natural and improved subgrade soil areas should be estimated from the available soil test data. The pavement sections presented on the Civil Standard drawings have been designed for a subgrade strength of CBR-9. If the local soil conditions do not meet this strength requirement, the Section Designer shall either devise a construction method to improve soil subgrade to CBR-9 or provide a new pavement design.

12 .28.4 Pavement:

Design shall be based upon a 20-year design period, a maximum peak-hour frequency of 200 buses and an AASHTO equivalent single axle loading of 25,000 pounds. All entrance roadways shall be asphalt pavement except that all bus areas shall be concrete pavement. Asphalt pavements shall be designed in accordance with Asphalt Institute's Design Manual MS-1, "Thickness Design - Full Depth Asphalt Pavement Structures for Highways and Streets." The minimum total pavement thickness shall be as shown on the Civil Standard Drawings

12 .28.4.1 Concrete pavements shall be designed in accordance with the Portland Cement Association Publication entitled, "Thickness Design for Concrete Pavements." The minimum total pavement thickness shall be as shown on the Civil Standard Drawings. The Designer shall design a rigid pavement joint layout plan, adhering to the Portland Cement Association's recommended criteria.

12 .29 RAMPS AND CURB CUTS

12 .29.1 Codes and Standards

12 .29.1.1 The design and construction of assessable ramps in areas controlled by WMATA shall follow the direction given in Section 2, WMATA Manual of Design Criteria, Facilities..

12 .29.1.2 Curb cuts in public space shall conform to the standards of the controlling agency of the involved jurisdiction.

12 .29.2 Design Criteria - General

12 .29.2.1 Curb cuts are to be included when curbs in public space are constructed or restored as part of a Metro contract.

12 .29.2.2 The Designer shall obtain from the appropriate agency of the local jurisdiction the locations of curb cuts in public spaces.

12 .29.2.3 Curbs shall be unpainted except where stipulated by applicable codes.

12 .29.2.4 Where more than one accessible ramp is to be provided, the entire length of sidewalk and curb is to be depressed rather than providing individual accessible ramps.

12 .30 STREET AND TRAFFIC LIGHTS

12 .30.1 Codes and Standards

All relocations, temporary or permanent, and restoration of these facilities shall be in strict accordance with the practices of the agencies involved.

12 .30.2 Design Criteria - District of Columbia

Street and traffic lights are usually served by cables located in ducts of the Potomac Electric Power Company. In some instances street lights are served by cables laid behind curb lines.

Work on street light and traffic signal facilities is to be performed as follows:

12 .30.2.1 Potomac Electric Power Company will:

12 .30.2.1.1 Remove and restore existing facilities.
12 .30.2.1.2 Install temporary facilities except for those to be installed by the Contractor.
12 .30.2.1.3 Maintain the electrical service during construction.

12 .30.2.2 District of Columbia will:

12 .30.2.2.1 Furnish temporary and permanent facilities.
12 .30.2.2.2 Adjust traffic signal controllers.

12 .30.2.3 WMATA's Contractor will:

12 .30.2.3.1 Install and ultimately remove conduits and standards for temporary traffic signals which are placed over construction decking.
12 .30.2.3.2 Install and ultimately remove the complete temporary street light facility when installation is required over construction decking.

12 .30.3 Design Criteria - Virginia

12 .30.3.1 Arlington County

Criteria is dependent upon the type of fixtures and area of County involved and shall be secured from County or state authorities, and, for the Pentagon, from the General Services Administration.

All work involving street lights, except certain privately owned poles, shall be handled by PEPCO and Dominion Virginia Power at no cost to Contractor.

The Contractor shall be responsible for and handle any work involving lights owned by private parties.

All work involving traffic lights controlled by Arlington County will be performed by County forces. Work on facilities of VDOT will be performed by contractors engaged by the owners. All of this work will be at no cost to the Metro contractor. In decked areas, temporary poles, lights and ducts shall be furnished, erected and removed by the Authority's contractor.

12 .30.3.2 Fairfax County

Work involving installation, removal and maintenance of street and traffic lights within Fairfax County, excluding state highways, will be performed by Dominion Virginia Power personnel at no cost to the Metro contractor.

Street and traffic lights located along state highways will be serviced by state crews or by contractors engaged by VDOT.

The contractor shall handle and be responsible for any work involving lights owned by private parties.

In decked areas, temporary poles, lights and ducts shall be furnished, erected and removed by the Authority’s contractor.

12 .30.3.3 City of Alexandria

All work involving street lights within the City of Alexandria will be handled by Dominion Virginia Power at no cost to the contractor.

The contractor shall handle and be responsible for any work involving lights owned by private parties.

Traffic light poles and guying of the poles in the City are to be handled by Dominion Virginia Power with the signal heads and wiring to be done by forces of the City of Alexandria, all at no cost to the Metro contractor.

In decked areas, temporary poles, lights and ducts shall be furnished, erected and removed by the Authority’s contractor.

12 .30.3.4 Virginia Department of Transportation

Where street lights belonging to the Virginia Department of Transportation are to be relocated, the replacement of these facilities shall be in kind and shall comply with VDOT standard drawings and specifications.

12 .30.4 Design Criteria - Maryland

12 .30.4.1 Montgomery County

Relocations, restorations and other work involving street and traffic lights shall meet the standards of Montgomery County and the Maryland State Highway Administration.

All work involving abandonment, relocation, restoration and temporary installation of street lights will be handled by PEPCO without cost to the Metro contractor.

The Montgomery County Department of Public Works will handle all work involving traffic lights and appurtenances on County and state roads at no cost to the Metro contractor. However, final approval of any work on state roads shall be directed through State Roads Commission.

In decked areas, temporary poles, lights and ducts shall be furnished, erected and removed by the Authority's contractor.

12 .30.4.2 Prince George's County

Relocation, restoration and other work involving street lights and traffic lights shall meet the standards of Prince George's County and the Maryland State Highway Administration.

The State Highway Administration is responsible for all work involving abandonment, restoration, relocation and temporary installation of street lights and traffic lights on state roads. The Prince George's County Department of Public Works is responsible for all work on County roads, although maintenance of some of the traffic lights and street lights on state roads is accomplished by the County. However, final approval of any work on state roads shall be directed through the State Highway Administration.

The Section Designer shall coordinate with MSHA, Prince George's County Department of Public Works and other affected municipalities to determine jurisdictional responsibility.

Work by the agencies will be at no cost to the contractor.

In decked areas, temporary poles, lights and ducts shall be furnished, erected, maintained and removed by the Authority's contractor.

SECTION 13 ELECTRICAL

13 .1 GENERAL

These design criteria include functional and design requirements for the supply and supervision of all electrical power to the Washington Metropolitan Area Rapid Rail Transit System.

The Electrical System shall supply power to all transit facilities to provide safe, efficient and continuous operation of the entire system. Design of the Electrical System shall be coordinated with the requirements of the individual power companies in D.C., Maryland and Virginia providing primary power to the system.

13 .1.1 Clearance to Installations

A minimum of 2" is required between any fixed installation (e.g., pipes, pipe hangers, pipe supports, signals, lighting fixtures, etc.) and the design vehicle dynamic outline. This is defined by the clearance envelope. However, installations shall be so dimensioned and located that maximal distances are obtained between these and the clearance envelope along tangent and curved alignments.

13 .2 SCOPE

The following shall be included in the Electrical System Scope of work:

13 .2.1 Auxiliary AC Electrical Systems to supply power for heating, ventilating, operation of mechanical equipment including elevators, escalators, pumps and ejectors, train control, fare collection equipment, communications, lighting and emergency power system.

13 .2.2 Lighting systems for illumination of passenger stations, tunnels, and all other facilities of the transit network.

13 .2.3 Electrical Supervisory Control functions required for supervising and controlling the performance of power and electrotechnical equipment vital to the continuous operation of the transit system. The Electrical Supervisory Control functions will interface with the Data Transmission System described in Systems Book of the WMATA Manual of Design Criteria.

13 .2.4 Energy Management System required for monitoring and controlling field equipment via the remote terminal units as described elsewhere in this criteria.

13 .3 GLOSSARY

13 .3.1 Standard Terminology

In general, definitions applied to AC Power, and Supervisory Control Functions shall conform to definitions listed in ANSI/IEEE C37.100 of the American National Standards Institute and the Institute of Electrical and Electronics Engineers.

Basic electrical terminologies used in these criteria, which are not defined in the ANSI/IEEE reference or in the following Special Terminology, are to be interpreted in their normal usage.

13 .4 STANDARDS AND CODES

Where applicable, AC Power and lighting system design shall conform to the following standards and codes:

13 .4.1 National Electrical Code (NEC)

13 .4.2 National Electrical Safety Code (NESC)

13 .4.3 Electrical Codes of the District of Columbia and Counties of Maryland and Virginia through which the Transit System will operate

13 .4.4 American National Standards Institute (ANSI)

13 .4.5 National Electrical Manufacturers Associations (NEMA)

13 .4.6 Institute of Electrical and Electronic Engineers (IEEE)

13 .4.7 Insulated Cable Engineers Association (ICEA)

13 .4.8 Underwriters Laboratories, Inc. (UL)

13 .4.9 Intertek Testing Services (ITS)

13 .5 TRACTION POWER SUPERVISORY CONTROLS

The supervisory control and indication functions shall be carried back to a zone control panel located in the traction power facility serving the traction power zone that the heater elements are installed on. Control cables shall be installed in the mainline ductbank.

The zone control panel supplies 480V ac control power and 120V DC power for indication functions to the trackside heater control panels located in its traction power zone. The zone control panel shall be operated locally or remotely through the Data Transmission System back to the Operations Control Center (OCC).

Each zone control panel controls a specified number of trackside heater control panels. Individual manual control of heater elements is available for each track. Outbound or inbound heater elements can be turned on or off individually.

Storage track isolation switch shall provide isolation for the heater tape.

Details of the contact rail heater system are shown on the Electrical Design Drawings.

13 .6 SUBSTATIONS

13 .6.1 Lighting and Auxiliary Electrical Systems

13 .6.1.1 Lighting - Traction Power Substations and Tie Breaker Stations

For lighting requirements, see 13.8.4.1.5.

13 .6.1.2 Convenience Outlets in Traction Power Substations and Tie Breaker Stations

Duplex convenience outlets for maintenance use shall be located approximately 20 feet apart around the interior walls of the substation. One outlet near each group of switchgear and rectifiers shall be supplied from a separate circuit to permit use of a heavy-duty vacuum cleaner.

In the open transformer yard of substations at least two weatherproof duplex ground fault circuit interrupter type convenience outlets shall be provided.

13 .6.1.3 One quick connect outlet rated 100 ampere, 4-pole, 480 volts, similar to that described in Section 13.7.4.5 shall be provided outside the building for hooking up an emergency mobile generator. Also, in traction power substation below ground, the quick connect shall be located as close to the street level as possible. The outlet shall be connected to the emergency 480V power panel ahead of the main breaker to permit feeding the substation emergency load during a prolonged outage or UPS/battery failure.

13 .6.1.4 AC Substation and Auxiliary Power

Substations and Tie Breaker Stations located at passenger stations shall be provided with a dedicated 277/480V feeder from the normal switchboard in the nearest AC switchboard room with the feeders terminated in panelboard. Provide a 480 - 208Y/120V, three-phase, four wire transformer and panelboard to serve 120V loads. The 277/480V power shall be used for lighting, ventilation and other uses. The 120V shall be used for switchgear heaters, receptacles, etc., as shown on design drawings. For substations and tie breaker stations not located at passenger stations, an economic analysis shall be conducted to consider the following options as means for obtaining power, subject to WMATA approval:

13 .6.1.4.1 Service from nearest passenger station AC switchboard room.

13 .6.1.4.2 Service from an auxiliary transformer fed from the substation high voltage switchgear.

13 .6.1.4.3 480/277 volt service from Utility Company. Auxiliary transformer shall be of sufficient capacity to provide auxiliary AC power to the substation and to associated AC power zones.

13 .6.1.5 Traction Power Substation and Tie Breaker Station Emergency Power and DC Power

When facilities are located at passenger stations, 120V emergency and 125V DC power feeders shall be provided from the nearest AC switchboard room. The feeders shall be terminated in panelboards. When substation and tie breaker stations are located away from passenger stations, the Uninterruptible Power System (UPS) rating shall be 5 kVA emergency AC load and 5 kW continuous DC load. Round-cell batteries shall be provided to feed emergency AC power and 125V DC power needs. The UPS shall be suitable for 480V 3-phase input and 120/208V, 3-phase output.

13 .6.2 Substation and Tie Breaker Station Grounding

AC substations shall be equipped with a 1/4" x 2" copper ground bus on the inside periphery and necessary extension cabling connected to a ground grid. Each substation ground bus shall have a maximum resistance to ground of 2 ohms.

Each tie breaker station ground bus shall have a maximum resistance to ground of 5 ohms.

Equipment enclosures and raceways for alternating current equipment, including AC switchgear and rectifier transformers, shall be firmly grounded to the ground bus. Structural metalwork where exposed within the substation, supervisory control cabinets, and ventilation equipment or ductwork shall be grounded to the ground bus.

13 .6.3 Automated Energy Management System (AEMS)

At each traction substation, provisions shall be made for selective indication and control functions to be available remotely at the OCCB using an energy management system. The system shall consist of providing transducers for analog output signals, contacts for indication, contacts for control functions, and interconnection wiring between I/O functions and remote terminal unit (RTU) located in the substation. The AEMS-RTU shall be compatible with the Authority's QEI, Inc. master station located at the OCCB.

I/O point count for RTU shall be as follows:

		Points
Analog Input:	0-1 Ma	16
	4-20 mA	16
Status Input:		40
Control Output:	Latching	16
	Momentary	16
Pulse Accumulator:		8

13 .7 AUXILIARY ELECTRICAL SYSTEMS

13 .7.1 General

This section identifies the requirements for installation and operation of all lighting circuits and auxiliary electrical equipment in the Rapid Rail Transit system. Specific criteria for lighting systems required for proper illumination of the passenger stations and connecting structures are covered more fully in subsequent sections.

13 .7.2 Scope

The following criteria covers all AC power electrical systems required to serve the lighting and auxiliary electrical and mechanical equipment throughout all parts of the system. In general this includes:

13 .7.2.1 Lighting

13 .7.2.2 Heating, Ventilating and Air Conditioning Equipment

13 .7.2.3 Escalators and Elevators

13 .7.2.4 Fare Collection Equipment

13 .7.2.5 Communications Systems, including fire alarms, security alarms, CCTV monitors, and public address systems.

13 .7.2.6 Train Control Equipment

13 .7.2.7 Emergency Power Systems

13 .7.2.8 Illuminated Signs

13 .7.2.9 Pumps (drainage, sewage, etc.)

13 .7.2.10 Kiosks

13 .7.2.11 Parking Facilities

13 .7.3 AC Switchboard Room Power Supply

13 .7.3.1 Power Source

As stated in Section 13.6.2, the utility company will provide the source of power within the territory served by each company.

Service voltage to WMATA facilities will generally be either 13.8 kV or 34.5 kV. In some areas and facilities (e.g., chiller plants which are located at considerable distances from the nearest passenger stations), service at 277/480 volts may be economically preferred. Final determination of the type of service at such sites will be made by the Authority. Design of facilities for 277/480 volt services shall comply with local codes and Utility Company requirements.

In general, each passenger station has either two AC switchboard rooms (one at each end of the station), or one combined AC switchboard room with both AC unit substations located in this room. Each unit substation will receive a separate three phase service from the power company serving the area and will transform and distribute the power to loads within the station and adjacent line and facilities as shown on General Plans.

In 13.8 kV power areas, supply one primary dedicated underground power service to each AC unit substation. In 34.5 kV power areas, supply one dedicated underground primary power service to each AC unit substation.

One normally open tie breaker shall connect the two unit substation secondary buses in the combined AC switchboard room, and two normally open tie breakers shall connect the two unit substation buses in the physically separated AC switchboard rooms to form a secondary selective network as indicated on the Electrical Design Drawings.

Minimum clearance in front of and at the rear of incoming service switchgear shall be coordinated with the utility company as applicable.

13 .7.3.2 Metering

13 .7.3.2.1 In a 13.8 kV service area, a unit substation or secondary distribution center shall include provisions for power company metering in accordance with their requirements. Provisions shall be made in the combined AC switchboard room or in one of the two AC Switchboard Rooms at a passenger station for mounting a meter cabinet on the wall. The metering transformers and meter cabinet will be furnished by the power company. Minimum clearance in front of the metering cabinet shall be coordinated with the utility company.

The transformers shall be installed in the auxiliary switchgear cubicle by the WMATA Contractor. The power consumption of each passenger station shall be totaled. Details of the meter tie conduit requirements for this purpose are shown on the Electrical Design Drawings. A 120 volt, 15 ampere dedicated normalcircuit shall be provided to the metering locations.

13 .7.3.3 Service Ducts

Cable ducts for primary power service shall be provided in the WMATA facility structures as required and approved by the Utility Company. Primary cable ducts shall generally extend from the switchboard room through the outside wall or roof to a point three feet below ground level and a minimum of five feet beyond the outside of the structure or to the WMATA right-of-way limit and then capped.

The Utility Company will furnish and install the ductwork from their manhole or substation to connect to the ductwork from the structure and will furnish and install the service cables.

For 13.8 kV services FRE conduits shall be installed as follows:

- To single AC switchboard rooms: 3-5"
- To combined AC switchboard rooms: 4-5"

For 34.5 kV services PVC conduits shall be installed as follows:

- To single AC switchboard rooms: 4-8"
- To combined AC Switchboard rooms: 6-8"
- Non-metered Traction Power Substation: 6-8"
- Metered Traction Power Substation: 10-8"

Provide O. Z. Gedney Type CSBE bushings or equal to plug empty Utility Company service ducts.

The design of incoming primary service cable ducts shall be included in the design of facilities by the Section Designer and shall be coordinated with the Utility Company to obtain their approval.

When the Utility Company is required to supply 480Y/277V power to a traction substation or chiller plant, the service ducts shall be included in the design of the substation/chiller plant. Quantities, sizes, and routing of service ducts shall be approved by the power company and shall comply with all local codes.

13 .7.4 AC Unit Substations

AC unit substations shall be housed in free-standing, ventilated, indoor, metal enclosures located in each switchboard room to provide clear space of not less than 6'-O" at the front and 3'-6" at the back and end.

AC unit substations shall contain incoming primary switchgear (including auxiliary cubicle for 13.8 kV service), distribution transformer, 480 volt switchgear, and switchboard; and shall form a dead front assembly.

13 .7.4.1 Equipment for 15KV Primary Service Area

13 .7.4.1.1 AC Incoming 15kV Primary Switchgear - either (a) or (b) below:

13 .7.4.1.1.1 One primary circuit breaker rated at 1200 amperes, 15 KV indoor, draw out, vacuum break, 3 phase, 60 hertz, having 750 MVA interrupting capacity of the stored energy type, with relays, necessary potential transformers, and current transformers. The primary service breaker shall be provided with local control and both local and supervisory status indication. Tripping and closing mechanisms shall draw power from a local 125 volts DC source.

All high-voltage primary (draw out) circuit breakers in the AC switchgear of 13.8KV or higher shall be located near the floor of the cubicle. Separate handling devices for removal or insertion of the circuit breaker, other than transfer truck or fifth-wheel steering bar, are prohibited.

Provisions shall be made for field mounting incoming service cable potheads or terminators, which shall be furnished by the Utility Company and installed by the contractor.

13 .7.4.1.2 Auxiliary Cubicle

One auxiliary cubicle with provisions for mounting and connecting metering potential transformers and current transformers for each primary service furnished by the Utility Company and all necessary transition buswork.

13 .7.4.1.3 Transformer

The transformer shall be indoor, ventilated, cast coil, dry type, 13.8 KV, 3 phase, 60 hertz, delta primary, 480Y/277V, 4-wire secondary.

It shall have sufficient self-cooled capacity to serve the total demand load (largest of winter or summer) of both unit substations, plus 20% for future growth.

To the extent practicable, the demand loads supplied by both unit Substations supplying a passenger station and transit facility shall be equalized. Where unusual demand loads occur, (such as a chiller plant load near one end of a passenger station, or a fan shaft on one side of a passenger station but not on the other) which results in a large difference in the demand loads of the two unit substations, the designer shall advise the Authority who will coordinate and assist in determining the solution.

In passenger stations, the designer shall design a unit substation design wherein all loads are connected to the main secondary bus. For unit substation designs, the transformers shall have sufficient self-cooled capacity to serve the total demand load of both unit substations plus 20% for future growth.

13 .7.4.2 Equipment for 34.5 KV Primary Service Area

13 .7.4.2.1 AC incoming 34.5 kV Primary Switchgear

One primary circuit breaker rated at 1200 amperes, 34.5 kV, indoor, vacuum break, draw out type, 3 phase, 60 hertz, having 1500 MVA interrupting capacity of the stored energy type, with relays, current transformers, and potential transformers. The primary breaker shall be provided with local control and both local and supervisory status indication. Tripping and closing mechanisms shall draw power from a local 125 volt DC source.

Provisions will be made for field mounting incoming service cable potheads or terminators, which will be furnished by the Utility Company and installed by the contractor.

13 .7.4.2.2 Transformer

The transformer shall be indoor, ventilated, cast coil, dry type, 34.5 KV, 3 phase, 60 hertz, delta primary, 480Y/277 volts, 4 wire secondary.

Self-cooled capacity shall be in accordance with Section 13.7.4.1.3.

To the extent practicable the demand loads for both unit substations shall be equalized in accordance with Section 13.7.4.1.3.

13 .7.4.3 480 Volt Switchgear and Switchboard

Secondary main and tie breakers, shall be rated at 480 volts, 3 phase, 60 hertz; and they shall be draw out type low voltage power circuit breakers with stored energy closing mechanisms. These circuit breakers shall be manually actuated close with manual and electrically operated trip; except that the tie breakers shall include electrically actuated close.

Each secondary main and tie breaker shall be equipped with a solid-state tripping system consisting of three current sensors, microprocessor-based controlled phase over current trip device and flux-transfer shunt trip, ground-fault protection, position indicating lights, spare auxiliary contacts for DTS, accessories and interlocks. The trip device shall have long-time and short-time elements, communication interface, power metering and non-volatile memory for protective settings. The trip unit shall be equipped with an energy monitoring function processor to provide at a minimum; Phase Current (amps), Peak Demand (Kilowatts), Present Demand (Kilowatts) and Energy Completion (Kilowatts-hours).

For each secondary main and tiebreaker, provide a Digital Power Metering system as follows:

13 .7.4.3.1 Provide Digital Power Metering to measure the real-time RMS values of phase currents, ampere demand and phase and line voltages plus power measurements including kW, kW demand, kW-hours, kVA, kVAR-hours. Power factor and frequency shall also be measured. Resettable minimum and maximum values for each measured value shall be recorded in a nonvolatile memory. The digital power meter shall derive power from a separate 125V ac or DC source, and includes the following:

13 .7.4.3.1.1 Internal illuminated display for reading all real-time and min\/max measured values as well as programming initial configuration and any relay set points.

13 .7.4.3.1.2 Three programmable relay outputs shall be provided to activate and release based on threshold and time-delay values associated with any of the measured parameters.

13 .7.4.3.1.3 Communications module to remotely read real-time and min/max measured values, interrogate the event log, reset min/max and kW/kVAR-hours, program configuration and any relay set points.

13 .7.4.3.1.4 Extended memory

13 .7.4.3.1.5 Portable Interface Device

13 .7.4.3.1.6 Software

In a 34.5 kV area, power company metering requirements are described in Section 13.6.2.

All breakers shall have short circuit interruption capacity as determined by short circuit calculations and approved by the Authority. Feeder breakers in switchboard shall be ambient compensated and shall be molded case bolt-on type. Integrally fused circuit breakers may be used where necessary to obtain suitable protection of down-stream equipment and wiring.

Time coordinated ground fault protection on secondary main, tie breakers and feeder breakers shall be provided. Single point grounding shall be provided as indicated on the electrical design drawings.

480 volt switchgear buses and secondary main circuit breaker frame sizes shall be based on transformer forced air-cooled capacity. Breaker trip ratings shall be based on calculated initial loads plus allowance for future 20% growth.

13 .7.4.4 Breaker Operation

Control power shall be provided at 125 volts DC, and shall be fed using a minimum of two No. 6 AWG wires. Unit substations for 34.5 kV or 13.8 kV service through metal-clad switchgear shall have the following control operation:

13 .7.4.4.1 Primary breaker is tripped by primary undervoltage condition (detected by 27/59 relay for 13.8 kV service and 27 relay for 34.5 kV service), residual ground, or phase over current relays. Primary breaker is closed via manually operated switch.

13 .7.4.4.2 Secondary main breaker is tripped automatically by tripping of primary breaker. Secondary main breaker is closed via manually operated switch.

13 .7.4.4.3 When the secondary main breaker is tripped by the primary breaker due to an undervoltage at the primary service, and if the other secondary main breaker is closed, the tie breaker(s) shall automatically close. Closing of the tie breaker(s) is blocked if the primary breaker or secondary main breaker has tripped because of over current or ground fault condition; closing of the breaker(s) is also blocked if both secondary main breakers in a passenger station are closed.

13 .7.4.4.4 Second stage transformer over temperature device shall trip the primary breaker.

13 .7.4.4.5 Where two tie breakers are required due to unit substation being located in separate switchboard rooms, both tie breakers shall close simultaneously, and the tripping of either tie breaker shall instantaneously trip the other tie breaker.

13 .7.4.4.6 LPC shall be provided to coordinate the operation of primary breakers, secondary main breakers and tie-breakers.

13 .7.4.5 At each passenger station provide an emergency generator quick connect system with the following requirements:

13 .7.4.5.1 Quick connect breaker shall be capable to handle up to 100 kW power from an emergency diesel generator.

13 .7.4.5.2 Provide a normally open quick connect circuit breaker in the three phase, 480V ac switchboard that feeds the normal side of the UPS system.

13 .7.4.5.3 The generator plug shall be 100 amp, 4-pole Crouse Hindes Type AR1041. The receptacle shall be installed outside the building but close to the station entrance as possible in an area suitable to park a 100 kW mobile generator. The cable from the generator to the receptacle shall not exceed 25 feet in length.

13 .7.4.5.4 Provide "warning nameplate" on quick connect circuit breaker that reads "Generator Quick Connect Circuit Breaker - Do not Close without Permission from Maintenance Operating Center, Phone Number 1058".

13 .7.4.6 Provision for System Growth

AC power service facilities shall be designed to permit an increase of 20% in load. This includes all switchboards, distribution transformers, feeders, panelboards, and motor control centers. Space shall be provided at each unit substation for the installation of one additional switchboard cubicle.

13 .7.4.7 Provisions for substation maintenance equipment.

In each AC unit substation provide the following:

13 .7.4.7.1 72" x 36" x 36" heavy-duty metal storage cabinet with 4 shelf arrangement.

13 .7.4.7.2 Eight (8) foot fiberglass step ladder.

13 .7.4.7.3 Full set of as-built, half-size, Electrical Contract and Equipment Shop Drawings bound in stiff cover resistant to oil, water and wear. Drawings shall be capable of being stored in the metal cabinet.

13 .7.4.7.4 11" x 17" Wall mounted Maintenance Map/Single Line Diagram. Mounting frame shall be metal with lexan or plexiglass. Mount frame as directed by the Engineer.

13 .7.4.7.5 30" x 48" heavy-duty metal work bench with reinforced steel top and task stock. Work bench shall be 34" high with one No. 12 gauge steel shelf, full width and depth of bench with back turned up 2 inches. Provide 1/4" rubber matting to cover entire top of work bench.

13 .7.5 General Electrical Characteristics

13 .7.5.1 Utilization Voltages

AC auxiliary power shall be nominal 480Y/277 volts, 3 phase, 4 wire, 60 hertz. Where other than this voltage is required for

utilization, such voltages shall be obtained by use of dry type transformers. Utilization voltages for devices and equipment requiring AC power shall conform to the following characteristics:

13 .7.5.1.1 Fluorescent Lights	277 volts (preferred) or120 volts single phase
13 .7.5.1.2 Incandescent Lights	
13 .7.5.1.2.1 Platform edge	120 volts, single phase lights controlled by flasher and dimmer control unit
13 .7.5.1.2.2 Maintenance lights	120 volts, single phase controlled manually

13 .7.5.1.2.3	Lights at platform	277 volts, single phase canopies, Type A-1 pylons, passage-ways, fare gates, and escalators/stairs landing
13 .7.5.1.3	High Intensity Discharge Lights	
13 .7.5.1.3.1	General	277 volts, single phase
13 .7.5.1.3.2	Lights equipped	120 volts, single phase with medium base 277 volts, single phase lamp holder
13 .7.5.1.4	Convenience Outlets	120 volts, single phase
13 .7.5.1.5	Motors	
13 .7.5.1.5.1	3/4 to 200 HP	460 Volts, three phase
13 .7.5.1.5.2	½ HP and below	115 volts, single phase
13 .7.5.1.6	Motor Control Power	120 volts, single phase
13 .7.5.1.7	Duct heaters and unit heaters	
13 .7.5.1.7.1	below 4 KW	277 volt, single phase
13 .7.5.1.7.2	4 KW and above	480 volts, three phase
13 .7.5.1.8	Wall convectors	
13 .7.5.1.8.1	below 4 KW	277 volts, single phase
13 .7.5.1.8.2	4 KW and above	480 volts, three phase
13 .7.5.1.9	Water heaters	
13 .7.5.1.9.1	6 GPH recovery	120 volts, single phase and below
13 .7.5.1.9.2	above 6 GPH	480 volts, three phase recovery
13 .7.5.1.10	Chillers	460 volts, three phase
13 .7.5.1.11	Air conditioning	
13 .7.5.1.11.1	10,000 BTUH	115 volts, single phase and below
13 .7.5.1.11.2	over 10,000 BTUH	208 volts, single phase and through 36000 BTUH
13 .7.5.1.11.3	over 36000 BTUH	460 volts, three phase
13 .7.5.2	Large Motor Starters	

For 460 volt motors, starter shall include a control transformer. Across-the-line motor starter shall be used for motors up to and including 50 HP at 460 volts, three phase.

All motors over this limit shall be equipped with reduced voltage starters of the auto-transformer, 2-step, closed transition type, unless otherwise approved by the Authority. All remotely located motor control centers (such as fan shafts, pumping stations or chiller plants) shall be provided with main incoming breakers.

13 .7.5.3 Load Classification

Load requirements are classified into two categories:

ormal loads and emergency loads (from the Uninterruptible Power Supply (UPS) System). Normal loads are listed below.

Emergency power loads are listed in Section 13.7.7

Essential Nnormal Loads

13 .7.5.3.1 Pumping stations

13 .7.5.3.2 Fan shafts

13 .7.5.3.3 Lighting (station areas, ancillary spaces, parking lots, fan and vent shafts, and tunnels)

13 .7.5.3.4 Entrance escalators and associated heaters

13 .7.5.3.5 Rectifier/charger for UPS

13 .7.5.3.6 UPS by-pass circuit

13 .7.5.3.7 Train control Equipment (Reserve Feeder)

13 .7.5.3.8 Fare collection equipment

13 .7.5.3.9 Elevators

13 .7.5.3.10 Parking lot entrance equipment

13 .7.5.3.11 Kiosk air conditioning/heating and lighting

13 .7.5.3.12 Battery Room ventilation fan

13 .7.5.3.13 Under platform exhaust (UPE) and dome exhaust (DE) systems and control

13 .7.5.3.14 Utility Company metering equipment

13 .7.5.3.15 Control air compressor

13 .7.5.3.16 Heat trace for piping

13 .7.5.3.17 Bus transfer dispenser

13 .7.5.3.18 Map and telephone case lights

13 .7.5.3.19 Emergency Generator Quick Connect

13 .7.5.3.20 Heating

13 .7.5.3.21 Air conditioning

13 .7.5.3.22 Ejectors

13 .7.5.3.23 Miscellaneous mechanical equipment (motors, heaters, ventilation fans)

13 .7.5.3.24 Water heaters

13 .7.5.3.25 Receptacles

13 .7.5.3.26 Sump pumps

13 .7.5.3.27 Mezzanine-to-platform escalators

Note: In maintenance facilities all loads shall be treated as normal loads except those requiring connection to emergency power.

13 .7.6 Panelboards

13 .7.6.1 Designations

The designation of each panelboard shall indicate the following information about the panelboard:

13 .7.6.1.1 General location of the panelboard in a passenger station -- (N) north, (S) south, (E) East, and (W) west.

13 .7.6.1.2 Specific location of the panelboard in a passenger station -- whether in AC switchboard room or electrical room, on mezzanine, or in a mechanical room.

13 .7.6.1.3 Identity of panel source -- normal or emergency.

Service voltage -- 480Y/277 volt AC or 208Y/120 volt AC, or 125volt DC.

The panelboards shall be designated and located as shown in Table 13.2. All circuits shall be identified with the panel identity and the branch circuit number. Thus a circuit fed by breaker #3 in panelboard NE is identified NE-3. The top of all panelboards shall be located 6'-6" maximum from the floor level.

No panelboards are to be located in cleaner's rooms, sewage ejector rooms, wash rooms, or locker rooms.

13 .7.6.1.4 TABLE 13.2 - LOCATIONS & IDENTITIES OF PANELBOARDS

AC Switchboard or Electrical Room		NORTH	EAST	SOUTH	WEST
480/277V	Normal	NES	EES	SES	WES
208/120V	Normal	NESS	EESS	SESS	WESS
480/120V	Emergency	NE	EE	SE	WE
208/120V	Emergency	NEE	EEE	SEE	WEE
125V DC		ND	ED	SD	WD
Mezzanine (Where only one mezzanine exists in a station the first letter of the designation (N, E, S or W) may be omitted.)		NORTH	EAST	SOUTH	WEST
480/277V	Normal	NMES	EMES	SMES	WMES
208/120V	Normal	NMESS	EMESS	SMESS	WMESS
480/120V	Emergency	NME	EME	SME	WME
208/120V	Emergency	NMEE	EMEE	SMEE	WMEE
Mechanical Room		NORTH	EAST	SOUTH	WEST
480/277V	Normal	NAES	EAES	SAES	WAES
208/120V	Normal	NAESS	EAESS	SAESS	WAESS
Traction Substation, Tie-Breaker Station, Chiller Plant (Note that the general location letter designation (N, E, S or W) is not required.)		T.P. SUBSTATION		T.B. STATION	CH. PLANT
480/277V	Normal	S		TB	CH
208/120V	Normal	SS		TBB	CHH
125V DC		SD		TBD	-

TUNNEL and FAN SHAFT load centers

Tunnel - TLCL, TLC2, etc. as required for contract

Fan Shaft - FLCL, FLC2, etc. as required for contract

13 .7.6.2 Panelboard Sizes

The following will serve as a guide in selecting panelboard sizes:

Minimum Breaker Poles Connected	No. of Spare 20A Breakers	Unused Spaces	Panel Size Single Poles
Up to 8	2	2	12
9 to 12	4	2	18
13 to 22	4	4	30
22 to 28	4	4	36
29 to 36	4	4	42

Unused spaces shall be equipped with buswork and terminations for breakers.

13 .7.6.3 Demand Factors

Service	Demand Factor
Lighting and Signs	100% of Connected Load
Emergency Lighting	100% of Connected Load
Fare Collection Equipment	90% of Connected Load
Escalators	80% of Connected Load
Elevators	50% of Connected Load
Ventilation Equipment	70% of Connected Load
Air Conditioning Equipment	70% of Connected Load
Chiller Plant	80% of Connected Load
Heating	70% of Connected Load
Drainage Pumps & Ejectors	70% of Connected Load
Train Control Equipment	70% of Connected Load
Communications Equipment	70% of Connected Load
Convenience Outlets	1.5 amperes per receptacle

The designer shall indicate the calculated demand load total at each panelboard schedule for summer and winter.

13 .7.6.4 DC Panel Board

This panel shall supply power for:

13 .7.6.4.1 High voltage and 480 volt switchgear and switchboard control.

13 .7.7 Emergency Power System

Provide an Uninterruptible Power Supply (UPS) system rated 50 kVA, 480/277 volt, three phase in at-grade or aerial passenger stations. Provide a UPS rated 62.5 kVA 480/277 volt, three phase in underground passenger stations.

Emergency power for loads listed below shall be provided from a UPS system. The UPS output is backed up by an alternate normal feeder and automatic transfer switch. The rectifier/charger, inverter, and transfer switch shall be located in the AC Switchboard room adjacent to the battery room. The battery disconnect

device (enclosed circuit breaker) shall be wall mounted inside and next to battery room entry door, if possible. The UPS shall be capable of operation from the power source of a mobile generator.

13 .7.7.1 Rectifier/Charger

A silicon rectifier/charger shall be of adequate capacity to provide DC input to inverter to give rated output while simultaneously providing charge to battery at rate to give full charge in 12 hours after battery has been fully discharged, and to provide control power for high voltage and 480 volt switchgear.

13 .7.7.2 Battery

13 .7.7.2.1 Storage batteries shall be UPS cycle duty, industrial flooded lead acid cell.

13 .7.7.2.1.1 The discharge capacity capable of providing DC inverter input to give rated inverter output at unity power factor for three hours at 77°F while simultaneously providing DC continuous and final minute

load for switchgear. Minimum battery terminal voltage of 105 volts under full load at end of three hour discharge period.

13 .7.7.2.1.2 The two tier battery rack is 1'-3" wide by 2'-6" long by 6'-4" high. Each rack has two cells per tier.

13 .7.7.2.1.3 The battery room in Aerial or At-grade Passenger Stations with 50 kVA UPS shall have 60 cells batteries. Where the load exceeds the capacity of 60 cells, a second set of 60 cells shall be connected in parallel.

13 .7.7.2.1.4 The battery rooms in Underground Passenger Station with 62.5 kVA UPS systems shall have one set of 60 cells batteries. Where the load exceeds the capacity of 60 cells, a second set of 60 cells shall be connected in parallel.

13 .7.7.2.1.5 Minimum battery room size in Aerial or At-grade Stations:

13 .7.7.2.1.5.1 13.8 kV Area: 18'-0" long by 24'-0" wide by 12'-0" clear height

13 .7.7.2.1.5.2 34.5 kV Area: 18'-0" long by 24'-0" wide by 16'-0" clear height

13 .7.7.2.1.6 Minimum battery room size in Underground Stations:

13 .7.7.2.1.6.1 13.8 kV Area: 18'-0" long by 24'-0" wide by 12'-0" clear height

13 .7.7.2.1.6.2 34.5 kV Area: 25'-0" long by 18'-0" wide by 16'-0" clear height

13 .7.7.2.2 Each battery room shall be ventilated as stated in Design Criteria, Section 14.4.2.3 and the ventilation fan shall run continuously from an normal power source. Where required by local jurisdiction, interlock to charger shall be provided to prevent operation if fan is not operating.

13 .7.7.3 Inverter

Inverter shall be of solid state design with 480/277V, 3 Phase, 4 wire, 60 Hertz output and capable of delivering rated kVA into load which has power factor of .8 lagging, minimum.

13 .7.7.4 Automatic Transfer Switch

The switch shall be static type and capable of transferring automatically emergency power load to AC by-pass line under the following conditions:

Capable of transferring automatically emergency power load to AC by-pass line under the following conditions:

- inverter failure
- inverter output voltage dropping to 80% of rated voltage.

The switch shall automatically retransfer emergency load from by-pass line to inverter when inverter output voltage returns to 90% of rated voltage.

13 .7.7.5 Load Requirements

The following loads shall be connected to the UPS:

13 .7.7.5.1 Communications.

13 .7.7.5.2 Exit lighting and 20% of indoor lighting.

13 .7.7.5.3 Emergency trip station lights.

13 .7.7.5.4 Kiosk emergency panel.

13 .7.7.5.5 Elevator car light, fan, and controls.

13 .7.7.5.6 Escalator newel and comb lights, 10% of balustrade lights, and entrance escalator controls.

13 .7.7.5.7 Fire suppression systems.

13 .7.7.5.8 Train control equipment (normal feeder).

13 .7.7.5.9 Public Service Radio System.

13 .7.7.5.10 Chemical detector.

13 .7.7.5.11 Passenger Information Display System(PIDS)

Data for these loads are provided elsewhere in this Section.

13 .7.7.6 Wiring

Emergency system wiring shall not occupy raceways common to other system wiring.

13 .7.8 Conduit

13 .7.8.1 Applications for the use of conduit shall include the following:

13 .7.8.1.1 Where access to wire or cable will not be available or required.

13 .7.8.1.2 Where concealed wiring is required, such as in public areas.

13 .7.8.1.3 Where mechanical protection is required beyond that provided by armored cable.

13 .7.8.1.4 Where clearances are limited, buried conduits shall be used.

13 .7.8.2 Types and Materials

13 .7.8.2.1 Rigid Aluminum Conduit

Aluminum conduit may be used only for traction power cables when surface mounted.

13 .7.8.2.2 Liquid-tight Flexible Metal Conduit

Flexible conduit shall be used where vibration isolation is required (e.g., motors, transformers) and for short connections between items of equipment whose alignment precludes the use of rigid conduit.

13 .7.8.2.3 Rigid Galvanized Steel Conduit

Generally, galvanized rigid steel conduit may not be embedded. It shall be used only for surface runs in normally dry underground areas including fan and vent shafts, on interior ceilings and walls, or concealed where conditions are normally dry, such as above drop ceilings, and in CMU walls.

13 .7.8.2.4 Fiberglass Reinforced Epoxy (FRE) Conduit

All embedded conduit for incoming service (with the exception of Virginia Power) for traction power, train control, communications, and auxiliary AC power requirements shall be FRE. Conduit embedded in concrete structure is encased, while conduit embedded in earth shall have concrete encasement added.

Surface mounted conduit for traction power cable shall be FRE conduit with or without concrete encasement, or rigid aluminum as approved by the Authority.

Conduit directly buried in ballast for train control cable shall be Heavy Wall FRE conduit, with minimum wall thickness of 0.095 inch.

All embedded incoming service conduits for 13.8 kV to WMATA facilities shall be fiberglass. Location and method of installation shall be coordinated with and approved by the Utility Company.

13 .7.8.2.5 PVC Conduit

All embedded incoming service conduits for 34.5kV to WMATA facilities shall be PVC. Location and method of installation shall be coordinated with and approved by the Utility company.

13 .7.8.3 General Requirements

Conduit size for train control and communications shall be as shown on electrical and train control Design or Standard Drawings.

FRE conduit size for individual traction power cable shall be 4". The number of bends shall not exceed 225° total between two pulling points.

Minimum size conduit shall be 3/4", and all conduits shall be sized in accordance with NEC Appendix 'C'.

Where non-metallic conduits are used for AC power cables, proper equipment grounding conductors shall be provided. Conduits shall not be installed in floating slabs unless absolutely necessary and shall do so only at right angles to the slab. Suitable isolation of conduit stub-ups shall be provided as indicated on Structural Design Drawings. Twenty percent spare conduits in embedded conduit runs and ductbank and sleeves in floors and walls shall be provided in the design for future needs.

13 .7.8.4 Terminate empty conduits as follows:

13 .7.8.4.1 For all non-traction power service conduits provide O. Z. Gedney Push-Pull Tab Cups, Type PPC, or Rayflate Duct Sealing System or equal.

13 .7.8.4.2 For traction power positive conduits, install O. Z. Gedney Type CSBE bushings with blank seals, or Rayflate Duct Sealing System or equal.

13 .7.8.4.3 For conduits under 1.5 inch diameter, install heavy wall shrink tube as a seal.

13 .7.8.4.4 For traction power negative conduit, install O. Z. Gedney Type CSBI-300P-1 with blank seals, or Rayflate Duct Sealing System or equal.

13 .7.9 Electrical Boxes

Boxes shall be provided where surface mounted multi-conductor cables interface with single conductor cable in embedded conduits for proper termination of cable and cable fittings. Boxes located in underground locations (except electrical equipment rooms) shall be fiberglass or stainless steel, watertight construction with threaded conduit hubs.

Boxes located in outdoor above ground locations shall be of fiberglass, watertight construction with threaded conduit hubs. All other boxes should be provided with knockouts.

13 .7.10 Conductors

13 .7.10.1 Material and Insulation

AC power, lighting and grounding conductors shall be copper with flame retardant insulation and jacket. Minimum conductor size shall be No. 12 AWG, except for control and signal wiring.

Power and lighting cables for all work shall be:

13 .7.10.1.1 Cable having specific low-smoke and zero halogen generation characteristics for use in underground structures.

Fixture wire shall be stranded copper conductor of No. 16 AWG minimum size with Type SF-2 silicone rubber insulated or as necessary to suit temperature ratings of lighting fixture, minimum of 90° C.

13 .7.10.1.2 Cable having zero halogen generation characteristics for use in all locations not in 13.7.10.1.1 above.

Fixture wire shall be stranded copper conductor of No. 16 AWG minimum size with Type SF-2 silicone rubber insulated or as necessary to suit temperature ratings of lighting fixture, minimum of 90° C.

13 .7.10.2 Voltage Drop

Voltage drop calculations shall be carried out on all long and heavily loaded circuits and feeders.

Maximum total voltage drop for feeders plus branch circuits shall not exceed five percent.

13 .7.10.3 Feeders

Fan shafts, jet fans and track drainage pumping stations shall be provided with dual feeders. These feeders shall originate from AC switchboard at passenger stations or traction power substations equipped with auxiliary power transformers.

Power supplies to fan shafts shall be connected to two power feeders from separate sources, such as ac normal switchboards in adjacent passenger stations. Each feeder shall originate from a different passenger station.

Power supplies to drainage pumping stations is similar to that of the fan shafts. If the Authority approves, both feeders could originate from two different normal switchboards located at a passenger station. Each feeder shall be routed in a separate tunnel. Pumping station shall be provided with “quick-connect” at conveniently accessible surface location

Feeders shall be physically separated as far as possible in fan shaft to avoid simultaneous failure from single accident or fire. Fan shaft feeder cables shall be installed in conduit embedded in concrete, and conform to NFPA 130 requirements.

The dual feeders serving the fan shafts shall be terminated in a separate electric room at the fan motor level. The electric room walls and doors shall conform to NFPA 130 requirements. Electric equipment serving the fan shaft (such as disconnecting devices, automatic transfer switch, motor control center, panelboards and fan controls, etc.) shall be installed in the electric room.

When the nearest WMATA-owned power source is at an excessive distance from the facility to be served, consideration may be given to use a separate utility service. The designer shall perform an economic evaluation to develop a recommended service scheme for these facilities. Final determination as to preferred service scheme will be made by the Authority, based on reliability and economics.

The neutral conductor shall be installed with three phase feeders only when required. An equipment ground conductor, sized in accordance with NEC, shall be provided with each feeder and cable assembly.

It is preferred that fan shaft motor feeders shall be protected using motor circuit protectors located in the motor control center.

13 .7.10.4 Cable

In order to provide the most economical installation of power and lighting feeder circuits, multi-conductor type MC cable shall be installed on channel inserts in air plenum under station platforms, in cable trough at aerial and at-grade sections, in ductbank, and underfloor duct.

All cables shall be readily accessible for future maintenance and protected from mechanical damage. In general, surface mounted channel inserts shall be used throughout Under platform air plenums at passenger stations for the support of cable and conduits. Cables which must be continued past adits and areas at fan shafts and drainage pumping stations open to both tunnels shall be routed past the opening in embedded conduits. Direct burial cables for stray current and cathodic protection shall be protected as specified in Standard Specification.

Feeder cables shall be sized to accommodate 20% future growth in loads. Cables and conduit shall not be exposed in public areas.

Only one length of cable shall be used in any feeder as far as it practicable. Cable splices where required shall be made in junction boxes. Splice box shall be used at any transition between MC cables and single conductor cable in conduit.

13 .7.10.5 Wiring methods

Wiring of emergency and normal AC systems, and DC systems shall each be independent of each other and shall not occupy common raceways or enclosures.

13 .7.11 Wiring Devices

13 .7.11.1 Switches

Snap switches shall be installed to control lighting in all service rooms. Switches shall be located inside the individual rooms, on the knob side of the door.

Switches shall be specification grade, 20A, 120 or 277V rated as required.

13 .7.11.2 Receptacle (Convenience Outlets)

Receptacles shall be duplex, heavy-duty, 20A, 125 volt rated. Receptacles in tunnel and outdoor areas and in damp or wet locations shall have weather-proof enclosures and ground-fault circuit-interrupters for protection of personnel. Receptacles in wash rooms shall have ground fault circuit interrupters. Receptacles will be supplied from multi-wire branch circuits, feeding adjoining receptacles from different phases. No more than 6 receptacles shall be placed on each circuit. Receptacles in ancillary areas and maintenance facilities will generally be located on 20-foot centers unless otherwise indicated below. Receptacles at the station platform, mezzanine and passage-way areas and the multi-story parking garages shall be located such that a 100-foot electric cord can be used to reach any point on the floor. Elevation for receptacles at the passage-way area shall be coordinated with the Authority. Additional requirements are as follows:

13 .7.11.2.1 Station platform area:

Flush mounted ground fault circuit interrupter receptacles shall be installed in parapets, in concrete supports for benches, and in concrete columns.

Receptacles shall not be installed in the floors or pylons.

13 .7.11.2.2 Station entrance areas:

Flush mounted ground fault circuit interrupter receptacles shall be installed at the concrete wall on the interior side of the entrance door or the folding gate. For long passage-ways, an additional receptacle shall be provided on the wall near the mezzanine area.

13 .7.11.2.3 Pedestrian walkways and bridges at station entrances:

Flush mounted ground fault circuit interrupter receptacles shall be installed on the entrance wall. Ground fault circuit interrupter receptacles may be installed on the steel members so that any point in the walkway can be reached with a 100 foot cord.

13 .7.11.2.4 Mezzanine areas:

One flush mounted receptacle shall be mounted in the base on the exterior wall of the kiosk and supplied from the kiosk panel. If required, receptacles shall also be mounted in parapets. Receptacles shall not be installed in the floors or on pylons.

13 .7.11.2.5 Ancillary and service rooms:

13 .7.11.2.5.1 Train Control Room:

Receptacles shall be installed on 5-foot centers on each wall.

13 .7.11.2.5.2 Communication room:

Receptacles shall be installed on 12-foot centers with a minimum of one receptacle on each wall.

13 .7.11.2.5.3 Dispatchers room:

Six receptacles shall be installed. Three of these shall be located above the desk level on the wall with the window facing the track.

13 .7.11.2.5.4 AC switchboard room, electrical rooms, mechanical rooms, chiller plants:

Receptacles shall be provided on 12-foot centers with a minimum of one receptacle on each wall.

13 .7.11.2.5.5 Elevator machine rooms and hoistways:

A minimum of two ground fault circuit interrupter (GFCI) receptacles shall be provided in elevator machine rooms. GFCI receptacles shall also be provided in hoistway as shown in the design drawings.

13 .7.11.2.5.6 Battery room, maintenance room, trainsmen's room, operation's room and bus driver's room:

A minimum of two receptacles shall be provided with one on each opposite wall.

13 .7.11.2.5.7 Wash rooms, cleaners room, water service room and locker room:

A minimum of two ground fault circuit interrupter receptacles shall be provided.

13 .7.11.2.5.8 Bell system room, cart storage room:

One receptacle shall be provided. Receptacles in these areas need not be provided with ground fault circuit interrupters.

13 .7.11.2.6 Track area between stations:

In tunnel area along each safety walk receptacles shall be located on 80-foot center and one receptacle at each point of switch. Each of these receptacles shall be ground fault circuit interrupters, and connected to load center branch circuits in accordance with the design drawings.

13 .7.11.2.7 Vent, fan and access shafts:

Receptacles shall be installed so that at any point in the shaft can be reached with a 50-foot cord.

13 .7.11.2.8 Multi-story parking structure:

Surface mounted receptacles shall be installed on walls or columns spaced so that at any point in the parking structure can be reached with a 100-foot cord or as required by the local fire department.

13 .7.11.2.9 Traction power substations, tie breaker stations and escalators:

Requirements are indicated in Section13.6.1 and Section13.7.14.

13 .7.12 Service Requirements for Ancillary Spaces

13 .7.12.1 Train Control Rooms

Each Train Control Equipment Room shall be provided with two 208Y/120 volt, three-phase, four-wire circuits, rated kVA as below, and terminated in disconnect switch.

13 .7.12.1.1 For train control room at passenger station or remotely located on main line: 9 kVA.

13 .7.12.1.1.1 At passenger stations, the transformers supplying the circuits shall be located in the nearest AC switchboard room or the combined AC switchboard room. The normal supply shall be from the emergency power panel. The reserve supply shall be from the AC Switchboard not used to feed the rectifier/charger in the UPS.

13 .7.12.1.1.2 For remotely located train control rooms not adjacent to a Tie Breaker or Traction Power Substation, provide a separate electric room as part of the train control building. Provide an normal power source and emergency power source originating from the nearest passenger station AC switchboard room or a traction power substation equipped with an auxiliary power transformer.

The transformers, and panelboards supplying lighting and power circuits shall be located in this electric room. For train control transformers, the normal supply shall be from the emergency power panel, and the reserve supply shall be from the normal power panel. All other loads will be from an normal power source.

13 .7.12.1.2 Train Control Room in the S&I Shop or Yard (15 kVA):

13 .7.12.1.2.1 Train Control Room in Yard Operation Building:

The transformers supplying the branch circuits shall be located in the Yard Operation Building, AC switchboard room.

13 .7.12.1.2.2 Shop:

The normal supply shall be from the emergency power panel. The reserve shall be from the normal switchboard not used to feed the rectifier/charger in the UPS. The transformers supplying the branch circuits shall be located in the Shop AC Switchboard Room.

13 .7.12.1.2.3 Yard Tie Breaker Station or Traction Power Substation:

The normal supply shall be from the emergency supply. The reserve supply shall be from the 480V power supply. The transformers supplying the branch circuits shall be located in the Tie Breaker or Substation.

Each feeder shall be routed in an individual conduit from its transformer and terminated in a disconnect switch in the Train Control Room. No transformers shall be located in the train control room.

The grounding conductors for the train control room ground bus and the transformer secondaries shall be connected to provide one point grounding in accordance with the Electrical Design Drawings.

13 .7.12.2 Communications Rooms

Each Communications Room located at a station shall be provided with an emergency 208Y/120 volts, three phase, four wire circuit, rated kVA as below, and terminated in a disconnect switch.

13 .7.12.2.1 For communications room at passenger station: 6 kVA.

13 .7.12.2.2 For communications room in S&I shop or yard: 15 kVA. The transformer supplying the circuit shall be located in the AC Switchboard room nearest to the Communication Room; and the transformer power source shall be from the emergency panel. One point grounding shall be provided as shown on the Electrical Design Drawings.

13 .7.12.2.3 For Passenger Information Display System (PIDS) plug-in accessories: 120V, 1 kVA (from emergency panel).

13 .7.13 Service Facilities and Requirements for Kiosk and Fare Collection

Multi-raceway underfloor duct shall be used to the maximum extent practicable to run power and control cabling to the Kiosk, Fare Collection equipment, Bus Transfer dispensers, and Map Case. Conduit shall be used where underfloor duct is not practicable. Sufficient space shall be maintained between ducts or conduits to ensure proper concrete bonding.

The underfloor raceway layout shall be similar to that shown on Electrical Design Drawings. Run between any two pull boxes shall be straight. Adequate junction boxes shall be provided wherever the raceways change direction. Underfloor

raceway shall be used for normal power distribution, controls, and signal circuits, communications, and for collection equipment, as indicated on Design Drawings.

Requirements for normal power and emergency power from the Uninterruptible Power Supply (UPS) are as indicated below. For kiosk and fare collection equipment, normal power (280/120 volts, three phase, four wire) shall be provided from one 42-circuit panel fed by a 75 kVA transformer; or, if more capacity is required, use two 32-circuit panels fed by one 112.5 kVA transformer. Panel(s) shall include 20 ampere rated single-pole circuit breakers plus one 3 pole, 40 ampere breaker for kiosk panel feeder, and are to be located in ancillary area nearest to the mezzanine.

These panel(s) shall service the kiosk normal panel and the following equipment:

13 .7.13.1 Telephone/map lights - 200 W. each, 120V, single phase.

13 .7.13.2 Fare card vending machines, fare gate consoles, and bus transfer dispensers - 1800 W. each 120V, single phase.

The kiosk normal panelboard (208/120V three phase, four wire) will have the following normal loads:

13 .7.13.3 Air conditioning condenser unit - 3200 VA, 208V, single phase.

13 .7.13.4 Heating - 4000 VA, 208V, single phase.

13 .7.13.5 Fan coil unit - 700 VA, 120V, single phase.

13 .7.13.6 Lighting - 1000 watts, 120V, single phase

13 .7.13.7 Convenience outlets - 800 VA, 120V, single phase.

Refer to Architectural drawings for exact quantities of kiosk, fare card vending machines, fare gate consoles, telephone/map cases, and bus transfer dispensers.

Emergency power (208/120 volt, three phase, four wire) from a transformer located in the AC switchboard room shall be provided for the kiosk emergency panel which shall accommodate the following emergency loads, all 120 volts, single phase:

13 .7.13.8 Lighting

13 .7.13.8.1 below grade stations: 1300 watts

13 .7.13.8.2 above grade stations: 300 watts

13 .7.13.9 Data acquisition display system (DADS): 1500 watts

13 .7.13.10 Fare gate bull's-eye lamps: 80 watts each console

13 .7.13.11 Communications amplifiers: 240 watts

13 .7.13.12 CCTV: 650 watts

13 .7.13.13 Passenger Information Display System: 100 watts.

The following empty conduits shall be provided and stubbed up under the kiosk, for future cable installation .

SIZE	SOURCE
1"	AC switchboard room ground bus
1-1/2"(*)	AC emergency panel

(*) For long feeder lengths, increase wire size to compensate for voltage drop. Size conduit accordingly.

Provide the normal and emergency kiosk panels, the feeders to these panels, the ground bus, and the electrode grounding conductor to the kiosk ground bus.

13 .7.14 Service Requirements for Escalators

A single 480V, 3-phase, 3-wire, 60 hertz feeder for each escalator wellway shall be provided to the machine room or upper pit area and terminated in fusible, lockable disconnect. (A wellway may contain more than one escalator.) This feeder shall be sized to include the total load of all escalator drive systems and escalators heating loads as specified below.

13 .7.14.1 POWER REQUIREMENTS FOR EACH ESCALATOR

Class	Rise	480-V, 3-PH 3W Drive Power Input kVA	480-V, 3-PH, 3-W Heating Load Kwf #1	#2
A1	UP to 20 feet	15.5	9.0	18.0
A2	Above 20 feet to 24 feet	29.7	9.0	18.0
B2	Above 24 feet to 40 feet	30.5	18.0	24.0
B3	Above 40 feet to 60 feet	44.6	24.0	30.0
C4	Above 60 feet to 80 feet	62.9	24.0	30.0
C5	Above 80 feet to 100 feet	78.0	24.0	30.0
C6	Above 100 feet to 120 feet	93.2	24.0	30.0

#1 - Entrance and passage-way escalators to underground station only. (There is no heat load for mezzanine to platform escalator at underground station.)

#2 - Aerial and at-grade station

Ampacity of the feeder phase conductor shall not be less than 125 percent of the total connected load. Neutral conductor shall be half the capacity of phase conductor. Trip setting of associated breaker shall not be less than 125 percent of the total load subject to a minimum of 50 amperes.

Normal power shall be provided for entrance and passage-way escalators to mezzanine at underground station and for Class B escalators at aerial and at-grade stations. Normal power shall be provided for mezzanine to platform escalators at underground stations and Class A escalators at aerial and at-grade stations.

The auxiliary electrical supply for each escalator wellway shall be a single normal feeder provided to the machine room or upper pit area and terminated in a fusible, lockable disconnect. It shall be a 208Y/120V, 3 phase, 4 wire service for entrance and passage-way escalators with balustrade lights. The auxiliary supply feeder shall be sized for lighting and convenience outlets based on the following requirement:

13 .7.14.2 Balustrade lights: For light sources and illumination level requirements, see Section 4.

13 .7.14.3 Maintenance lights: Class A escalators--15-foot candles in each pit area and 30-foot candles in wellways. Class B and C escalators--30-foot candles in wellways and pit areas.

13 .7.14.4 Receptacles: Class A escalators - One row between every two escalators, including one at upper and lower pit areas and every 25 feet maximum along the truss. Class B and C escalators - minimum of three in the machine room and one row between every two escalators, including one in the lower pit area and one every 25 feet maximum along the truss.

One or more emergency circuits, each rated 120 volts, 1800 watts maximum, shall be provided for each machine room and upper pit area of the wellway and shall be terminated in a fusible, lockable disconnect box in the wellway. These circuits shall be based on the following requirements: comb plate lights (4-40W lamps per escalator); 10 percent of the maintenance lights; and 10 percent of the balustrade lights. In addition the circuit load shall include a 75 watt allowance for escalator control on entrance escalators, and a 50 watt allowance for escalator fire suppression control for those underground stations having a single escalator entrance.

A 3/4-inch conduit with cables (No.14 AWG conductor) and limit switches rated for 120 volts shall be provided for each folding gate, where directed by the Authority, to the nearest upper or lower escalator pit and terminated in a junction box, as shown on the electrical design drawings.

A one-inch conduit per escalator between the machine room or upper pit area and the nearest kiosk shall be provided for control purposes. Two one-inch conduit per escalator between the machine room or upper pit area and the communications room shall be provided for fire alarm circuits and telephone.

The section contractor shall provide the conduits, cables, and other electrical equipment to furnish the electrical services to each escalator machine room or upper pit area. The escalator contractor shall provide all conduit, cables, disconnect switches or circuit breakers, panelboards, lighting, control, heating,

and wiring devices to extend the incoming services within the escalator wellway for a complete installation.

13 .7.15 Service Requirements for Parking Lots, Bus Service, Kiss and Ride Areas

Each parking lot, bus service, kiss and ride area shall be served from a three-phase, four-wire 480/277 volt normal panelboard located in the passenger stations. The loads will include control gates and lighting for the parking areas, bus passenger and supervisor shelters. Except for the control gates, all 120 volt circuits shall be fed from 208/120 volt panelboard located in passenger stations. Emergency lighting is not required for outdoor parking areas. Security lighting shall be provided for exterior areas.

Lighting fixture types and locations shall be provided in accordance with requirements given in the WMATA Manual of Design Criteria,, General Plans and Architectural criteria and standards.

Parking lot entrances and exits shall be equipped with control gates in accordance with parking lot general plans. The parking lot control gates may consist of any combination of combined entrance/exit, entrance only, or exit only gates. Site preparation for parking lot control gates shall be designed as per Parking Lot Control Gate Design Drawings.

The conduit requirements from the Metro station to the nearest control gate, between the control gates and the lot full sign shall be designed according to Design Drawings.

A separate three phase 15 kVA, 480 volts service shall be provided to each control gate whether a combined entrance/exit, entrance only, or exit only area. These services shall be terminated in the load center enclosure at the control gate.

Equipment for control gates, the load center for each control gate shall be provided by section contractor. The section contractor shall provide the lighting fixture at the control gate along with photoelectric control for automatic operation. Provisions shall be included for a manual override switch to be installed by the section contractor.

Control of lighting shall be in accordance with the requirements for outdoor lighting of the WMATA Manual of Design Criteria, Section 4.

Use of handholes, junction and pull boxes in parking lots, kiss and ride area shall be avoided. When necessary, only handholes with non-metallic covers and non-metallic junction and pull boxes shall be installed in landscaping or grassy areas.

13 .7.16 Electrical Service Requirements for Elevators

Three feeders are required for the elevator machine room as follows: 1) 480 volts 3 phase 3 wire normal power feeder; 2) 208/120 volt 3 phase 4 wire auxiliary normal feeder; and 3) 120 volt single phase emergency feeder. The 480 volt feeder shall be terminated near the doorway inside the machine room. It shall be a single feeder and sized for the total load of all elevator motor drive systems in accordance with Section 14.17.5 of Mechanical design criteria. A separate

disconnecting means, in accordance with local codes, will be provided for each elevator drive unit.

The 208/120 volt auxiliary feeder shall be provided to the elevator machine room and terminated in a multi-circuit panelboard or other disconnecting means where required by local codes. The number of circuits in the panelboard shall be based on the following 120 volt circuits, as required for each elevator: a) lighted signal system (100 watts); b) hoistway lights; c) hoistway GFCI receptacles; d) canopy light. Conduit and cables for hoistway lighting and receptacles and canopy light shall be installed from the elevator machine room to and in the hoistway. The 120 volt AC emergency feeder shall be installed to the elevator machine room and terminated in a separate disconnecting means for each elevator in accordance with local codes. For each elevator the load will include 500 watts for elevator car lighting and exhaust fan, 125 watts for intercom, and 300 watts future provision for elevator relay controls. Conduit and cables for elevator car lighting and exhaust fan shall be installed from the machine room to the hoistway pit and terminated in a junction box.

Conduits for all other functions shall be installed from the elevator machine room to the hoistway and to other areas in the passenger stations shown on the electrical design drawings.

Two one-inch diameter conduits per elevator between the machine room and the communications room shall be provided for fire alarm circuits and telephone circuits.

A 3/4 inch diameter conduit between the elevator machine room and the AEMS RTU in the AC switchboard room shall be provided for remote monitoring.

13 .7.17 Service Requirement for Fire Suppression Systems

A 120 volt, 250 watt emergency power circuit shall be provided and terminated in a junction box adjacent to each Fire Suppression system control panel.

13 .7.18 Electrical Power Service Requirement for Passenger Information Display System (PIDS)

Platform PIDS: A 2- pole, 480V, 20A circuit shall be provided from the nearest AC Switchboard Room's Fused Switch Emergency Panel and terminated in a NEMA 4X rated disconnect (safety) switch near where the PIDS will be located. The disconnect (safety) switch shall provide input power to a 5 kVA, single phase, 480/240-120V transformer which will supply the 120-volt power for the platform PIDS.

Mezzanine PIDS: A 120V, 20A circuit shall be provided from the nearest Emergency Panel to where the mezzanine PIDS is located.

13 .7.19 AC System and Equipment Grounding

A complete AC power grounding system shall be provided for the protection of property and human life. The grounding system shall comply with the National Electrical Code and with requirements in this criteria, guide specifications and design drawings. In addition to the grounding of all enclosures and raceways of the AC power and distribution system the grounding system shall provide a low

impedance path to ground for all exposed metallic structures, railings, stairways, etc., in the vicinity of the AC power systems.

The grounding system shall be physically isolated from structural rebars, stray current systems, and cathodic protection systems. Intentional metallic contact or electrical bonding between the two systems is not permitted. Where soldier piles are used for AC power system grounding purposes, any number of soldier piles may be bonded together provided they are in the same row and are adjacent to each other. Soldier piles for grounding shall be isolated from other soldier piles which are bonded and connected to drainage circuits and from reinforcing bars in the structure.

A ground grid shall be provided for each AC service at shop buildings, passenger stations, traction power substations, tie breaker stations, chiller plants and fan shaft and pumping stations. Ground grid/bus resistance shall not exceed two ohms for AC switchboard rooms, traction power substations and chiller plants, and five ohms for tie breaker stations, electrical rooms, fan shafts, and pumping stations. Where a traction power substation or a tie breaker station is in close proximity to a passenger station AC unit substation, only one ground grid is required. Grid shall consist of bare or insulated copper conductors and ground rods conductors and ground rods buried in earth and in a pattern to suit the structure; a rectangular pattern is preferred. In at-grade locations grid shall be 24 inches minimum below grade. Where grid is below the bottom of the slab or near metallic objects, minimum 24" separation shall be maintained. In underground locations, grids may be installed under the structure. A minimum of 24 inches separation must be provided between grid and soldier piles used for stray current control between grid and cathodic protection systems. In soils of high resistivity and in rock construction where normal grounding grid design does not provide required low resistance, alternate methods of ground grid design, or location, or soil treatment, etc., are to be submitted to the Authority for approval. Grounding of outdoor service transformers shall be provided by means of a grounding electrode conductor from the transformer pad to the nearest ground grid, as well as to the substation ground bus.

After locations for ground grid(s) are determined and staked by survey personnel, an engineering consultant will conduct a soil resistivity survey and report the data for use in design.

Main ground bus on walls of substation rooms shall be used to ground the neutral of the secondary AC power distribution systems and to connect grounding sub-buses in kiosk, train control and communication rooms, dispatcher and Bell system rooms, escalator pits, elevator machine rooms and other grounding as required. Ground bus shall be copper, approximately 24 inches above floor and mounted on insulators 1-1/2 inches from wall. Where there is insufficient clearance behind the electrical AC or DC switchgear, install ground bus bar above the switchgear.

Requirements for installing grounding connections in train control and communication rooms shall be as follows:

13 .7.19.1 The only connection on the bus bar provided for train control/ communication equipment grounding is the cable leading to the AC switchboard room.

13 .7.19.2 No equipment or metallic structure shall be bonded to the ground bus provided for train control and communications equipment.

13 .7.19.3 For items requiring bonding, the grounding conductors must go to the nearest ground bus beyond the ground bus provided for the train control and communications equipment.

13 .7.19.4 Grounding transformers to the dedicated train control and communication room ground bus bars is not permitted.

Ground bus shall be installed as follows:

13 .7.19.5 AC switchboard room: 1/4" x 2" main bus installed around the inside periphery of the room.

13 .7.19.6 Chiller plants: 1/4" x 2" x 24" main bus installed on the wall adjacent to service equipment.

13 .7.19.7 Train control room: 1/4" x 2" x 24" sub-bus near power supply switch and connected to AC switchboard room bus with No. 2/0 AWG insulated grounding conductor. The sub-bus insulated grounding conductor shall be connected to the AC switchboard room ground bus within 2" of the grounding conductor connection for the transformers supplying power to the train control room per electrical design drawing.

13 .7.19.8 Communications room: 1/4" x 2" x 24" sub-bus near power supply switch and connected to AC switchboard room bus with No. 2/0 AWG insulated grounding conductor. The sub-bus insulated grounding conductor shall be connected to the AC switchboard room ground bus within 2" of the grounding conductor connection for the transformer supplying power to the train control room per electrical design drawing.

13 .7.19.9 Kiosk: 1/4" x 2" x 12" sub-bus connected to ground bus in nearest AC switchboard room via No.2/0 AWG insulated ground conductor in 1" conduit. The sub-bus insulated ground conductor shall be connected to the AC switchboard room ground bus within 2" of the grounding conductor connection for the transformer supplying power to the kiosk emergency panel. Sub-buses in Kiosk, Train Control, and Communications rooms are respectively dedicated to kiosks, train control, and communications equipment, and no other grounding to these buses is permitted.

13 .7.19.10 Others: Sub-bus in electrical and mechanical rooms, dispatcher and bell system rooms, as required for convenient grounding of separately derived AC power systems.

13 .7.19.11 One No. 4/0 AWG insulated copper ground conductor (sub-bus) shall be provided in each tunnel section, in each cable trough of aerial section, in ductbank of at-grade section of main line and in each cable tunnel or cable space located below station platform.

13 .7.19.12 Fan Shafts: 1/4" x 2" x 24" main bus installed on the wall adjacent to the AC power equipment.

13 .7.19.13 Drainage pumping stations: 1/4" x 2" x 24" main bus installed on the wall adjacent to the AC power equipment.

13 .7.19.14 Escalator Pits and Elevator Machine Rooms: 1/4" x 2" x 24" long grounding sub-bus bar installed on wall adjacent to AC power equipment.

13 .7.19.15 Battery Rooms: 1/4" x 2" x 24" long grounding sub-bus bar located below battery disconnected device.

The complete AC power grounding system shall include ground bus in each distribution equipment enclosure such as switchgear, panelboards, motor control centers, and load centers, which shall be interconnected by insulated equipment grounding conductors that run with the feeders from the source panelboard or switchboard. Such conductors shall be identified by a continuous green color and be sized in accordance with NEC and shall run in a common conduit with the associated phase and neutral conductors. Multiple-conductor cables with metallic sheaths shall be provided with insulated or bare equipment grounding conductors; use of the metallic covering for grounding is not considered adequate.

Equipment grounding conductors shall be provided by means of insulated copper grounding conductors for the following services:

13 .7.19.16 All feeders.

13 .7.19.17 All branch circuits.

Grounding for personnel safety shall be provided to minimize shock hazards as follows:

13 .7.19.18 In substations, electrical and mechanical rooms, fan shafts and pumping stations, all exposed metallic structures, motor frames, AC equipment enclosures, ductwork and metallic piping shall be bonded to the local main ground bus with an exterior No. 6 AWG minimum insulated grounding conductor.

13 .7.19.19 Escalators, elevators and kiosks metallic structure shall be bonded to equipment grounding conductor in the AC feeder and to local ground bus bar. All electrical equipment (motor frames, AC equipment and lighting fixture enclosures) shall be provided with a minimum of two ground paths as follows:

13 .7.19.19.1 Bonding to green insulated equipment grounding conductor in the AC feeder/branch circuit.

13 .7.19.19.2 Connection to grounded metallic structure using metallic fasteners, metallic conduit and/or bonding jumper.

13 .7.19.19.3 For escalators and elevators provide a second ground path connecting trusses and guide rails using a No.1/0 AWG insulated ground conductor connected to ground bus bar in AC switchboard room. Leave a 20-foot length of conductor coiled up in pits or wellways.

Metallic structure grounding may be supplemented by a connection to the ground grid where conveniently available.

13 .7.19.19.4 For kiosks, provide a second ground path connecting the metallic structure to nearest ground bar bus using a No. 2/0 AWG insulated

ground conductor in 1 inch conduit. Leave 10 feet length of conductor coiled up at kiosk.

13 .7.19.20 Where a dielectric water fitting is installed for cathodic protection of underground piping, only the exposed piping may be grounded. Do not install jumper around the fitting. (The use of municipal water system as a grounding electrode is not permitted.) All exposed structural metalwork such as stairways, handrails and safety walk gratings within reach of AC power equipment (5'-0"+) shall be bonded to the nearest AC equipment ground bus or sub-bus.

13 .7.19.21 Exposed metallic structures in open areas such as light standards, handrails, cable trough and metallic deck structures on aerial track, and fence on at-grade construction, shall be bonded and grounded to separate ground rods.

Handrails and cable troughs on aerial tracks shall be grounded at each pier and abutment to a ground rod or piles with an embedded insulated grounding conductor. All fencing shall be grounded at approximate 50-foot intervals to ground rods, and jumpers provided where required for grounding continuity. Fencing around transformer pads shall be suitably grounded. Flexible jumpers shall be provided at gates to ensure continuity.

13 .7.19.22 Exposed metallic structure of passenger and supervisor shelters equipped with lighting fixtures or receptacles, illuminated diorama, pylon equipped with lighting fixture, map case and telephone enclosures shall be provided with a minimum of two ground paths as follows:

13 .7.19.22.1 Bonding to green insulated equipment grounding conductor in AC branch circuit.

13 .7.19.22.2 Connection to nearest ground bus in electrical room or sub-bus or to 5/8-inch diameter by 10-feet long ground rod buried adjacent to the structure, using a minimum No.6 AWG insulated grounding conductor.

13 .7.19.22.3 For metallic structures on station platforms bond to No.4/0 AWG ground conductor in cable space under the platform.

13 .7.19.23 Manholes, handholes, junction and pull boxes metallic body, cover frame and cover shall be grounded as follows:

13 .7.19.23.1 Metallic cover shall be bonded to metallic frame using a minimum No. 6 AWG insulated grounding conductor and a bronze or brass chain inside rubber hose.

13 .7.19.23.2 Metallic body and frame shall be grounded to 5/8-inch diameter by 10-feet long ground rod using a minimum No. 6 AWG insulated grounding conductor.

13 .7.19.23.3 When a cable is spliced or tapped in handhole, manhole and junction or pull box, metallic body and frame shall be also bonded to equipment grounding conductor.

13 .7.19.24 Connections to metallic structure, safety walk grating, cable trough, stairway, hand railing, telephone and map case enclosures, fence, frame columns of shelters, pylon frame, diorama metallic cover and metallic body and metallic cover frame of handhole, manhole and junction box shall be made by exothermic welding or gas torch brazing.

13 .7.19.25 In outdoor public areas (passage-way, parking lot, kiss and ride area), use of manholes, handholes, junction and pull boxes shall be avoided. When necessary, only handholes with non-metallic cover and non-metallic junction and pull boxes shall be installed in landscape and grassy areas.

13 .7.19.26 Cable splices and taps in outdoor handhole, manhole, junction and pull boxes shall be covered by watertight heat-shrinkable tubing or wraparound sleeve in accordance with Electrical Design Drawings.

13 .7.20 Automated Energy Management System (AEMS)

At each traction power substation, chiller plants, Service and Inspection Shops, Maintenance Shops and AC Switchgear Rooms, provisions shall be made for indication and control functions to be available remotely at the OCCB using an energy management system. The system shall consist of all sensors, transducers for analog output signal, power supplies, transmitters, wiring and accessories required for a complete and operational automated energy management system (AEMS).

13 .7.20.1 The AEMS shall have provisions for interconnection wiring from each status, control and analog telemetry points to the AEMS interface cabinet located in equipment rooms where equipment requires monitoring.

13 .7.20.2 Provide a heavy-duty three position selector switch (HAND/ OFF/AUTO) for controlling station ACU fans, AC units, exterior lighting and unit heaters over 10 kW. The HOA switch shall be equipped with auxiliary contacts to indicate HOA position.

13 .7.20.3 The transmitter power supply shall be located in the AEMS interface cabinet.

13 .7.20.4 For chiller plants, an electronic power meter and communication module shall be provided to monitor the total chiller feeder circuit and each chiller motor starter. The power meter analog signal and communication RS-485 interface shall be wired to the AEMS interface cabinet.

13 .7.20.5 Provide auxiliary contacts at motor starters and equipment contractors to indicate equipment ON/OFF status. Equipment included shall be chillers, condenser water pumps, chilled water pumps, cooling tower fans, ACU fans, AC units, exterior lighting and unit heaters. Provide interconnection wiring between motor starters and equipment contractors to the AEMS interface cabinet.

The AEMS-RTU shall be compatible with the Authority's QEI, Inc. master station located at the OCCB. AEMS RTU’s shall be provided in traction power substations, chiller plants and AC Switchboard Rooms. RTU point counts and wiring requirements shall be as follows:

13 .7.20.6 AEMS RTU REQUIREMENTS[3]

RTU Location	Control Points		Status Points	Analog Points		Accum Points	Analog Control
	Momentary	Latching		0-1mA	4-20mA		4-20mA
Traction Power Substation	8	8	24	16		16	8
Passenger Station (AC SWBD RM)	16	16	40	16		16	8
S&I Shop (AC SWBD RM)	40	40	88	16		16	8
Chiller Plant	8	8	24	16	32	8	8

13 .7.20.7 Wiring Requirements[4]

Function	Wire Type	Number of Conductors	Minimum Size
Power	Stranded copper	3	No. 12 AWG
Meter, Pulse Accum.	Stranded copper	6	No. 14 AWG
Communications	Solid copper, shielded	4	No. 24 AWG
Analog	Stranded copper, shielded	2	No. 16 AWG
Ground	Bare stranded copper	1	No. 6 AWG

[3]Coordinate with Section 6.4.11.1 of Manual of Design Criteria, Systems

[4]Coordinate with Section 6.4.11.2 of Manual of Design Criteria, Systems

13 .7.20.8 PASSENGER STATION ENERGY MANAGEMENT INTERFACE REQUIREMENTS

(For Mechanical Equipment Requirements, see Section14)

A. PULSE ACCUMULATOR POINTS (Contact Closure)

1. Utility Meter or Switchgear Power Meter kWH

B. EQUIPMENT STATUS POINTS (Contact Closure)

1. Exterior Lighting* ON/OFF
2. Unit Heaters over 10 KW ON/OFF

C. HOA SWITCH STATUS POINTS (Contact Closure)

1. Exterior Lighting* AUTO/HAND
2. Unit Heaters over 10 KW AUTO/HAND

D. CONTROL POINTS (Contact Closure)

1. Exterior Lighting* ON/OFF
2. Unit Heaters over 10 KW ON/OFF

*Parking lot, garage, site, exterior platform and mezzanine.

13 .8 LIGHTING SYSTEMS

13 .8.1 General

This criteria establishes desirable standards for illumination and design requirements for electrical fixtures and control for the rail transit system.

13 .8.2 Scope

The criteria covers lighting requirements for the following:
a. Passenger Stations
b. Shafts and Tunnels
c. Parking Areas
d. Traction Power Substations and Tie Breaker Stations
e. Station Ancillary Spaces
f. Car Storage Yards and Maintenance Facilities

The lighting of public areas of passenger stations, including entrances, escalators and passage-ways, and station exterior areas, such as parking facilities, ramps, walkways, and bus loops, are included within the scope of work of the architectural branch of CENF and Metrorail Station Lighting Criteria. Illumination levels and other criteria in this section shall govern.

13 .8.3 Illumination Levels

Minimum maintained lighting levels for various areas shall be as indicated in Tables 13.3 and 13.4.

The method for calculating these levels shall be as outlined in the Illuminating Engineering Society (IES) Lighting Handbook. For indoor lighting the zonal cavity method shall be used. Lamp mean lumens or lamp depreciation as listed in the IES Lighting Handbook and the luminaire dirt depreciation factor classified as "Dirty" shall be assumed.

For outdoor lighting (car storage yards, parking lots, driveways, and bus loops) a light loss factor (maintenance factor) of 64% shall be assumed. In addition to level of lighting, it is normal that illumination on open sections of the transit system be designed to minimize glare which would tend to interfere with observation of track by the train attendant. Luminaires should be so selected, located and aimed so that while accomplishing their primary purpose they will produce a minimum of objectionable glare and interference with vehicular traffic and neighboring surroundings.

Where rapid transit tracks or yard areas are located adjacent to railroad operating tracks, particular attention shall be given to placement and direction of rapid transit illumination to avoid interference with railroad signals or operations.

13 .8.4 Lighting Fixtures and Control

13 .8.4.1 Lighting Fixtures

Refer to the WMATA Manual of Design Criteria, Section 4; Architectural and Electrical Standard and Design Drawings for fixture types and applications. Lighting fixtures shall be selected and located as follows:

13 .8.4.1.1 Station Areas including Kiosks, passage-ways, Stairs, Escalator ways, Station Entrances and Elevators as per Architectural General Plans for individual stations and WMATA Manual of Design Criteria, Section 4.

The fixture Type L2 and S-15 should be equipped with HID lamps and ballasts.

13 .8.4.1.2 Service Areas

Industrial Type fixtures as appropriate to give levels of illumination indicated in Table 13.3, and in Section 13.8.5 for emergency lighting.

Fluorescent fixture Types 1, 2, 3, 4 and 5 shall be equipped with energy saving ballasts and T8 lamps. Type 6 fixtures shall be equipped with compact fluorescent lamps. Exit light Type X shall have backlit light emitting diode (LED) as its lighting source.

In attic spaces high pressure sodium fixtures (type 7A) shall be mounted over the train room arch at nominal forty foot centers along and within approximately five feet of the arch centerline.

13 .8.4.1.3 Train Control, Communications Equipment Rooms, traction power substations, and tie breaker stations. General illumination levels in accordance with Tables 13.3 & .13.4 Location of light fixtures shall be coordinated with the preliminary layouts for equipment to be installed in these rooms.

13 .8.4.1.4 Subway Sections between Stations

Single fluorescent fixtures shall be mounted over each safety walk and spaced at nominal 24'-0" centers.

In double-track tunnels with center safety walk, two-in-tandem fluorescent fixtures (type 4A) shall be mounted over the safety walk and spaced at nominal 24'-0" centers.

Lighting calculations shall be provided to verify the footcandle requirements shown in Table 13.3.

13 .8.4.1.5 Traction Power Substations and Tie Breaker Stations

General lighting shall be provided by fluorescent fixtures. Such lighting shall be located to satisfactorily illuminate the vertical surfaces of all switchgear, rectifiers, etc. Location of all lighting fixtures shall be coordinated to avoid interference with overhead bus ducts or other major wiring and mechanical equipment, and shall not be located directly above switchgear, rectifiers, cable trays, or transformers. Approximately 10 percent of the inside substation lighting shall be connected to emergency power and controlled from emergency panel only. Remaining substation lights shall be controlled by a switch at the entrance doorway.

13 .8.4.1.6 No light fixtures shall be installed on the ceiling above the escalators.

13 .8.4.2 TABLE 13.3 - GENERAL ILLUMINATION LEVELS

AREA	AVERAGE LEVEL OF ILLUMINATION (Footcandles Maintained)	LAMPS
1. Subway Tunnel Structures, platform plenum, cable spaces and mechanical chases	1.0	Fluorescent
2. Special Trackwork Areas	3.0	Fluorescent/High Pressure Sodium
3. Traction Power Substations and Tie Breaker Rooms	30.0	Fluorescent
4. Car Storage Yards - Special Trackwork	3.0	High Pressure Sodium
5. Car Storage Yards - Other Areas	1.0	High Pressure Sodium
6. Bus Loops	(1)	(1)
7. Parking Areas	(1)	(1)
8. Bus Platforms	(1)	(1)
9. Fan and Vent Shafts	3.0	High Pressure Sodium
10. Emergency Exit Shafts	5.0	High Pressure Sodium
11. Pumping Stations & Ventilation Equipment Areas	15.0	Fluorescent
Interlocking Area	30.0	High Pressure Sodium
NOTE: (1) - Fixtures and level of illumination to be used in this area are specified in Standard Architectural Details and WMATA Manual of Design Criteria, Facilities, Section 4.		

13 .8.4.3 TABLE 13.4 - ILLUMINATION LEVELS IN PASSENGERS STATIONS

AREA	AVERAGE LEVEL OF ILLUMINATION	LAMPS
1. Station Platforms	(1)	(1)
2. Mezzanine	(1)	(1)
3. Fare Gates and Fare Collection Areas	(1)	(1)
4. Fare Collection Kiosk	(1)	(1)
5. Pedestrian passage-ways	(1)	(1)
6. Escalator & Stairway Entrances	(1)	(1)
7. Electrical Service Rooms, including Substations & Tie Breaker Rooms	30.0	Fluorescent
8. Battery Rooms	30.0	Fluorescent
9. Train Control and Communications Rooms	50	Fluorescent
10. Dispatch and Trainmen's Rooms	50.0	Fluorescent
11. Staff Washrooms and Lobbies	50.0	Fluorescent
12. Mechanical Rooms	30.0	Fluorescent
13. Cleaner’s and Service Rooms	15.0	Fluorescent
14. Operations Rooms	50.0	Fluorescent
15. Elevator Machine Room	30.0	Fluorescent

NOTE: (1) Fixtures and level of illumination to be used in station areas are specified in Standard Architectural Details and WMATA Manual of Design Criteria, Facilities, Section 4.

13 .8.4.4 Special Trackwork in Subway

13 .8.4.4.1 Fluorescent / HPS fixtures shall be located at nominal 20-foot centers in a staggered arrangement on either side of track where possible. Care shall be taken not to infringe on car clearances. Section Designer shall submit lighting calculations verifying the footcandle requirements shown in Table 13.3.

13 .8.4.4.2 Interlocking lighting fixture shall be fed from emergency circuit with local on/off switch.

13 .8.4.5 Emergency Trip Station Locations

Special blue light fixtures with mercury vapor lamp shall be located at all Traction Power emergency trip stations and special trackwork (crossovers).

13 .8.4.6 Parking Lots, Bus Loops and Roadways

Fixtures and locations shall be defined by Architectural Standards and WMATA Manual of Design Criteria, Section 4.

13 .8.4.7 Subway tunnel portal areas shall be equipped with Type 4 fluorescent fixtures spaced at nominal 20-foot centers for a distance of 300 feet from the portal.

13 .8.4.7.1 Control of Lighting

13 .8.4.7.1.1 Indoor General Lighting

Lighting in indoor public areas and in tunnel areas shall be controlled by means of breakers on the panel-boards. Lighting in service areas, including maintenance and service & inspection shops, shall be manually controlled by switches.

13 .8.4.7.1.2 Lighting for At-Grade and Aerial Stations

Lighting for platform canopies, open mezzanine areas and pylons shall be controlled by AEMS. The emergency lighting (twenty five percent of pylon lights and approximately 10% of platform canopy and mezzanine lighting) shall be controlled by photoelectric control so that lights are on all night for security purposes. The control shall include manual override switches so they can be turned on any time manually. All lighting controls shall be located in AC switchboard rooms for interface with Automated Energy Management System (AEMS).

13 .8.4.7.1.3 Attic Lighting

The lights shall be fed from a 277 volt panel at one end of the station and controlled via a single pole contactor wired to turn lights on or off from switches located at each entry point to attic.

13 .8.4.7.1.4 Tunnel Portal Lighting

Photoelectric control shall be provided for tunnel portal lights indicated in paragraph 13.8.4.7, to turn all lights on during the day, and to turn off 50% of these lights (excluding emergency lights) at night. Emergency lights shall be on continuously.

13 .8.4.7.1.5 Platform Edge Lights

Platform edge lights shall be fed from a 120/208 volt normal panel and be controlled for each track by AEMS and a flasher/dimmer control as follows:

13 .8.4.7.1.5.1 lights to remain off during non-revenue operation

13 .8.4.7.1.5.2 lights to be normally on at approximately 50 percent intensity during revenue operation.

13 .8.4.7.1.5.3 Normally, platform edge lights shall be "on" (non-flashing mode) at 50% intensity. Sixty seconds before the arrival of the train at the passenger station, the flasher shall be energized by a 28 volt DC circuit and contact in the train control room, via DTS terminal cabinet provided in AC switchboard room. The flasher shall commence simultaneous flashing of all the lights on the train side of the platform edge at 60 flashes per minute between 50 and 100% intensity. On departure of the train, the flasher DC control shall be de-energize and the light shall revert to 50% intensity level (non-flashing mode). The light circuits shall be designed as shown on the electrical design drawings.

13 .8.4.7.1.6 Exterior Lighting Controls

All exterior lighting shall be controlled by AEMS.

The AEMS shall turn on all lighting when north sky luminance falls below 5 foot-lambert. The AEMS shall turn off 80% of the lighting during non-revenue hours. The remaining 20% of site luminaires, on a separate control and evenly distributed throughout the site, shall remain on all night for security. The security lights shall be turned off by the photocell when north sky luminance rises above 5 foot-lambert. The photocell shall be mounted on a light pole in the middle of a lot with an unobstructed view to the north sky.

Lighting system controls shall have auxiliary contacts for control by the Automated Energy Management System (AEMS).

13 .8.4.7.2 Lighting Feeders

Where multi phase branch circuits are used for feeding power to lighting fixtures, adjacent fixtures shall be alternately connected to different phases and the protective devices shall be single-pole type to maintain a more uniform illumination with de-energization of one or two phases.

13 .8.5 Emergency Lighting

Emergency lighting in stations and tunnels shall be provided by a percentage of the normal continuous burning lighting fixtures to obtain the desired illumination levels. The designer shall submit lighting calculations verifying the level of illumination for each area listed below. Minimum maintained illumination for emergency purposes shall be provided as follows:

13 .8.5.1 AVERAGE LEVEL OF ILLUMINATION

AREA	AVERAGE LEVEL OF ILLUMINATION (Foot-candles)
Tunnels	0.2
Platforms	2.0
Washrooms	1.0
Communications Rooms	1.0
Train Control Rooms	1.0
AC Switchboard Room	6.0
Stairs, Escalators, Mezzanines	2.0
Emergency Exit	2.5
Fan and Vent Shafts	1.5
Kiosk	6.0
Elevator Car Lights	5.0

Approximately 50 percent of the lighting fixtures in emergency exit shafts and stairways, and 20 percent of the indoor lighting fixtures, shall be connected on emergency circuits. Outdoor lighting fixtures shall not be connected on emergency circuits unless approved by the Authority.

In all cases the emergency lighting shall conform to the codes and regulations of all jurisdictional Authorities. Exit lights and normal signs shall be fed from the emergency power system.

Emergency lighting for the stairs and escalators shall be designed to emphasize illumination on the top and bottom steps or landings.

Provide emergency lighting in shafts with ladders for safety of incoming emergency and WMATA personnel who may be required to reach an incident site.

All escalator step (newel and comb) lighting shall be on emergency 120 volt AC circuits.

Escalators shall have ten (10) percent of the balustrade and maintenance lighting on emergency 120 volt AC circuits. Emergency lighting circuits for blue lights at emergency trip stations (ETS) shall be rated at 277 volts for ETS units located in passenger stations and at trackside (remote from passenger stations).

13 .9 SUPERVISORY CONTROL AND INDICATION OF ELECTRICAL SYSTEMS

13 .9.1 General

These design criteria include functional and design requirements for supervision and control of Traction Power and Auxiliary Electrical Systems of the Washington Metropolitan Area Transit Authority's rail rapid transit system.

The Electrical Supervisory Control System utilizes the Data Transmission System (DTS) installed under the Train Control Contract for transmission of all supervisory data between field controlled facilities and the Central Control Room. The Central Supervisory Display and Control Console is also designed and installed under the Train Control Contract. The design of these two systems must be closely coordinated, particularly with respect to interface details and locations.

13 .9.2 Scope

The Electrical Supervisory Control System shall monitor, and in some instances have control of the traction power and other electrical equipment necessary for the continuous operation of the system. The following is included in the design of this system:

13 .9.2.1 Facilities required for control and supervision of Traction Power Substation and Tie Breaker Stations, except in yards and service and inspection shops.

13 .9.2.2 Facilities for monitoring of passenger station auxiliary equipment and AC power unit substations.

13 .9.3 Glossary

Definitions pertaining to Supervisory Control are included in the General Glossary for Section 13.3 of this Criteria.

13 .9.4 Standards

The Supervisory Control equipment for electrical functions shall embody modern designs which provide the highest degree of safety and reliability. Whenever applicable, design of equipment for these functions shall be in accordance with ANSI, NEMA and IEEE Standards and Specifications. The functional principles of these specifications shall also be maintained where new devices or techniques are developed, even though the technicalities of the specifications may require modification.

13 .9.5 Equipment and System Interfaces

13 .9.5.1 Control Center Console

The Control Center located in the OCCB shall contain an Electrical Display and Control Console which shall give immediate alarm and visual indication of status changes, faults, or other abnormal conditions associated with traction power substations, tie breaker stations, AC switchboard rooms, ventilation fans, fan shafts, vent shafts, drainage/pumping stations, and chiller plants. This Control Console shall be further equipped to provide the operating attendant with the capability to control or adjust electric power systems (as indicated in Table 13.5 and Table 13.6) serving the transit facilities, to maintain continuous rapid transit operation.

Additional functions of the Control Console are described in subsequent sections of these criteria. This equipment is designed and installed under the Train Control and Communications contracts.

13 .9.5.2 Remote Terminals and Interface to DTS

13 .9.5.2.1 Traction Power Substations and Tie Breaker Stations Cabling and connections from the equipment to a terminal cabinet, and the terminal cabinet itself (located in the respective substation or tie breaker station) will be furnished and installed by the contractor. Extension of wiring from the terminal cabinet to OCCB will be by the train control stage contractor. Extension of wiring to yard control tower shall be by the section contractor.

13 .9.5.2.2 Passenger station AC switchboard rooms - Cabling and connections from the equipment to a terminal cabinet, and the terminal cabinet itself (located in the respective switchboard room) will be furnished and installed by the section contractor. Extension of wiring from the terminal cabinet to OCCB will be by the train control stage contractor.

13 .9.5.2.3 Fan shafts, vent shafts, drainage/pumping stations, and chiller plants - Cabling and connections from the equipment to a terminal cabinet, and the terminal cabinet itself, will be furnished and installed by the section contractor. For fan shafts, vent shafts, drainage/pumping stations, and chiller plant located at passenger stations, the terminal cabinet shall be located in the nearest AC switchboard room and shall also serve the AC switchboard room equipment. For fan shafts, vent shafts, drainage/pumping stations, and chiller plants located remote from passenger stations, the terminal cabinet shall be located at the site to be monitored. Extension of wiring from the terminal cabinet to OCCB will be by the train control stage contractor.

13 .9.6 System Functions

The field response equipment in the remote zone control units shall permit the traction power substation functions to be supervised or controlled remotely from the Operation Control Center.

Tables 13.5 and 13.6 list the various location and supervisory control functions for traction power substations and auxiliary electrical equipment respectively. Local and supervisory control functions for these systems and for other equipment shall be as shown on electrical, mechanical and train control design and standard drawings.

13 .10 MAINTAINABILITY AND CONSTRUCTIBILITY

The design of the electrical system comprising equipment, raceways, fixtures, devices, wires and cables shall be coordinated with structural, mechanical architectural and other disciplines for the purposes of providing adequate space, clearances and structural support, and to ensure non-interference with other trades during construction. It shall take into account the ease of maintainability of the electrical equipment installed. Maintenance operations include inspection, adjustments, cleaning, trouble shooting, servicing, repairs and replacement of electrical equipment. The equipment selected should be subject to minimal system component failure.

13 .10.1 Space

Sufficient working space and adequate access shall be provided for the maintenance and replacement of electrical equipment. Adequate space around electrical equipment shall be provided and maintained to allow for heat dissipation and cooling. This requirement shall include adequate space for movement of equipment during initial installation, and during subsequent unscheduled maintenance involving removal and replacement of failed equipment.

13 .10.2 Accessibility

All electrical system switching and over current protection devices shall be accessible to authorized persons only. Access to cables or conduits installed in return air plenums under station platforms shall be provided through manhole covers at appropriate locations.

Adequate means, such as lifting eyes and/or I beams with a running hoist, shall be provided for raising, lowering, shifting, removal or replacement of heavy electrical equipment. Pulling eyes shall be provided for the pulling of cables at the following locations:

13 .10.2.1 AC Switchboard Rooms

13 .10.2.2 Traction Power Substations

13 .10.2.3 Tie Breaker Stations

13 .10.2.4 Chiller Plants

13 .10.2.5 Train Control Rooms

13 .10.2.6 Communications Rooms

13 .10.2.7 Electrical Rooms

13 .10.2.8 Cable shafts

13 .10.2.9 Manholes

13 .10.2.10 Other locations where considered necessary.

13 .10.3 Equipment Protection Against Water and Moisture:

Each substation building and electrical room shall be designed to preclude any entry of water. Seals shall be provided on raceway and cable penetrating a building wall, floor or ceiling at a point. No water or sewage piping shall be installed inside substation and electrical equipment rooms. No pipe or mechanical duct that could cause moisture or condensation to fall on the electrical equipment shall be located above any major electrical equipment.

13 .10.4 Embedded Conduits, Conduit Sleeves and Channel Inserts:

Embedded conduits can be installed in the space available between rebars. Where a slab has to carry a large number of conduits, steps shall be taken to ensure that it will be feasible to install all the conduits without compromising the structural integrity of the concrete structure. Adequate cross sections shall be shown on the drawings to indicate how the raceways and other embedded items will be installed and cross each other where applicable. Where embedded FRE conduit emerges from a concrete slab or a wall, a FRE to galvanized rigid steel conduit adapter shall be provided, except traction power conduit.

Where conduits are not provided as raceways, channel inserts shall be installed for supporting multiple conductor cables located under platforms, and in manholes. Spare conduit and sleeves shall be provided in concrete walls, floors or ceiling slabs of the AC Switchboard Rooms, Electrical Rooms, Traction Power Substation, Tie Breaker Stations, Mechanical Rooms, ductbank and other areas as required for possible future requirements.

13 .10.5 Electrical Plans, Details and Schedules:

Plans and details showing physical arrangement and elevation with dimensions shall be provided on the drawings for all major electrical and mechanical equipment, raceways, junction boxes, fixtures and other items so that the design and construction can be coordinated with mechanical, structural and other disciplines.

Schedules of all major electrical equipment including switchgear, switchboards, panelboards, transformers, disconnect switches, conduits, and cables shall be provided on the drawings. These schedules shall be complete and consistent with plans on associated electrical and mechanical drawings.

13 .10.6 Lighting System

The use of incandescent lamps, whenever practical, will be avoided. Where incandescent lamps are used, they shall be of the long life type. When multi phase branch circuits are used for feeding lighting fixtures, the fixtures shall be alternately connected on different phase and the protection devices shall be of single pole type so that a uniform illumination may be maintained in a large area when any one or two phases are de-energized.

The locations of lighting fixtures selected shall permit easy cleaning, replacement and maintenance. Adequate illumination shall be provided on all working areas around the electrical equipment.

13 .10.7 Operation and Maintenance Manual:

Operation and Maintenance Manual shall be provided for major electrical equipment. It shall include manufacturer's operation and maintenance instructions, wiring diagram, control and power elementary diagrams, list of spare parts and recommended stock quantities for one year routine maintenance and repair. A copy of approved shop drawing of equipment and other items where considered necessary shall be included.

13 .11 ELECTRICAL REQUIREMENTS FOR BUS FACILITIES

13 .11.1 Power Systems

13 .11.1.1 Main Incoming Service: The main incoming electrical service must be coordinated with the local Power Company having responsibility for supply. The initial discussions with the Power Company should investigate the availability of service from the medium power grid (13.8kV or 34.5 kV) which should provide a better billing rate for the facility. Electrical service guidelines and requirements must be determined prior to and followed during design of the utility interface and incoming service equipment. The preferred location for this equipment is in a separate structure situated on the site away from the main building, but within a limited distance to keep the secondary conduit and cable run to a minimum. The incoming service equipment will typically include a primary fused disconnecting switch, an incoming utility section with metering per Power Company requirements and a pad mounted transformer with primary to meet Power Company supply voltage and 277/480 volts, 3 phase, 4 wire secondary. Transformer size will be determined from load calculations performed after mechanical equipment, lighting and utility loads have been established along with a 25% factor for any future expansion considerations.

13 .11.1.2 Facility Power Distribution: The main distribution switchboard shall be 277/480 volt with a current capacity based on facility load calculations and future expansion considerations. The switchboard shall be metal enclosed dead front safety type free standing with a sufficient number of circuit breakers to meet facility design needs and adequate spare capacity to meet future growth. The switchboard fabrication and features shall include hinged front panels, hard drawn copper bus material with silver-plated contact surfaces and uniform capacity over entire length and front panel meters to display phase to phase and phase to neutral voltage and current. The circuit breakers in the switchboard shall be current limiting molded case NEMA AB 1 with 75,000 amp interrupting capacity or as necessary to meet available fault current. The switchboard shall be located in a dedicated electrical equipment room along with the main electrical distribution panelboards and transformers. This room shall be appropriately sized to accommodate equipment clearance requirements as defined by National Electric Code (NEC) latest revision, IBC, local and State codes, and as described below. Panelboard enclosures shall be NEMA PB 1 Type 1. The motor control centers shall be located in the mechanical equipment room. It is preferred that there be two separate motor control centers, one for equipment on normal power and another for equipment on emergency power. Appropriate space shall be provided in the mechanical equipment room to accommodate equipment clearance requirements as defined by National Electric Code (NEC) latest revision and as described below. Motor control center and disconnect switch enclosures shall be NEMA Type 1 or as otherwise specified to meet environmental conditions. The bus material in this equipment shall be hard drawn copper of 98% conductivity. Main distribution panels and any panelboards rated greater than 200 amps shall be located with 2'-0" clear space on both sides and any other panelboards shall have 18" clear space on both sides for ease of maintenance. Any panels mounted adjacent to each other shall have 2'-0" clear space between them and shall have 3'-0" clear space in front of panels for access, or as otherwise defined by the National Electric Code (NEC) latest revision. Any panelboards and control panels in maintenance or service areas

shall be centrally located in the area covered and shall be flush mounted and/or protected by bollards or guard rails. For all panelboards, installation of conduits shall be top or bottom entry at rear of entering surface such that all available rear surface space is used prior to installing conduits on surface toward front of panelboard. Panelboards and their installation shall comply with NFPA 30A. Space shall be provided for conduit runs at ceiling including space consideration for future conduits. All conduit and cable shall be installed as per the latest revision of the National Electric Code (NEC) and NFPA 30A with routing done overhead and drops from ceiling space and not run within slabs on grade. Conduit for power distribution shall be minimum ¾ inch size. Exterior underground conduit shall be rigid galvanized steel encased in concrete under paved areas and rigid nonmetallic concrete encased in other areas. Interior conduit shall be rigid galvanized steel. All power wiring rated 600 volts and below shall be type THHN/THWN in raceway with a minimum No.12 AWG size. All general purpose duplex receptacles are to be rated for 20 amps, 125 volts.

13 .11.1.3 Stand-By (Emergency) Power System: The stand-by generator equipment shall be located in a structure adjacent to the incoming service equipment structure. Load calculations of the equipment and devices to be connected plus any future considerations shall determine emergency generator size. The stand-by generator shall enable the facility to maintain the most normal operations during an extended power failure. The standby generator shall meet the requirements of NFPA 110. The preferred fuel source for the generator is diesel fuel. Fuel storage for the generator shall be by an equipment mounted day tank along with a remotely mounted underground storage tank with 2000 gallon capacity. The requirements for the underground tank are described in Section 16 and Section 18.4.2.1-Underground Storage Tanks. The generator shall start automatically on occurrence of power failure. Multiple Automatic transfer switches shall be provided to transfer power load from normal power to the emergency generator. Emergency and equipment loads shall be separated on different transfer switches as required by NEC. Lighting and equipment on the stand-by system shall be marked with a red dot. The stand-by system shall provide services to the following as a minimum:

13 .11.1.3.1 Emergency lighting

13 .11.1.3.2 Exit lighting

13 .11.1.3.3 Fire alarm control panel

13 .11.1.3.4 Computer system

13 .11.1.3.5 Ventilation equipment in selected areas

13 .11.1.3.6 Security system

13 .11.1.3.7 Fueling system equipment and monitoring (NFPA 30A) (NFPA 497)

13 .11.1.3.8 The communication system

13 .11.1.3.9 Selected hydraulic lifts

13 .11.1.3.10 Selected air compressors

13 .11.1.3.11 Elevators

13 .11.1.3.12 Boiler and associated pumps

13 .11.1.3.13 CNG related equipment

13 .11.1.4 Specialty Power Systems: Utility power for tools, task lighting and portable equipment shall be provided at the bus maintenance and repair bays via reels suspended from overhead. Electrical cables for portable lifts shall be routed down from ceiling. Utility power receptacles with GFI protection and weatherproof enclosures shall be provided in wash areas or any other potentially wet areas and outside areas at various light poles throughout the yard area to allow for use of power tools for maintenance purposes. Explosion proof receptacles and devices shall be required in battery rooms, hazard material storage areas, maintenance pits, fuel distribution areas and any class 1 div. 1& 2 areas (NEC 500 and 511).

13 .11.1.5 Grounding Systems: The grounding system for the main pad mounted transformer shall meet the requirements of the power company and National Electric Code (NEC) latest revision, IBC, State and local codes. As a minimum, there shall be a ground loop around the transformer consisting of #4/0 awg bare stranded copper cable with ground rods (10'-0" long, ¾" diameter, copper clad steel) installed at ten foot spacing and driven 18" below grade with all connections being exothermic welded type. All metal parts of the transformer installation shall be connected to the loop using #2/0 awg bare stranded copper cable. The emergency generator shall have as a minimum a ground loop consisting of # 4/0 awg bare stranded copper cable with ground rods (10'-0" long, ¾" diameter, copper clad steel) installed at the corners of the unit and shall be connected to the transformer grounding system at least two points. All connections shall be exothermic welded type. The steel frame of the building shall be an effectively grounded system by bonding the steel frame to the foundation rebar using a minimum # 4 awg bare stranded copper cable with exothermic welded connections.

13 .11.2 Lighting Systems

13 .11.2.1 Exterior Lighting: Lighting design levels for parking areas and driveways shall be determined using IES roadway illumination methods. Luminaire maintenance factor of 65% shall be assumed and luminaire selection, location and directional aim criteria shall be such as to minimize objectionable glare and interference. Fixture selection shall include features such as High-Pressure Sodium lamps, photocells, captive hardware and safety chains on components to provide for ease of maintenance.

13 .11.2.2 Interior Lighting: The lighting design for interior spaces will be based on room type and space usage. Table E-1 shall serve as a guide for minimum illumination levels acceptable in the various operational areas within the facility. In addition to illumination levels design consideration must be given to such criteria as glare elimination, color rendition, transition eye comfort and special task lighting. Fixture, lamp and ballast selection shall take into consideration the latest in energy efficient technology.

AREA or ROOM	FOOT CANDLES	LIGHT SOURCE
Outside Parking Areas	10	High Pressure Sodium
Access Driveways	10	High Pressure Sodium
Outdoor Building Entrances	10	High Pressure Sodium
Bus Service and Maintenance Bays	100 / 50*	Metal Halide
Lift and Pit areas	100 / 50*	Metal Halide
Tire Repair Bays	100 / 50*	Metal Halide
Offices and conference rooms	50	Fluorescent (w/ T8 lamps)
* The higher value is for task lighting and lower value is general level.		

TABLE E-1 REQUIRED LIGHTING TYPES AND LEVELS

13 .11.3 FIRE ALARM

13 .11.3.1 The fire alarm system shall be designed to conform to the International Building Code, State and of the local jurisdictional body and NFPA 72.

13 .11.3.2 The fire alarm system within the facility shall be an uncoded addressable standalone system with all components supplied from the same manufacturer. System components shall consist of the following:

13 .11.3.2.1 Tamper resistant fire alarm control panels located in strategic positions throughout the facility. Each panel shall have appropriate signs and marker lights. The main fire alarm control panel shall be located in 24-hour manned area and all sub panels shall be interfaced to the main panel. A printer and monitor shall be provided as part of the system.

13 .11.3.2.2 The main fire alarm panel shall include a trouble signal connection from the HVAC equipment such that a trouble alarm is initiated when that equipment is in the bypass mode.

13 .11.3.2.3 All wiring for the fire alarm system shall meet the requirements of the system manufacturer. All wiring shall be in conduit and designed and installed per the requirements of the National Electric Code (NEC) latest revision.

13 .11.3.2.4 An exterior electronic horn and strobe beacon, visible from the street, shall operate continuously during alarm condition until reset from the control panel. Other electronic horn/strobe unit shall comply with ADA requirements.

13 .11.3.2.5 All fire alarm system components shall be indicated on the main panel. The system components may include fire alarm pull stations, smoke/heat detectors, duct detectors for shutting down HVAC systems, tamper/flow switches for sprinkler systems, Halon or special extinguishing systems, elevator control system and hydrogen detection for battery charging areas.

13 .11.3.3 Thermal detectors shall be used in areas not covered by the sprinkler system. Component spacing shall conform to manufacturer's requirements and UL standards.

13 .11.3.4 A pre-test and a final acceptance test of the fire alarm system shall be performed. These tests shall include all functions of the system in various trouble and alarm modes.

13 .11.4 Communication/Telephone

13 .11.4.1 The communication/telephone system shall include components within the facility for internal telephone network links, external communication link and link to the intercom/PA system.

13 .11.4.2 The facility telephone system shall be connected to the local telephone company cable. The facility shall have overhead routed telephone conduit; outlet boxes, Category 5 wiring and terminal equipment built in during construction. Communication cables that are not run in conduit shall be supported at four foot intervals using approved supporting devices such as 'J' or 'D' hooks or cable tray. Cables run in plenum spaces shall be plenum rated type cable. Communication cables shall not be run parallel to power cables and shall cross power cables at right angles. Communication cables shall be separated a minimum of 18 inches from sources of electromagnetic interference such as fluorescent fixtures, motors, transformers, power cables, etc. The telephone system vendor shall supply instruments and required interconnections within the facility. Where possible, dedicated lines shall be provided for any fax or modem equipment within the facility.

13 .11.5 Security

13 .11.5.1 A Closed Circuit Television (CCTV) system shall consist of video cameras mounted in various locations on light poles or on building exterior in order to provide adequate viewing of the site and building. A monitoring system shall be located in a designated security office with a control panel to allow automatic switching to sequence through each camera location as well as manual selection of specific cameras. The system shall be capable of accommodating one or more television monitors as required. The system shall meet WMATA requirements and shall have the capability of recording selected images, switching sequentially and "Quad Screening". All cameras shall be equipped with solid-state imaging devices.

13 .11.5.2 All exit doors, including overhead roll-up doors, shall be equipped with magnetic contacts, visual and audible local alarms.

13 .11.5.3 A "Talk-Back" system shall be provided at exit points and CCTV locations, to enable contact with personnel monitoring the system.

13 .11.5.4 Areas designated as "sensitive", such as the automatic fare collection area, small parts storage room, etc., shall be monitored by video motion detection, passive, infrared and multifaceted detection units. The detection system shall be activated upon entering a secured space.

13 .11.5.5 All alarm and detection devices shall be connected to a computerized alarm monitoring system with extensive capacity for application to monitor magnetic contacts, fire alarms, intrusion detection alarms, and any other electro-mechanical controls for building access and egress. Monitors shall be located in the 24-hour security booth.

13 .11.5.6 Intercom/PA: The intercom/PA system shall be a talk's back paging system consisting of a system control console located in a supervisor office with various speakers, microphones and intercom stations distributed throughout the facility. The system shall have zoned paging capability as well as emergency override to interrupt calls. The facility shall be pre-wired for intercom/PA with all wiring as per manufacturer's requirements and run in a complete conduit system using overhead routing methods.

13 .11.5.7 Computer/Data

13 .11.5.7.1 The computer/data system has specific requirements separate from the facility power and communication systems.

13 .11.5.7.2 The power distribution for the computer equipment shall consist of 120 volt, 20 amp, single phase, 3 wire, and 60 Hz circuits with a maximum of 3 workstations per circuit. A separate distribution panel is preferred with integral surge protection at the panel or local surge protection at the workstation. Isolated ground receptacles shall be used and the neutral conductor in the feeder circuit shall only be tied to ground at one location that being the primary distribution panel.

13 .11.5.7.3 Data network cabling shall be category 5E type. Conduits shall be provided for routing data cable from outlet boxes to open ceiling space with no routing in concrete slabs. Data cables that are not run in conduit shall be supported at four foot intervals using approved supporting devices such as 'J' or 'D' hooks or cable tray. Data cables run in plenum spaces shall be plenum rated type cable. Data cables shall not be run parallel to power cables and shall cross power cables at right angles. Data cables shall be separated a minimum of 18 inches from sources of electromagnetic interference such as fluorescent fixtures, motors, transformers, power cables, etc.

13 .11.5.7.4 Data network hub equipment and servers shall be located in rooms with dedicated space for this equipment. Equipment racks or shelves shall be provided with appropriate cable management systems to accommodate the type and quantity of cable being used. Any equipment or workstations that must be located in an atmosphere exposed to dust or corrosives shall have an appropriate type filter installed on the air intake side of the equipment. Conditioned air shall be provided for servers and hub equipment and it is recommended that uninterruptible power supplies, power

conditioners and/or isolation transformers are provided to reduce electrical interference.

13 .11.5.8 Specialty Systems

13 .11.5.8.1 Master Clock system shall consist of a master time control center, carrier signal generator, "Daylight Savings Time" switch control and any other manufacturer associated equipment. The master clock should be tied into time cards and audible alarms for breaks, lunch and any other scheduled events.

13 .11.5.8.2 Door Clearance System shall include limit switches, red/yellow traffic signal lights and associated components. A red light shall remain illuminated to protect each exit door until the door is fully opened; at which time the signal will turn to yellow.

13 .11.5.8.3 Traffic Monitoring System shall include bus detectors, warning lights, audible signals, control equipment and other associated components and materials. The system shall monitor and control traffic in areas of restricted or limited space, access or visibility.

SECTION 14 MECHANICAL

14 .1 GENERAL

These criteria cover the design of mechanical facilities for the subway, including:

Tunnel Ventilation Systems

Heating

Air Conditioning and Filtration

Drainage

Fire Protection

Gratings and Miscellaneous Metals

Emergency Access Shafts

Elevators

Escalators

Maintainability and Constructibility

14 .2 CODES AND REGULATIONS

Unless otherwise required herein, mechanical designs and installations shall be governed by all applicable local codes in addition to the codes, guidelines and standards listed below. In cases where national codes, local codes, and WMATA standards conflict, the most stringent code or standard shall take precedence.

14 .2.1 Heating, Ventilating and Air Conditioning

All heating, ventilating and air conditioning system designs shall be based on the version of International Mechanical Code, as amended by the local jurisdiction, in effect at the time of design.

Air conditioning and refrigerating equipment shall bear the ARI stamp.

14 .2.2 Sheet Metal Ductwork

All sheet metal ductwork shall be constructed in accordance with Sheet Metal and Air Conditioning Contractors National Association Inc. (SMACNA) standards.

14 .2.3 Fans

All fans shall be rated in accordance with the "Standard Test Code for Air Moving Devices" and the "Test Code for Sound Rating Air moving Devices" of the Air Movement and Control Association, Inc. Fans utilized for subway smoke management purposes shall comply with the elevated temperature requirements defined in NFPA 130.

14 .2.4 Plumbing

All plumbing system designs shall be based on the International Plumbing Code, as amended by the local jurisdiction, in effect at the time of design. ~~Plumbing shall meet the standards of the appropriate local authority.~~
All plumbing installations and fixtures shall comply with the applicable requirements of the Americans with Disabilities Act Guidelines (ADAG).

14 .2.5 Acoustical Materials

Acoustical materials shall be rated in accordance with the standards of the Acoustical Society of America, UL, ASTM and NFPA.

14 .2.6 Noise Criteria

Noise criteria shall be as described herein and in the current handbook series published by the American Society of Heating, Refrigeration, and Air Conditioning Engineers (ASHRAE).

14 .2.7 Piping

Provide all pipe calculations including formulas used and assumptions made in the design. ~~Friction losses in piping shall be as described in the current edition of the "Cameron Hydraulic Handbook".~~

14 .2.8 Fire Protection

Fire protection system designs shall be based on National Fire Protection Association (NFPA) Standard No. 130, Fixed Guideway Transit Systems, including all additional NFPA standards referenced in NFPA 130.

14 .3 TUNNEL VENTILATION SYSTEM

14 .3.1 Tunnel Ventilation System Capacity and Arrangement

Tunnel ventilation system component shall be provided and sized for emergency ventilation in accordance with current NFPA 130 requirements. The ventilation system shall be capable of preventing back layering in all tunnel segments served by that system. As verification, designer shall demonstrate that when the fire is present in any tunnel segment, the predicted air velocity in that segment exceeds the critical air velocity. The critical air velocity represents the minimum air velocity required to prevent back layering of smoke and shall be calculated on the basis of maximum grade in any tunnel segment and site specific tunnel geometric data and specific density and temperature of air in the tunnel.

14 .3.1.1 The engineering analysis of the ventilation system as outlined in NFPA 130 shall include a validated subway analytical simulation program augmented as appropriate by a quantitative analysis of airflow dynamics produced in the fire scenario, such as would result from the application of a validated computational fluid dynamic (CFD). Critical air velocity shall be calculated in accordance with the Subway Environment Simulation (SES) Computer Program by using the current version of the Users Manual.

14 .3.1.2 The fire magnitude shall be 69.7 million BTUH per hour. This magnitude was used previously for modeling, consult WMATA for direction.

In cases where jet fans are utilized, the system shall be sized to prevent back layering assuming failure of jet fan /fans in one niche .

Primary ventilation will be provided by the following means:

14 .3.1.3 Gravity ventilation in conjunction with train piston-action induced airflows.

14 .3.1.4 Mechanical ventilation provided by fans.

To facilitate ventilation by gravity and train piston action air flows, the tunnel ventilation system includes vent shafts located at each end of underground stations and if required in mid-tunnel locations. These vent shafts perform the following functions:

14 .3.1.5 Provide a source of outdoor air for tunnel ventilation.

14 .3.1.6 Provide a means of relieving piston action airflows.

Mechanical ventilation shall be accomplished by one of the following means:

14 .3.1.7 Reversible fans housed in fan shafts.

14 .3.1.8 Reversible jet fans housed in recesses in the tunnel walls.

In all cases , make-up air will enter the subway through portals and station entrances. During normal transit operations, vent shafts remain open and provide an additional source of make-up air. During emergency operation, vent shaft dampers close, thereby increasing the air flow through station entrances.

14 .3.2 Purpose of Tunnel Ventilation System

The tunnel ventilation system shall provide the following capabilities:

14 .3.2.1 Smoke Control - Provide the required mechanical ventilation in the event of a fire within a tunnel section.

14 .3.2.2 Heat or Diesel Smoke Removal - Augment the ventilation provided by train piston action during normal operations and, when necessary, provide the primary means of limiting tunnel temperatures when train piston action induced air flows are no longer present. Allow for maintenance operations using diesel equipment.

14 .3.2.3 Blast Relief - Reduce excessive air movement within stations due to piston-action of trains by provision of vent shafts at each end of each station.

14 .3.2.4 Access - Accommodate emergency, construction or maintenance access stairs and/or ladders within vent and fan shafts.

14 .3.3 Smoke Control

The primary function of the tunnel ventilation system is provision of emergency ventilation in the event of a fire within a tunnel section per NFPA 130 requirements. Mechanical ventilation is required to control the flow of smoke in a manner which provides evacuating passengers with a smoke free exit path without back layering of smoke.

14 .3.4 Heat Removal

The heat generated within the subway is attributable to five general sources:

14 .3.4.1 Traction equipment - equipment which provides power to the third rail.

14 .3.4.2 Train auxiliaries - equipment on the train such as brakes, motors, etc.

14 .3.4.3 Wayside and station lighting and equipment

14 .3.4.4 Subway passengers

14 .3.4.5 Solar heat carried by train

Train piston-action, natural convection and conduction through the tunnel walls will, at most times, provide sufficient tunnel heat removal. However, when tunnel temperature conditions exceed the established limits, mechanical ventilation shall be utilized.

14 .3.5 Arrangement of Fan Shaft System

In the arrangement of the tunnel ventilation system utilizing fan shafts, the following criteria shall govern design:

14 .3.5.1 The tunnel ventilation system shall utilize fan and vent shafts. Fan shafts shall house reversible fans of sufficient total capacity to account for both normal and emergency conditions. In addition by-pass dampers shall be provided at each fan shaft for the purpose of relieving piston-action induced airflow. Vent shafts shall operate in conjunction with fan shafts and shall function as either air intakes or reliefs depending on fan shaft fan operating mode.

14 .3.5.2 Certain fan and vent shafts shall be used for emergency access and egress from the subway. See "Emergency Access Shafts" Section 14.10.

14 .3.5.3 Fan and vent shaft openings at street level shall be located to avoid pedestrian and vehicle crossings and to minimize the danger of flooding the subway. Surface pavement around opening shall be sloped away from the opening. Where located in sidewalks, openings shall occupy not more than 40% of the sidewalk width and be located as far from the street curb as possible. Where possible, openings shall be located in median strips or off-street locations. Where feasible, vent and fan shaft structures shall be raised 12 inches above the adjacent level to prevent runoff water from flooding the subway and suitably screened with planting or other decorative treatment. Under no circumstances shall vent or fan shaft openings be located in roadways.

14 .3.6 Jet Fans

In the arrangement of the tunnel ventilation system utilizing jet fans, the following criteria shall govern design:

14 .3.6.1 The tunnel ventilation system in selected sections shall utilize jet fans and vent shafts with the approval of the authority. Jet fans shall be wall mounted within tunnel recesses and shall be of sufficient total capacity to account for emergency conditions.

14 .3.6.2 Jet fans shall be reversible and have the capability of moving smoke away from passengers during an emergency. Local and remote controls shall be provided to stop and reverse jet fan operating modes.

14 .3.6.3 The tunnel fans in the original 106 mile system are 50,000 cfm., New installations shall conform to the current verison of NFPA 130 at the time of design. ~~Volume as per VI.C.1, 100%~~ The fans shall be reversible with factory installed sound attenuations.

14 .3.6.4 Jet fans shall be secured to the tunnel walls with stainless steel hardware. Submit calculations verifying support and fastener adequacy.

14 .3.6.5 Electrical Characteristics 460 volts, 3 phase, 60 hertz, essential power.

14 .3.6.6 Motor Control Magnetic, across-the-line start, circuit breaker disconnect, magnetically operated overload protectors ~~(t~~Thermal type overload will not be permitted~~)~~, fans are to run until failure in an emergency. ~~l~~Local manual on-off automatic and forward-reverse selector switches shall be provided.

14 .3.6.7 Remote control and supervisory control from Operations Control Center (OCC).

14 .3.6.8 Jet fans and all associated equipment shall be rated for operation at elevated temperatures as defined in latest NFPA 130.

14 .3.7 Calculation of Friction Losses

The following formula shall be applied in the calculation of friction losses for air flow in structures:

$$H_f = (F * L * v^2)/(2 * D * g)$$

Where:F = Darcy Weisbach friction factor (determined from Moody diagram).
L = Length of tunnel ~~in feet~~.
D = Hydraulic diameter ~~in feet~~ = 4A/P
g = gravitational acceleration
Where:
A = Area ~~in square feet~~
P = Perimeter ~~in feet~~
~~V~~ v = Velocity of air ~~in feet per minute~~

The friction factor "F" shall be derived from the Moody diagram and shall be based on the relative roughness (roughness length/hydraulic diameter) of the material involved and the Reynold's number of the expected air flow. Specific Roughness ε ~~lengths~~ shall be as follows:

Material	Specific Roughness ~~Length~~ (ft)
Clean steel	0.00015
Smooth Concrete	0.001
Average Concrete	0.003
Rough Concrete	0.01

14 .3.8 Vent Shafts

Each vent shaft shall be designed to suit local conditions. Vent shafts shall be sized to handle ventilation volume generated by train piston action and make-up air for station exhaust systems at a velocity of not more than 350 feet per minute (f.p.m).

Where vent shaft structures are utilized for station exhaust systems (under platform and dome), separate ducts are to be provided for these systems within the vent shaft. These ducts shall have concrete or masonry walls and shall be sized in accordance with fan shaft criteria. The size of the vent shaft structure shall be increased accordingly. Intake, exhaust and reversible system openings shall be separated at grade by a distance of not less than 25 feet.

Vent shafts shall be measured as the gross face area of the grille or grating within the supporting shaft dimensions. Sudden expansions and contractions shall be avoided in the design of vent shafts, and a uniform cross section shall be maintained.

Vent shaft equipment shall include:

14 .3.8.1 Electronically or ~~P~~pneumatically operated dampers controlled by thermostats located near tunnel fan shafts and the supervisory control system to control dampers from Operation Command C~~c~~enter. Air compressor to be located as close to dampers as possible, long pneumatic piping runs to be avoided. Compressed air to be properly treated and dried (by descant dryer or other means) in order to remove moisture or contaminants from the air.

14 .3.8.2 Where emergency access/egress are combined with vent shafts, stairs are required for patron evacuation in emergencies. Maintenance ladders are provided in all other shafts for maintenance and emergency ~~in~~egress of WMATA personnel except where shaft bottom is within 100 feet of end of station and readily accessible.

14 .3.8.3 Drainage (See Drainage, Section 14.8).

14 .3.8.4 Fire standpipe system(s) (See Fire Protection, Section 14.13).

14 .3.8.5 Access hatchway (See Emergency Access/Egress Shafts, Section 14.10).

14 .3.8.6 Surface gratings (See Gratings, Section 14.9).

14 .3.8.7 The following electrical slots, sleeves or conduits shall be provided in each vent shaft:

14 .3.8.7.1 A.C. lighting

14 .3.8.7.2 Emergency lighting (Emergency egress shafts only)

14 .3.8.7.3 Convenience outlet

14 .3.8.7.4 Supervisory control & surveillance

14 .3.9 Fan Shafts

Each fan shaft shall be designed to suit local conditions.

Fan shafts shall be equipped with two or more fans. Each fan shall exhaust air from or direct air into both tunnels where tracks are in separate tunnels.

Fan shaft size shall be selected to meet the ventilation requirements calculated as per Section 14.3.1. Air discharge velocities from fan shafts shall fall into the following categories:

14 .3.9.1 Through sidewalks or into areas where people will be affected by the discharge of air, maximum discharge velocity - 500 fpm.

14 .3.9.2 Through medians or off-street properties where people will not be affected by the discharge of air, maximum discharge velocity - 1,000 fpm.

The maximum discharge velocity shall be based on the gross area of the grating or grille. Shafts between fan discharge and grating chamber may be designed for a maximum velocity of 1,000 fpm. Sudden expansions and contractions in the shaft cross section shall be avoided in the design of fan shafts. The minimum number of turns or elbows shall be used. Streamlining of obstructions and fan shaft passages shall be undertaken where economically warranted.

Electrically or ~~P~~pneumatically-operated by-pass dampers shall be provided in tunnel fan shafts. By-pass dampers shall be sized in accordance with free area established for the fan shaft but shall be no greater than 200 square feet, free area. Structural design of dampers shall meet requirements of structural design criteria.

14 .3.10 Fan shaft equipment shall include:

14 .3.10.1 Screen, inlet bell, fan, outlet transition and dampers

14 .3.10.2 By-pass dampers

14 .3.10.3 Motor control equipment controlled by the supervisory control system, thermostats, and local manual on-off controls

14 .3.10.4 Emergency access stairs-or maintenance ladders.

14 .3.10.5 Drainage

14 .3.10.6 Acoustic treatment when required to meet the noise requirements outlined in the Environmental Section of the Design Criteria.

14 .3.10.7 Sound attenuations when required to meet the noise requirements outlined in the Environmental Section of the Design Criteria.

14 .3.10.8 Dry fire standpipe system

14 .3.10.9 Access hatchway

14 .3.10.10 Surface grating

14 .3.10.11 Steel stairs and ladders shall be provided as required.

14 .3.11 The following electrical sleeves or conduits shall be provided at each fan shaft:

14 .3.11.1 A.C. lighting

14 .3.11.2 Emergency lighting

14 .3.11.3 Convenience outlet

14 .3.11.4 Power for fans

14 .3.11.5 Supervisory control and surveillance

14 .3.11.6 Telephone or other means of communication with Control Center

14 .3.12 Tunnel Ventilation Fans (Fan Shaft System)

Primary ventilation fans shall be reversible and in accordance with the following:

14 .3.12.1 Characteristics in the exhaust direction

Volume	~~As per VI.C.1~~ Designed to comply with NFPA130 control to close when tunnel temperature drops below reaches 50F,
Type	Axial
~~Air Velocity Through Fan~~	~~2,600 fpm. maximum~~

14 .3.12.2 Equipment Dampers

14 .3.12.3 Motor Reversible Type

14 .3.12.4 Electrical Characteristics 460 volts, 3 phase, 60 hertz, essential power

14 .3.12.5 Motor Control Magnetic, across-the-line start, circuit breaker disconnect, magnetically operated overload protectors (thermal type will not be permitted), local manual on-off automatic and forward-reverse selector switches.

Remote control and supervisory control from Operations Control Center (OCC).

14 .3.12.6 Dampers

Dampers operate by thermostatic control, control to close when tunnel temperature drops below 50°F, at the start of a fan, or a remote signal from Control Center. The entire damper installation shall be designed to withstand, with the blades closed, repetitive loading of 70 lb./sq. foot due to pressure transients applied to either side of the damper.

14 .3.12.7 Fans and all associated equipment shall be rated for operation at elevated temperatures as defined in NFPA 130.

14 .3.13 NOT USED

14 .3.14 Standby Equipment

Standby ventilating equipment shall not be provided unless special circumstances indicate that it is necessary. The Authority's concurrence is required.

14 .3.15 Equipment Handling

Provisions shall be made in the form of lifting hooks and removable panels for the installation and removal of ventilating equipment.

Structural openings shall be sized so that each complete factory-built item of equipment can be installed without disassembly or special construction.

Access to vent shaft damper banks exceeding 10 feet in height shall be provided in the form of catwalks, platforms and ladders. The required arrangement shall optimize access to damper linkage, motor operators and all other serviceable damper components.

All dampers shall be located in a manner which prevents the possibility of a damper section falling on the trackway in the event of a damper failure.

14 .3.16 Control Schematics

Final designs shall include overall control air piping and/or electrical schematics. Schematics shall identify piping runs, control air origin, electrical wiring, wiring identification, major equipment items served and any other information necessary to fully describe the proposed control system, including cross reference to applicable standard drawings.

14 .4 SECONDARY VENTILATION SYSTEMS

14 .4.1 General

Separate secondary mechanical ventilation systems shall provide ventilation for Rapid Rail Transit System facilities and rooms as presented below.

14 .4.2 Characteristics

The characteristics of the individual ventilation systems for all areas and rooms in the Rapid Rail Transit System are described below. The following are minimum requirements:

14 .4.2.1 AC Switchboard Rooms

Provide two fans of equal capacity. A room thermostat shall cycle the lead fan when the room temperature reaches 90°F. The two fans shall not operate simultaneously except when under manual control. During each cycle, one fan shall serve as a stand-by which will operate only upon failure of the lead fan. Lead fan and stand-by fan shall alternate automatically after each operating cycle. Provide a H-0-A switch for each fan. ~~Provide controls such that the air intake dampers remain open when neither fan is operating.~~ During operation of any one fan, the intake damper with other fan shall be closed. Use of gravity type dampers is preferred - The fans shall be located on the supply side of the system. The ductwork, air distribution system, intake and

relief louvers and dampers shall be sized for one fan operation. Relief air shall be discharged to a point outside of the subway unless otherwise approved by the Authority. Supply air shall be from a point outside of subway filtered through a pleated ~~bag~~ filter sized for one fan operation and discharged into the AC Switchboard Room to maintain a positive pressure of 0.1 inch of water gauge within the room with respect to adjacent space. ~~Should the room have a direct connection to outside air then the pleated bag filter requirement can be reexamined by the Chief Engineer on a case by case basis to determine the appropriate level of filtering required for the specific room. The requestor should submit a Request for Variance form to the Chief Engineer for evaluation.~~ Air quantities for each fan shall be based on the following:

- Single AC Switchboard Rooms - 8 cfm per kVA for the total output rating of the main and auxiliary transformers and 51 cfm per kVA for the total output rating of the uninterrupted power system.

- Combined AC Switchboard Rooms - 8 cfm per kVA for 65% of the combined total output rating of the two main transformers, 8 cfm per kVA of the total output rating of the auxiliary transformers, and 51 cfm per kVA of the total output rating of the uninterrupted power system. When it is determined that a combined switchboard room has only essential loads, reference Section 13.7.4.1.3, provide 8 cfm per kVA for only 50% of the combined total output rating of the two main transformers. If the switchgear and transformers are located in separate rooms, the air shall be distributed in proportion to the load in each room. Transfer of air from one room to the other is not allowed. Provide tight fitting, weatherstripped doors with no undercuts on underground AC Switchboard Rooms.

- A special consideration shall be given for control of humidity in the room.

14 .4.2.2 DC Breaker Rooms (Tie Breaker Station)

Below Grade

Supply: ~~Provide~~ Ventilation shall be designed to maintain eight air changes per hour. Provide a H-0-A switch. Air shall be drawn from and discharged to a point outside of the subway unless otherwise approved by the Authority, filtered, and discharged into the breaker room so as to maintain a positive pressure not exceeding 0.1"WG within the room. Provide tight fitting, weatherstripped doors with no undercuts. Fan will be operated by thermostat to maintain room temperature of 90°F.

Surface

Supply: ~~Provide~~ Ventilation shall be designed to maintain eight air changes per hour. Maintain positive pressure not exceeding 0.1" WG within the room. Filtering of air not required unless special conditions exist.

14 .4.2.3 Battery Rooms

To the extent practicable ventilation design shall take advantage of passive ventilation to maintain the hydrogen concentration level below 1% and comply with applicable code requirements. Where passive ventilation is not applicable, mechanical ventilation shall be used to maintain the concentration level below 1%. Redundant ventilation shall be provided. Rooms to be mechanically ventilated at temperatures above 77°F. ~~Exhaust: 18 Air Changes Per Hour.~~

~~Exhaust system shall be operated continuously. Air shall be drawn from adjacent AC Switchboard Rooms and discharged to a point outside of the subway unless otherwise approved by the Authority. Additional filtering is not required.~~ Provide tight fitting, weatherstripped doors with no undercuts on underground Battery Rooms.

Suspended ceilings are not allowed. Battery Rooms shall be under negative pressure not to exceed 0.1"WG. Battery rooms dependent on mechanical ventilation require remote monitoring by OCC for failure of one of the redundant fans. Local building codes may require monitoring of hydrogen levels. Hydrogen monitoring is not preferred because it requires regular sensor calibration and replacement.

14 .4.2.4 Train Control, Communications, Dispatch and Trainmen's Rooms

Provide air conditioning with 0.3 CFM of filtered, outside air per square foot of floor area to maintain 72°F during the cooling season.

Heat loads from internal electrical components and lighting in Train control rooms and Communications rooms shall be calculated based on the equipment used in those rooms. Equipment efficiency has increased but so has the amount of equipment now used in these rooms. Design should be based on actual load. Provide a basis for assumed loads. ~~has 8,000 watts of internal electrical heat load, plus a lighting load of 4 watts per square foot. Communication Room has 6,000 watts of internal electrical heat load plus a lighting load of 4 watts per square foot.~~ Train Control and Communications Rooms doors shall be tight fitting with no undercutting for relief air. Relief venting of these rooms shall be accomplished by means of adjustable, motorized dampers. Dampers shall be sized at 1100 feet per minute to maintain slight positive pressure in the rooms.

14 .4.2.5 Maintenance Rooms

Exhaust: 10 Air Changes Per Hour

14 .4.2.6 Station Attendant's Kiosk

Air conditioning and air filtration will be provided in the Kiosk to maintain 72°F.

14 .4.2.7 Washrooms, Cleaners' Rooms, and Sewage Ejector Rooms

Exhaust: 2-1/2 CFM per square foot of floor area, exhausted to outside where possible. If not practical, exhaust to subway running tunnel remote from public areas and on same side as trains leaving the station.

14 .4.2.8 Underground Traction Power Substations

Supply air for ventilation and heat dissipation shall be drawn from ground surface area and not from tunnel. Supply air shall be introduced by two 25,000 cfm fans operating in parallel. Fan operation shall be by a two step ~~thermostat~~ controller set to operate one fan when ambient substation temperature exceeds 85°F and turn off temperature reaches 80°F. The second fan shall operate upon a temperature of 90~~100~~°F ambient and turn off when temperature reaches 80°F . An alternator circuit shall be included to

ensure that each fan is exercised equally. Manual control of fans shall be provided to permit usage when substation is occupied by maintenance personnel. The controller shall be capable of remote monitoring over the Ethernet using Modbus communication protocols.

The air volume given above is based on a 9 megawatts total transformer capacity. In cases where a non-standard substation is planned, the total ventilation air flow rate shall be based on the following:

$$FlowRate(cfm) = (0.02 \times Transformerrating(Kw) \times 3413)/(1.08 \times 11(degreesFahrenheit))$$

Two fans shall be provided with each fan sized for one half of the calculated total air flow rate.

High efficiency, pleated ~~bag~~ type filters shall be provided.

Air shall be supplied to the substation, directed past the major equipment and relieved through ventilation shafts to the ground surface. Ductwork shall be minimized and shall not be run over electrical equipment. Air velocity through relief shafts shall not exceed 500 fpm. A slight positive pressure (not to exceed 0.1 inches water gage) shall be maintained within the substation to reduce infiltration of dust.

14 .4.2.9 Aboveground Traction Power Substations

Above ground substations are normally arranged with rectifier transformers located outside the substation building. Where substations must be located at grade with rectifier transformers within the building, they are to be treated as underground substations for ventilation requirements

Aboveground substations shall be ventilated with outside air brought in by a single 12,000 cfm fan, ~~thermostatically controlled~~ using a programmable logic controller to operate when room temperature exceeds 85~~80~~°Fand turn off when temperature reaches 80°F. Manual control of fans shall be provided to permit usage when substation is occupied by maintenance personnel. The controller shall be capable of remote monitoring over the Ethernet using Modbus communication protocols.

Air intakes shall be located to minimize introduction of dirt or gaseous exhaust fumes into the substation with pleated filtration provided. A slight positive pressure (not to exceed 0.1 inches water gage) shall be maintained within the substation to reduce infiltration of dust.

14 .4.2.10 Elevator Machine Rooms - See Section 14.17.5.1.

14 .4.2.11 Operations Rooms, Police Service Rooms and Dispatcher's Rooms

Provide air conditioning designed for two occupants and a lighting load of 4 watts per square foot. Provide manual on/off control. In the case of underground stations, use split system air conditioning units. Locate condensers in areas where exposure to track dust is minimized. Small

capacity, package type heat pumps or self contained air conditioning units are acceptable for use in isolated rooms above ground.

14 .4.2.12 Electric and telephone equipment rooms - no mechanical ventilation unless heat producing equipment, i.e. transformers, is to be installed in the room(s).

14 .4.2.13 Areas of Rescue Assistance and adjacent stairways - provide positive ventilation as defined in ADA and in accordance with local code. Bring supply air from outside the system to insure smoke free air.

14 .4.3 Ductwork Insulation

The following ductwork shall be insulated:

14 .4.3.1 Platform and mezzanine air conditioning supply ductwork.

14 .4.3.2 Ancillary area cooling supply and return ductwork, except ductwork in conditioned spaces.

14 .4.3.3 Ancillary area heating supply and return ductwork, except ductwork in heated spaces.

14 .4.3.4 Outside air intake ductwork.

14 .4.3.5 With the exception of Underplatform and dome exhaust fans, exhaust air ductwork between automatic damper on fan discharge and the exhaust louver.

14 .4.4 Access

Work platforms shall be provided for major mechanical equipment items mounted 8 feet or higher above the finish floor. ~~Access to work platforms less than 10 feet shall be by portable ladder.~~ Fixed ladders shall be provided to work platforms 10 feet or more in height.

14 .4.5 Control Sequence

Control sequences not included in the standard specifications shall be given on the contract drawings.

14 .5 HEATING

14 .5.1 General

All-heating equipment shall be electric ~~resistance type~~ unless specifically designated otherwise. Electric wall heaters, electric unit heaters, electric duct heaters or combination heat pump heating/cooling units may be employed as required by the application. Convective type electrical wall heaters are preferred to force-flow types provided units are available in the required capacity. Refer to Section D, "Secondary Ventilation Systems", for volume of air to be heated.

14 .5.2 Design Temperature

Electrical heating equipment shall be provided in the following locations for total heating requirements or to supplement the heating provided in the ventilation system. In general, maintain a temperature of 68°F to 72 °F in occupied rooms. In unoccupied rooms, maintain a temperature of 50°F but provide controls to allow

temperature to be raised to 68°F when occupied. The temperature controls shall have the ability to automatically reset to 50°F after 1 to 8 hours.

Design dry-bulb temperatures for each room are as follows:

14 .5.2.1 AC Switchboard Rooms (Below Ground): No heat required.

14 .5.2.2 AC Switchboard Rooms (Above Ground): Provide heat to maintain 50°F. Calculations of heating load shall include a deduction of 10,000 BTU. per hour for each 100 KVA of transformer capacity.

14 .5.2.3 D.C. Breaker Rooms / Tie Breaker Station - Below and above ground, provide heat to maintain ~~77~~50°F with the ability to raise the temperature to 68°F.

14 .5.2.4 Battery Rooms -~~Provide heating for underground battery rooms to maintain 77°F. Assume heat gain from the adjoining AC switchgear room equal to one percent of the rated capacity of the transformers in the switchboard room.~~ Above ground, provide heat to maintain ~~77~~ 50°F with the ability to raise the temperature to 68°F. Provide occupancy sensor to elevate temperature when occupied and to reduce temperature when unoccupied.

14 .5.2.5 Train Control and Communications Rooms-68°F.

14 .5.2.6 Dispatch, Operations, and Trainmen's Rooms-~~70~~68°F. Deductions shall not be made for internal loads in the computation of heating load.

14 .5.2.7 Above Ground Maintenance Rooms-~~60~~50°F, no heating is required in below ground maintenance rooms.

14 .5.2.8 Below Ground Traction Power Substation - no heat required provided that calculations show that electrical heat rejection is sufficient to maintain ~~77~~50°F.

14 .5.2.9 Above Ground Traction Power Substation-~~77~~50°F, provide thermostatically controlled, electric heat sufficient to maintain required temperature with the rectifier units inoperative.

14 .5.2.10 Station Attendant's Kiosks, ~~70~~68°F. Provide electric heat as a part of package air conditioning unit.

14 .5.2.11 Washrooms, ~~70~~68°F.

14 .5.2.12 Cleaner's Rooms and water service rooms, 50°F.

14 .5.2.13 Escalator wellway heating, 50°F.

14 .5.2.14 Elevator Machine Rooms (See Section 14.17.5.1), 50°F.

14 .5.2.15 Above Ground Electric rooms and mechanical rooms-~~60~~50°F, except no heating is required in below-ground rooms.

14 .5.2.16 All ancillary rooms with employees occupancy shall be maintained at ~~68~~50° F as per the International Mechanical code

14 .5.3 Heat Loss Parameters

Underground:

14 .5.3.1 One BTU. per square foot per hour loss to ground.

14 .5.3.2 Ambient temperature assumptions: 14°F outdoor, 30°F in tunnels and underground station platforms.

14 .5.4 Heating Equipment - Electrical Characteristics

See Section 13.7.5 for electrical characteristics. Verify that scheduled equipment is commercially available. All heating equipment shall be thermostatically controlled with automatic set back non-user adjustable. Remote monitoring shall be the normal configuration with exceptions when approved by the Authority. Control transformers shall be provided where required.

~~**14 .5.5 Special Systems**~~

~~Air curtains: Air curtain supply in patron areas to be tempered to a minimum of 50°F DB.~~

14 .6 AIR CONDITIONING OF UNDERGROUND STATIONS

14 .6.1 General

The air conditioning system shall be designed to provide localized cooling for passengers from the time of station entry until entering air conditioned trains.

Cooling will be accomplished by the following:

14 .6.1.1 Natural stratification and convection of air due to temperature differences.

14 .6.1.2 Distribution of conditioned air to cool passenger areas.

14 .6.1.3 The design and location of tunnel vent shafts, exhaust fans, and fan shafts to reduce the effect of train heat and piston action into the station. Temperature rise in stations due to heat generated in the tunnels will be reduced by the flow of air through these shafts.

14 .6.1.4 Heat transfer to the ground sink through the station walls.

14 .6.2 Design Factors

14 .6.2.1 Each station shall have 350 tons of refrigeration capacity unless otherwise directed by the Authority.

14 .6.2.2 Design temperature shall be 85°F Dry Bulb in passenger areas when outside air temperature is 91°F Dry Bulb and 74°F Wet Bulb.

14 .6.2.3 Air quantities shall be maximum feasible for cooling of the platform area and mezzanine area. The total air supply for the platform air conditioning shall be not less than 50,000 CFM.

14 .6.2.4 Coils are to be selected for maximum sensible cooling.

Underground station cooling is accomplished by a spot cooling system. This system is designed to cool only the occupied portions of the platform and mezzanine. The basis of the 350 refrigeration capacity is as follows:

14 .6.2.5 Passenger heat load 1,000 BTU/hr./person

On platforms 16 sq. ft. per person

On mezzanine and in ticketing areas 40 sq. ft. per person

14 .6.2.6 Lighting and miscellaneous power load - 3 watts per sq. ft. of pedestrian floor area plus motor load of escalators from mezzanines to platform. Motor heat is dissipated to mezzanine.

14 .6.2.7 Estimated heat gain due to entrainment of warm air to distribution air, 20% of loads 14.6.2.5 and 14.6.2.6.

14 .6.2.8 Estimated heat gain due loss into tunnels and station track areas, 20% of loads 14.6.2.5 and 14.6.2.6..

14 .6.3 Distribution of Conditioned Air

Air conditioning units shall supply conditioned air via supply air registers or pylons for localized cooling of the passenger areas. Supply air register size, locations, mounting height, throw, discharge velocity, and return grille locations shall be such as to provide proper air distribution. At side platform stations, supply air registers shall be located to discharge air horizontally at 9'0" above the finished floor and with sufficient throw to reach the edges of the platform and mezzanine. The supply grille face bars shall be horizontal.

In center platform stations, unless otherwise specifically indicated, distribution shall be provided by means of standardized air conditioning pylons 9'-0" in height, and ducts in escalator wellways. The maximum capacity of each pylon shall be 3,000 CFM. Mezzanines in center platform stations shall utilize either pylons or supply air registers.

Return air from platform areas shall be carried through the tunnels under platforms from return grilles which are incorporated into platform benches, escalator wellways or located on the station endwalls. For side platform stations, return air will be picked up at the back edge of the platforms. This method requires openings in platform parapet walls.

Ductwork serving elevator machine rooms within return air plenum spaces shall be fireproofed.

Intake air for mezzanine air conditioning units shall be taken from entrance passageways and shall be considered outside air.

14 .6.4 Air Conditioning units

There shall be four air conditioning units (A.C.U.) per station for side platform stations and two units per station for center platform station. There shall be one additional air conditioning unit for each mezzanine.

The mezzanine units shall be sized to handle 100% outside air. The units shall consist of filters, chilled water coils and a fan section. The air conditioning unit components shall comply with the following:

14 .6.4.1 Filters shall be of the high efficiency, ~~bag~~ pleated type.

14 .6.4.2 Water Coils

Water coils shall have a maximum face velocity of 550 fpm. Where water velocities less than 2 fps are encountered, a method of tribulation shall be provided.

Cooling coils shall be designed for water inlet temperatures of 43°F and outlet temperature of 55°F.

14 .6.4.3 Power Supply

In addition to air conditioning units, provide power for all associated controls and control devices.

14 .6.5 Underplatform Exhaust and Ceiling (Dome) Exhaust Fans

There shall be two fans, each with a capacity of 60,000 cfm, configured to exhaust air from the trackway through ducts located under the platforms of each underground station. These fans, designated "underplatform exhaust fans," shall be reversible, of the axial type, and capable of delivering 70% of the forward (i.e. exhaust) air volume in the reverse direction.

There shall be two additional fans, each with a capacity of 25,000 cfm, configured to exhaust air from the top of the station arch through a shaft terminating in the street. These fans, designated "dome exhaust fans," shall be reversible, of the vane axial type, and capable of delivering 70% of the forward (i.e. exhaust) air volume in the reverse direction.

14 .6.6 Duct System

Duct sizes shall be selected on the basis of a maximum constant air pressure drop of 0.15 inches of water per 100' and a maximum air velocity of 2,400 fpm.

High pressure ductwork shall be provided regardless of air velocity, for systems with a static pressure in ducts above six inches water gauge pressure loss.

Medium pressure ductwork shall be provided on all air supply ducts for the station platform and mezzanine areas, regardless of air velocity, where the duct static pressure is more than two inches and does not exceed six inches water gauge pressure loss.

Low pressure ductwork (SMACNA Duct Construction Standards) shall be provided on all air supply and return ducts, regardless of air velocity, where the duct static pressure does not exceed two inches water gauge pressure loss.

Supply air ductwork encased in concrete shall be constructed of materials which meet structural requirements and shall be adequately braced. See Standard Specifications. Return and exhaust air passages may be constructed as for supply air or of smooth concrete or masonry.

Asbestos cement pipe shall not be used for ductwork.

14 .6.7 Chilled Water Plants

Chilled water plants shall be located to supply one passenger station. Locations of this shall be selected by the designer with the approval of the authority. As required by ASHRAE - 15-1992, chilled water plants shall be provided with refrigerant sensors specifically designed for HFC 134a. Upon detection of a refrigerant leak, the monitor shall actuate an alarm and start mechanical ventilation in a purge cycle. Chilled water plant ventilation shall be designed to satisfy ~~normal and~~ purge ventilation flow rates. ~~The normal ventilation requirements shall be determined on basis of providing a minimum flow rate of 0.5 cfm per square foot. The Designer shall identify the heat sources located within the chilled water plant and increase the normal ventilation rate to reduce excessive temperature rises within the space.~~ The purge ventilation rate shall be based on the refrigerant mass in the system The Designer shall identify the heat sources located within the chilled water plant and provide cooling to maintain 76°F. The chiller plant shall be treated as unoccupied space during winter months maintain 50°F with ability to raise temperature to 68°F. Each plant shall include the following basic components.

14 .6.7.1 Water Chillers

Water chillers shall be of the oil free centrifugal type with motor compressor, evaporator, condenser, electronic control panel including sensors, safety devices, limit control and accessories. Capacity calculations and performance specification of chillers shall be approved by the Authority.

Units shall be factory packaged, charged and tested. Chilled water shall be cooled from 55°F in, to 42°F out, with condenser water temperatures of 85°F in, to 95°F out.

Chillers shall utilize refrigerant 134a.

14 .6.7.2 Chilled Water and Condenser Water Pumps

Chilled water and condenser water pumps shall be of the centrifugal, split case, flexible coupling, mechanical seal and base-mounted type. Pumps shall comply with the following:

Maximum pump motor speed	1750 rpm
Full Load Efficiency for Station Chiller ~~Operating efficiency~~	0.47 kW/ton ~~within 5% of maximum efficiency~~
Integrated Part Load Value For variable load situations	0.38
Motor selection	non-overloading, high efficiency type

Chilled water and condenser water shall be chemically treated to prolong the life and efficiency of the systems.

If directed by the Authority, provide stand-by chilled water and condenser water pumps.

14 .6.7.3 Cooling Tower

Cooling towers shall be counter-flow, blow-through design with vertical air discharge. The following shall be the basis of selection.

Ambient air wet-bulb temperature	79°F
Entering water temperature	95°F
Leaving water temperature	85°F
Water flow rate	3 GPM per ton
Make up water rate	l.5% of total condenser water flow
Bleed off rate	0.3% of total condenser water flow design safety factor--10 percent of tower load

The make-up water and bleed off lines shall be designed to meet the sewer charge exemption requirements of the local authorities having jurisdiction. The Designer shall verify the requirements given below and include in his design any changes and/or additional requirements. For any deviations from such requirements, prior permission of the authorities having jurisdiction will be required.

14 .6.7.3.1 Water Meters

Make-up and blow down meters shall be remotely monitored by the Chiller Plant Control Panel. The intent is to provide remote monitoring and alarm based on these inputs.

14 .6.7.4 District of Columbia

14 .6.7.4.1 The make-up water line shall have a separate water meter with a valved bypass around the meter, equal to the size of the line. Make-up water line and meter shall be protected against any possible freeze up.

14 .6.7.4.2 All meters shall register in 'gallons'.

14 .6.7.4.3 All meters must be installed three feet above the floor and must be easily accessible to the meter reader.

14 .6.7.4.4 The bleed off line shall have a strainer and water meter without any bypass around the meter.

14 .6.7.4.5 The bleed off water shall be discharged into the sanitary sewer system.

14 .6.7.4.6 No other connections between make-up water meter and the float valve controlling make-up water shall be permitted.

14 .6.7.5 Arlington County

14 .6.7.5.1 The make-up water line shall have a separate water meter. No bypass line is permitted around the meter. The make-up water meter and line shall be protected against any possible freeze up.

14 .6.7.5.2 The water meter shall register in gallons.

14 .6.7.5.3 bleed off shall not be discharged into the sanitary sewer system.

14 .6.7.5.4 The meter and service connection shall be installed in the public right-of-way immediately adjacent to the water main serving the property.

14 .6.7.6 Maryland (Washington Suburban Sanitary Commission)

14 .6.7.6.1 The make-up water line shall have a separate water meter. For water meters one inch and over in size, a bypass line with valves shall be provided. The make-up water line and meter shall be protected against any possible freeze up.

14 .6.7.6.2 WSSC will supply and install all meters 1-1/2 inch or less and supply all meters over 1-1/2 inches.

14 .6.7.6.3 Meters shall be installed in areas where they are easily accessible to the meter reader.

14 .6.7.6.4 The bleed off from the tower shall be discharged into the storm sewer.

14 .6.7.6.5 Cooling tower shall be located at grade or on roof. But shall not be located under ground.

Sound attenuation shall be provided to bring the noise levels from cooling towers to within NC 45 in business districts and NC 35 in residential neighborhoods. Reference points, however, shall be established 30 feet from the cooling towers or cooling towers enclosures. If buildings or activities are closer, the reference point shall be at the closer point.

14 .6.7.7 Motor Control Center

Each chilled water plant shall have a motor control center. Characteristics of motors and starters shall be determined by power availability at each location. See Section 13.7.5.

14 .6.7.8 Freeze Protection

Ethylene glycol ~~or other antifreeze~~ shall not be used. Other antifreeze products may be approved by the Authority on a case by case basis.

14 .6.7.9 Chilled water lines shall be arranged to permit convenient drainage of all, or portions of the water system. Heat tracing shall be provided for chilled and

condenser water piping exposed to outside air with the exception of those portions of condenser water piping which are drained during cold weather.

Where burial of chilled water piping is required, burial depth shall be a minimum 2'-6" below grade and the pipe shall be encased in conduit with the following requirements.

14 .6.7.9.1 Leakplates - To provide an effective moisture barrier, conduits shall be equipped with leakplates in building or manhole walls - but only when there is an anchor plate within 5 feet outside the wall. Leakplates shall consist of a steel plate flange 4" larger in outside diameter than the conduit, welded to the conduit only and located in the wall approximately 6" from the end of the conduit. Wall sleeves are recommended where anchor plates are not available within 5 feet.

14 .6.7.9.2 Anchors - Prefabricated plate anchors shall be furnished and installed where shown on plans and shall consist of a steel plate, welded to pipe and conduit. The steel plate shall be 3/8" thick for 6-5/8" to 10-3/4" conduit, ½" thick for 12-3/4" to 22" conduit, and 3/4" thick for conduit over 22". A concrete block shall be cast over the plate and conduit shall be as shown for firm anchorage into undisturbed trench sidewalls and/or bottom. The concrete block to be at least 30" in length and extend a: minimum of 9" beyond the top and bottom of the anchor plate.

14 .6.7.9.3 End and Gland Seals - Terminal ends of conduits inside manholes, pits, or building walls shall be equipped with end seals consisting of a steel bulk head plate welded to the pipe and conduit. Where there is no anchor within twenty feet of a terminal end, conduits shall be equipped with gland seals consisting of a packed stuffing box and gland follower mounted on a steel plate welded to the end of the conduit. Gland seals shall only be used if it is not possible to install an end seal. All conduits shall be terminated 2" beyond the inside face of manhole or building walls to protect any exposed piping insulation from damp-wall condensation.

14 .6.7.9.4 Aggregate for subgrade foundations shall be provided in accordance with the Standard Specification.

14 .6.8 Station Air Conditioning System Operation

The under-platform exhaust fan(s) will start when the platform temperature rises above 70°F DB. The under-platform exhaust fans shall be capable of being reversed manually from the Control Center, with a local override, to supply fresh air to the track area.

The platform and mezzanine air conditioning unit fans will start when the respective space temperatures rise above 80°F DB. A thermostat set at 85°F will open and close the chilled water coil control valve.

The chilled water pumps will be capable of being started locally ~~or by a remote manual switch at the Remote Terminal Unit (RTU).~~ The chilled water aquastat will start the chiller and, through interlocks, will start the condenser water pump. The chiller, by means of flow switches, will be prevented from operating if chilled and condenser water flow have not been established. When chiller is started, the

chilled water aquastat maintains chilled water temperature ~~by modulating compressor inlet vane damper~~. When the condenser water pumps is operating, a condenser water aquastat will ~~cycle~~ modulate the variable speed cooling tower fans to maintain condenser water temperature. A ~~thermostat~~ temperature sensor located in the subway near tunnel exhaust fan shafts will be monitored by a controller and open vent shaft, fan shaft by-pass dampers and fan shaft dampers when temperature rises above 50°F.

Tunnel exhaust fans, jet fans and their corresponding vent shaft dampers can ~~also~~ be controlled remotely from Operations Control Center (OCC) to clear smoke from the tunnels. The modes available during smoke control are "emergency on" and "emergency off". During the "emergency on" mode, the tunnel ventilation fans may operate in either the forward or reverse mode with the vent shaft dampers closed. The forward and reverse modes of fans in adjacent fan shafts or adjoining tunnels can be used in combination to achieve controlled air movement. "Emergency off" turns the fans off. The fail-safe mode for the vent shaft dampers is closed and for fan shaft dampers is open.

Local control panels shall be provided for all tunnel ventilation fans and shall be equipped with selector switches for "automatic" and “emergency-exhaust (forward in the case of jet fans)" and "emergency- supply (reverse in the case of jet fans)". The latter two modes override the Supervisory Control Console at OCC. Actual fan operations shall be monitored by pressure sensors at fan outlets and shall be annunciated at OCC.

System control shall be provided by a pneumatic system in legacy systems and electronically in new or rehabilitated systems. In addition to pneumatic controls, the tunnel ventilation fans shall be provided with redundant electric control to permit, in the event of control air failure, control locally or from OCC. Compressed air for individual passenger stations, subway ventilation and chilled water plant shall be provided by a duplex compressor at each chilled water plant. A desiccant dryer shall be provided to lower the main compressed air dew point below minus 10°F at 80 psi. Compressed air shall be supplied through a filter and reducing stations to maintain 20 psig. main air pressure at controls. Each station air conditioning control system, exclusive of the chiller plant, requires one cfm of air when measured at standard atmospheric pressure. When a train station is more than 500 feet from the chiller plant compressor, the air shall be available at the first control location at a minimum of 86 psig and then reduced. Installation of a compressor closer to the point of use should be evaluated. Maintenance of compressed air lines in the roadway have limited available access for leak detection and repair.

14 .6.9 Under-platform Exhaust Supply/Air System

Portions of the heat generated by the car braking resistor-grids beneath cars shall be removed, as hot air, from the station before it can enter the station environment. The hot air shall be exhausted to grade through an interconnected under-platform duct, fan system and fan shaft at each end of the station. The fan shaft and gratings shall conform to "Fan Shaft" criteria. The air passages beneath the platform shall. be constructed of smooth concrete. The under-platform exhaust fan shall be reversible so that the fan can be operated in either a supply or exhaust mode, with exhaust mode being normal. Local control panel shall be provided for under-platform exhaust fans which shall have selector switches for "automatic," "emergency exhaust," and "emergency supply."

The under-platform exhaust air passages beneath the platform shall have minimum dimensions of 5'-0" wide by 3'-6" deep unless approved otherwise by the Authority. There shall be 80 standard exhaust ports under the platform. Each port shall be provided with air balancing dampers.

14 .6.10 Ductwork Insulation

Indicate on design drawings by means of symbols and/or notes, all ductwork to be insulated. If simpler and more clear, ductwork not to be insulated may be indicated instead. Following ductwork to be insulated:

14 .6.10.1 Outside air intake ductwork

14 .6.10.2 Supply air ductwork for platform and mezzanine air conditioning system

Ductwork for under-platform and dome ventilation systems is not to be insulated.

14 .6.11 Ceiling (Dome) Smoke Exhaust Fans

In addition to the underplatform exhaust system, two ceiling (dome) smoke exhaust fans shall be provided and equipped with reversible motors capable of being controlled from the Operations Control Center, with a local override. The exhaust shafts shall follow the same air discharge and equipment criteria as "Fans Shafts". The normal mode for these fans shall be exhaust. Fan intakes shall be located at nominal 1/4 and 3/4 points of station platform unless approved otherwise by the Authority. Fans and other related equipment shall have characteristics as listed below:

a. Volume	25,000 CFM in exhaust mode with delivery between 16,000 and 18,500 CFM in supply mode.
b. Type	Axial
c. Equipment	Dampers
d. Motor	Reversible type
e. Electrical characteristics	460 volts, 3 phase, 60 hertz. Essential power
f. Motor Control	Magnetic, across-the-line start, circuit breaker disconnect, magnetically operated overload protectors (thermal type will not be permitted), local manual on-off automatic selector switches. Remote control and indication and supervisory control from operations Control Center (OCC).
g. Dampers	Dampers open by thermostatic control, start of fan, or a remote signal from Operations Control Center. Assume fresh air for under- platform and dome exhaust systems make-up is brought into the station from the vent shafts. Disregard the entrance ways as sources of make-up air.

14 .6.12 Control Panel Location

Local control panels for under platform and dome exhaust fans shall be located adjacent to a mezzanine-level fire equipment cabinet.

14 .6.13 Access

Work platforms shall be provided for mechanical equipment items mounted 8 feet or higher above the finish floor. Access to work platforms shall be by fixed ladder.

14 .7 AIR CONDITIONING OF ANCILLARY SPACES

14 .7.1 General

Refer to "Secondary Ventilation Systems" for air conditioning requirements in the ancillary spaces.

In general, air conditioning shall be provided in rooms where personnel are stationed for extended periods of time or where equipment operation requires lower temperatures than can be provided by mechanical ventilation. Variation from this criteria must be approved by the Authority.

14 .7.2 Design Conditions

The following conditions shall be used in the selection of equipment and design of air conditioning systems.

Ambient summer design conditions:

Dry Bulb 91°F Wet Bulb 77°F

Design room conditions at peak load:

Dry Bulb 72°F

14 .7.3 Air Conditioning Equipment

Air conditioning equipment for ancillary spaces may be self-contained or split system type. For electrical characteristics, see Section 13.7.5. Thermostatic control shall be provided. Control voltage shall not exceed 120 volts.

14 .7.4 Air Filtration

Air filters shall be of the following types:

Under 5,000 cfm	-	Replaceable media
5,000 cfm and over	-	Primary - pleated ~~bag~~ type, 80-85% efficiency;
Prefilter	-	Replaceable media

14 .8 DRAINAGE

Typical details for the drainage system are shown on the Mechanical Design Drawings.

14 .8.1 General Requirements

Invert elevations and locating of drainage piping at each end of a contract shall be coordinated with related Designers. Elevations or locations of drainage facilities shall be determined by the Designer with approval of the Authority.

As far as practical, drainage shall be by gravity flow. Where sections are such that gravity outfalls cannot be provided, pumping stations shall be installed.

Surface drainage except for tunnel portals, decks, entrances, ventilation shafts, fan shafts and similar openings shall not be-collected in subway drainage systems except with specific approval of the Authority.

No sanitary drainage shall be permitted to enter the track drainage system. Surface ventilation openings, where feasible shall be located at a higher elevation than adjacent pavement and if that is not permitted adjacent pavement shall be sloped away from the openings to prevent flooding.

14 .8.2 Location of Drains

In train tunnel sections, manholes or drainage slot inlets shall be provided at maximum 350 foot centers.

In station sections manholes or drainage slot inlets shall be provided at maximum 120 foot centers. Manholes shall be located at the high ends of stations 15 feet before start of platform. The last manholes shall have a minimum distance of 15 feet from lower end of station platforms.

Drainage from the low point in each escalator pit and the spaces under the platforms including depressed areas under escalator and elevator pits shall be provided. Elevator and escalator pits shall be provided with high water alarm reporting to kiosk. Where walls divide the space under the platform, sleeves to allow drainage to escape to other inlets may be provided.

Cleanouts are required for each 90° bend and for each two 45° bends. In stations where low points cannot be drained by gravity, pumping shall be provided with the pumps located so as to be readily accessible. Drain more than one depression to a single sump where feasible.

14 .8.3 Drainage Fittings

The following fittings shall be used for drainage purposes

Description	Use
Manhole frame and Cover	Access to main track drain. Drainage inlet directly to main track drain.
Drain Inlet	Drainage inlet - connection to main track drain required.
Scupper Drain	Drain inlet from fan shafts, vent shafts, and escalator pits

Clean-Out	Access to drainage piping for clean-out purposes only

14 .8.4 Drainage Piping

The drainage piping for open track sections shall be concrete pipe selected in accordance with the flow requirements and depth of burial.

The drainage piping for subway sections shall be selected from the following:

Diameter (Inches)	Material	Use
4 and over	Service weight cast iron in soil pipe	Drain connection structural walls and floors
4 and over	Extra heavy cast iron soil pipe	Drain connections under floor slabs
6 and over	Polyvinylchloride (PVC), Polyethylene (PE), (Corrugated)	Branch in structural and underground
8 and over	Polyvinylchloride (PVC), Polyethylene (PE), (Corrugated)	Main track drain

14 .8.5 Drainage Volumes

The volumes of water to be handled by each drainage system shall be calculated as follows:

14 .8.5.1 Drainage for open areas other than decks, entrances, tunnel portals, ventilation shafts, fan shafts and similar openings draining into the subway drainage system shall be calculated by means of the formula:

$$Q = c * i * A$$

Where Q = Volume in cubic feet per second

A = Drainage area in acres

c = Coefficient of runoff,.

I = Intensity for 50 year frequency. From duration rainfall curves established by the local jurisdiction.

14 .8.5.2 **Drainage** for tunnels, tunnel portals, decks, entrances, ventilation shafts, fan shafts, and similar openings shall be calculated as follows:

14 .8.5.2.1 Underground Sections in Earth

Drainage for underground section in earth designed to exclude groundwater shall be based on the formula:

$$q=(a/14)+(L/500)$$

Where :

q = Volume, in gallons per minute

a = Horizontal projected area of all subway openings in square feet, i.e., station entrances, fan shafts, etc.

L = Linear feet of structure in the drainage system.

14 .8.5.2.2 Underground Sections in Rock

Drainage for underground sections in rock designed to collect groundwater in order to relieve hydrostatic pressure shall be based on the formula:

$$q=(a/14)+(L/50)$$

14 .8.6 Flow Formulas

Flow and velocity in drainage piping shall be calculated using Manning's formula.

$$V = k / n * R^{2/3} * \sqrt{S}$$

Where V = Cross section average velocity (ft/s)
k = conversion constant 1.486
n = Manning coefficient (see below)
R = Hydraulic radius (ft)
S = Slope of water surface or linear hydraulic head loss (ft/ft)

In the use of this formula, the following factors for "n" shall be used:

n = 0.015 for concrete pipe 24" diameter and less

n = 0.013 for concrete pipe over 24" in diameter

n = 0.016 for polyethylene corrugated pipe, 8" diameter or less

n = 0.017 for polyethylene corrugated pipe, over 8" diameter.

14 .8.7 Grades

The following minimum grades shall apply:

Pipe Diameter (Inches)	Minimum Grade
4	2.0% or 1/4" per foot
6	1.0% or 1/8" per foot

8	0.65%

For the design of main drains, the Designer should consider the economics of increasing the size of the drain to permit as close a correlation between drain profile and T/R profile as possible. Main drains should be designed in such a manner that the grades produce a minimum velocity of 2.5 feet per second with the pipe flowing 50% and 100% full.

14 .8.8 Plastic (PVC and PE) Piping

Plastic piping shall not be exposed in its installed position because it gives off toxic gases when it burns and is a source of fuel for a fire. The last two feet of drain pipe at exposed termination points shall be concrete, cast iron, vitrified clay pipe. Suitable adaptor fittings are to be provided for connections between different pipe materials.

Designer shall provide separate flow calculations for PE corrugated piping and shall clearly indicate on design drawings where larger size corrugated pipe (over PVC pipe) is required to meet design flows.

14 .8.9 Pumping Stations

Pumping stations shall be ~~of the submersible type completely assembled and tested at the factory~~ of the wet well/dry well with pump type.

The pumping stations shall be selected on the following basis:

Minimum Number of Pumps:	3
Pump Rating:	Each pump 100% of "Drainage Volume." 500 GPM minimum for pumps at low point. 150 GPM minimum for pumps above low point (interceptor pumps) in drainage system.
Pump Head:	To suit static and friction heads of each installation. Friction head calculated with two pumps operating
Pump Type:	Non clog submersible sewage type.
Check Valves:	Swing “non slamming” type with weighted outside arms.
Motor Selection:	Pumps to be operated with Variable Frequency Drives (VFDs) See Electrical Design Criteria
Meter:	All discharge to be metered ~~Required only for Drainage Pumping Stations in the District of Columbia to record discharge into the combined storm and sanitary sewer system.~~

Calculations for pump discharge piping pressure losses shall include an allowance for future deterioration of the interior surface of the piping, i.e., C=100 (Hazen - Williams Formula) or equivalent. Pressure calculations to include a factor of 10% to account for unforeseen losses.

Provide fire alarm and intrusion alarm detectors. See Section 27.2.3.7.

In determining pump head, an investigation of existing sewers shall be made. If the sewer is liable to be overcharged, the pump discharge head shall be increased to exceed the overcharge head.

Pumping stations shall discharge into sanitary or combined sanitary/storm sewers only upon specific approval by the Authority. The designer shall design a system to treat pump discharge to meet federal, state and local regulations. The discharge water will likely contain the following requirements; PH range 6.0-8.5, total suspended solids 30mg/liter, oil and grease 30mg/liter. For the specific requirement, the designer shall consult with the respective regulatory authorities .In addition to the basic criteria for package units, the station utilizing submersibles shall conform to the following:

14 .8.9.1 The pumping station shall consist of a wet and dry well, with the submersible pumps housed in the dry well. The wet well shall be sized such that volume allows the pumps to operate without short cycling less than three runs per hour. Pumping system to be designed so that pumps still operate if the drywell is flooded with water. Piping to have valves so that pumps can be isolated for service without taking the pumping station off line.

On stations where no dry well exists, pumps are to located in the wet well on stainless steel guide rail connection assemblies which allow pumps to be installed and removed without entering the wet well.

Provide an enclosed pump room heated as required to maintain a minimum room temperature of 50°F and ventilated to provide 10 air changes per hour when room temperatures exceeds 90°F. Walls and doors must be able to withstand reversing transient air pressures to 70 psf where required by structural design criteria. Access is to be provided from the tunnel section. For stations of 1000 GPM or more, access will be provided from the surface if the station is not located with or adjacent to another means of access. . Dry wells and wet wells where no dry well exists shall be provided with ladder access and covered with grating. Grating to be corrosion resistant and in sections to allow for one or two person removal. Float tree, sonar mounting, etc to be stainless and accomplished above pit in order to eliminate confined space requirements.

14 .8.9.2 Pumps are to be supported independent of discharge piping. Pumps to be located on concrete pads or stainless steel support frames secured with stainless steel fasteners.

14 .8.9.3 Discharge line to be fixed, ductile iron with quick-connection coupling to pumps.

14 .8.9.4 Pumps to discharge to a redundant piping system (dual pipes) to discharge. ~~common header with a single discharge line from station~~ Existing pumping stations where single discharge pipes are inaccessible/embedded does not apply.

14 .8.9.5 Provide permanent provisions for removal and installation of pumps, including overhead hoisting system. Lifting/hoisting provisions to be clearly marked and identified with rated lifting capacity.

14 .8.9.6 Pump motors to be controlled with VFDs in order to allow the pumps to operate at lower more economical speeds and eliminate short run times which can be detrimental to the pump and electrical system. The VFDs shall be programmed to provide a flushing velocity at the start of each pumping cycle. Pump controls to be PLC type with ultrasonic level monitor to provide start/stop control with automatic alternation of pumps through an alternate duty assist algorithm after each pumping cycle. The control interface is to be through a Human Machine Interface (HMI) with ~~e~~Ethernet communication for remote monitoring and e-mail server for alarm notification The controller shall record the number of pump starts, pump run time, volume discharged and pump efficiency. It shall also be capable of performing the following functions:

1. Fluid level monitor
2. Space available monitor
3. Differential level monitor
4. Volume totalizer

14 .8.9.7 Electrical equipment to be in NEMA 4 dust-tight enclosures and installed at least 18 inches above the pump room floor.

~~Third pump shall be permanent stand by for manual use by maintenance staff.~~

Where a great difference exists between estimated normal drainage flow and that expected under 50-year storm conditions, the Designer should augment the pumps sized for normal conditions, with additional pumps as required to meet maximum emergency predicted conditions. Designer to submit his recommendation, with back-up calculations, to the Authority for approval prior to proceeding with the pump station design.

14 .9 GRATINGS

The following grating types shall be adopted as standards for use in this project.

14 .9.1 Light Loading

14 .9.1.1 For general use below grade

Design loading	250 p.s.f uniform loading.
Maximum allowable deflection	1/200 span
Maximum spacing of bearing bars	1 3/16" centers
Type bearing bars	serrated, rectangular

14 .9.1.2 For walkways, shaft opening, etc. at surface subject to pedestrian traffic but not vehicular traffic.

Design loading	250 p.s.f. uniform loading

Maximum allowable deflection	1/300 span
Maximum spacing of bearing bars	1 3/16" centers
Type bearing bars	plain, rectangular

14 .9.2 Heavy Loading

14 .9.2.1 For gratings subject to vehicular traffic

Design loading	AASHTO HS20-44
Maximum allowable deflection	1/300 span
Maximum spacing of bearing bars	1 3/16" centers
Type bearing bars	plain, rectangular

Gratings located in accessible areas shall be placed so that the long dimension is perpendicular to the dominant direction of travel and openings shall be no greater than ½ inch in the direction of dominant travel.

The Designer shall ensure that emergency egress hatches are not located in areas subject to vehicular traffic. Where it is not possible to avoid this, bollards or other means of preventing a vehicle from driving over a hatch shall be provided.

14 .10 EMERGENCY ACCESS/EGRESS SHAFTS

Access shall be provided to the subway at maximum 2500 foot centers so that no point in the subway system shall be over 1250 feet from a point of access or egress and in compliance with NFPA 130 Standards.

Where stations are over 2500 feet apart, intermediate emergency access shafts shall be provided. These shafts may be combined with fan or vent shafts with the approval of the authority. Refer to the Mechanical Design Drawings for typical emergency access shaft details.

For single entrance stations, the vent shaft at the end of the station farthest from platform escalator landings shall be an emergency access shaft.

Access shaft stairways shall be of the serrated grating type having the following characteristics and in accordance with NFPA 130 and IBC Standards:

Provide rise and tread widths as required by local code 48" overall width (two exit units)

Hatches for access shafts shall be in accordance with mechanical standard drawings. Hatch loadings (250 PSF) shall be indicated on drawings. Exit hatches shall be equipped with hardware and latches of readily opened from side of exit.

Hatches shall be readily opened from the outside by authorized personnel. Continuous handrails shall be provided in access shaft passageways as well as on stairways. Where locks are required, they shall be provided with panic hardware.

Where access shafts are not combined with fan or vent shafts, enclose the top flight of stairs leading to the surface hatch and provide a partition, complete with door, across the

landing at the foot of this flight of stairs. The enclosure and partition are to be of non-combustible material and may be of openwork material, subject to its rejecting a 2-inch steel ball. The door is to be solid and equipped with a lock operated by a key on the outside and by panic hardware on the inside. If openwork material is used for the partition, provisions shall be made to assure that the panic hardware cannot be operated from the outside through the openings in the material.

14 .11 ESCALATORS

14 .11.1 General

Escalators shall be supplied and installed, complete with exterior balustrade lighting, heaters, maintenance lighting and 110-120 VAC duplex GFCI receptacles within the envelope of the escalator. The Designer shall design the space, structural supports, electric service and conduits for the installation of the escalators. Escalators shall be designed with the following parameters***:***

14 .11.1.1 Each escalator wellway shall have at least one stair plus the required amount of escalators, a minimum of 2 escalators and a stair 10' - 0" wide between, from the surface. The stair must be provided with code required handrails for safety.

14 .11.1.2 The maximum vertical rise for an escalator shall not exceed 30' - 0".

14 .11.1.3 A vertical escalator rise over 30' - 0" shall be designed with multiple escalator runs connected by landings between them.

14 .11.1.4 Landings between escalator runs shall have a minimum queuing distance of 40' - 0” measured from the balustrades.

14 .11.2 Codes and Regulations

Escalators shall as a minimum conform with requirements of the latest edition and any or supplements of the "American Standard Safety Code for Elevators, Dumbwaiters, Escalators, and Moving Walks A17.1" (ASME), Americans with Disabilities Act (ADA) and local related codes or shall exceed code requirements as defined in the WMATA Technical Provisions for Heavy Duty Escalators. Escalators shall be of the heavy-duty type, specifically designed to withstand the extreme patron traffic loads, environment, and potential for abuse associated with rapid transit installations. Heavy-duty escalators shall substantially exceed the operating (load carrying and braking) capacity and durability of commercial type escalators. Escalators shall have operating controls at both landings and skirt deflectors on both sides of the moving steps.

14 .11.3 Number of Escalators

The number of escalators installed at each location shall be as ***required*** by the authority.

14 .11.4 Width

All escalators shall be nominal 48" width units between balustrades as defined in the ANSI Code. The width of the finished opening shall be as shown on the Design Drawings. This width shall include the machine room and pit, where required.

14 .11.5 Rise

Escalators and escalator wellways shall be divided into the following classes based on vertical rise between working points:

a. Class A1 - Rise of 20'-0" or less
A2 - Rise of over 20'-0" to 24'-0"

b. Class B2 - Rise of over 24'-0" to 30'-0"

These classifications are based on an arbitrary definition purely for the Authority's convenience.

14 .11.6 Speeds

Escalator speeds for all escalators shall be 90 fpm. All escalators shall be equipped for inching during maintenance and inspection or a single maintenance speed adjustable between 0 and 120 fpm.

14 .11.7 Direction of Travel

All escalators shall be reversible.

14 .11.8 Angle of Inclination

Escalators shall be constructed at the standard 30° angle of inclination to horizontal in accordance with ASME A17.1. "Working points" (upper and lower) are intersections of this line with the finish floor elevations of the two levels.

14 .11.9 Flat Steps

The following minimum number of flat steps at the top and bottom of each escalator shall be provided:

Class A1 (Rise of 20'-0" or less) - 3 steps

Class A2 (Rise of over 20'-0" to 24'-0") - 3 steps

Class B2 (Rise of over 24'-0" to 30'-0") - 4 steps

14 .11.10 Dimensions

Design Drawings show the controlling structural dimensions for the installation of escalators. Escalators shall have a minimum headroom of 9'-0". The pit areas shall have a minimum clearance of 36" from the step to the end of the truss.

14 .11.11 Motors and Drive Mechanisms

The motors and drive mechanisms shall be installed within the truss or directly below and aligned with the respective units. Drive motors shall be high efficiency, total enclosed, fan cooled units with lubrication fittings installed. Drive motor controls shall be AC variable voltage, variable frequency electronic drives that run

the motor during both normal and maintenance operation. Sufficient wellway and equipment room spaces shall be provided for equipment placement to meet all applicable codes.

14 .11.12 Supports

There shall be no obstruction within the machine rooms or machine pits, such as supporting posts for the upper support beam, partitions, or piping. This area is reserved for the installation of controllers of various sizes and placements. Intermediate supports shall be provided for all escalators with over 18' vertical rise as shown on Design Drawings.

14 .11.13 Vertical and Horizontal Reactions

Escalator support structures shall be designed to develop the reactions given on Design Drawings. The entire reaction at a support shall be assumed uniformly distributed over a distance equal to the width of the escalator truss. Reactions given include an impact load of approximately 33% of the total live and dead loads, including escalator cladding. Reactions are based on equally-spaced supports. Where supports cannot be equally spaced, modified reactions may be calculated by the Design Engineer using a method approved by the Authority. In all cases, the number of supports for a given rise shall remain the same. Reactions for rises not given may be determined by linear interpolation. With the drive located inside the escalator truss, the chain pull "P" does not act on the supporting structure. The drive weight has been accounted for in the reactions. Prior to escalator installation, the escalator contractor shall furnish the Designer with actual reactions and shall check the support designs and certify that the supports are adequate.

14 .11.14 Structural Safety Factor

In the design of structural supports, a safety factor of five (5) shall be used to determine the allowable stresses in a structural material as a function of the ultimate strength of the material. This is in conformance with the requirement of the ASME A17.1 for trusses and all structural members.

14 .11.15 Electrical Supply

For electrical service to escalator pits, See Section 13.7.14.

14 .11.16 Controls

Non-proprietary micro-processor/PLC controllers shall be used. The controller shall provide a data port for communicating with WMATA's Remote Monitoring System (See Section 14.15). All escalators shall be equipped with a "fault display" to automatically register the operation of the escalator and activation of each safety device. The fault display shall be located on the controller cabinet door . The electronic controls shall operate in ambient temperatures from +32° F to +105°F and relative humidity of up to 95%.

14 .11.17 Controller Location and Pit Access

The escalator controller shall be located in a locked walk-in machine room at floor level under the escalator incline for easy access and suitable operating environment. In situations where this is not possible, a floor mounted locked cabinet within view of the escalator may be used.

The escalator contractor shall furnish and install an access hatch or removable panel in the upper and lower landing plates of each escalator. If a removable panel is furnished, it shall be of a size and weight that permits removal by one person without special lifting tools.

Maintenance access hatches and ship ladders shall be provided by the Designer at the upper landing of all Class A, B, and C escalator wellways, except for platform to mezzanine escalators in underground stations. In the case of platform to mezzanine escalators, furnish and install an access hatch or removable panel in the upper landing plates.

Maintenance access hatches locations shall be selected to minimize obstruction of passenger traffic. Hatches shall be located as close practicable to the machine room proper without being located above the projected area of the entire machine room floor. Landing and floor plates provided shall cover the entire area of the landings within the extremities of the truss supporting elements. The hatch to the escalator machine room will not be located in the escalator queuing area or any passenger walkway.

14 .11.18 Electrical Interlock

An interlock switch shall be provided on each folding/rolling gate at the mezzanine or passageway level of entrance escalators to prevent the escalators from operating if the folding gates are not fully open. The interlock switches shall be wired in series and shall be open when the switch contacts for the folding gate are not fully open. The wiring for the switches shall terminate in a junction box in the lower escalator pit. The escalator installation shall connect the escalator controls so as to stop the escalator when the contacts open.

14 .11.19 Weatherproofing

All escalators which extend to street level and are exposed to the weather shall have weatherproof features including but not limited to:

14 .11.19.1 Nonferrous or stainless steel exposed parts.

14 .11.19.2 Protective covers over electrical equipment.

14 .11.19.3 Snow-melting heaters along the length of the escalator units and escalator machinery rooms.

14 .11.19.4 Waterproof construction of electrical equipment.

14 .11.19.5 Balustrade skirt edges sealed against moisture.

14 .11.19.6 Canopy covers for exterior escalators in accordance with ANSI A17.1 shall be provided in the station contract. A construction sequence shall be provided to allow for escalator installation without obstruction from the cover.

14 .11.19.7 Weatherproof escalator truss, truss support beams and truss mounting angles

14 .11.19.8 Corrosion protection for escalator truss support beams and truss mounting angles.

14 .12 VIBRATION ISOLATION

14 .12.1 Vibration Isolation

Equipment producing vibrations shall be isolated from the structure by spring or rubber-in-shear vibration isolators. All pipe and ducts connected to equipment mounted on vibration isolators shall contain flexible connections or provisions made for vibration isolating type supports. Identify on drawings where vibration isolators are to be provided.

14 .12.2 Equipment Mountings

Equipment to be mounted on the floor shall be placed on reinforced concrete housekeeping pads. Minimum pad height shall be six inches, all equipment to be suspended from ceiling shall be provided with suspension type hangers consisting of combination of spring and neoprene in series.

14 .13 FIRE PROTECTION

14 .13.1 Fire Alarm System

Fire Alarm Systems shall be designed as per this section and communication Section 27.2.3.7 .

14 .13.2 Smoke and Fire Detection System

Detectors will be of the ionization type, combined rate of rise/fixed temperature type . Detectors will be designed to detect abnormal smoke densities, products of combustion or heat in station ancillary rooms, ducts of air conditioning systems, elevator machine rooms, and escalator pits. The detection system will be equipped with contacts which can perform the following functions:

14 .13.2.1 With the exception of underplatform exhaust fans, ceiling (dome) exhaust fans and tunnel ventilation fans, stop all air conditioning fan units and ventilation fans having a capacity in excess of 2000 cfm and battery room fans that serve or are located in the zone protected by activated detector.

Terminal boxes shall be located in mechanical equipment rooms and control wiring shall be run to nearest terminal box. Equipment schedules shall identify the units served by each terminal box.

14 .13.2.2 Stop all street entrance escalators moving contrary to the direction of exit travel when any fire detection or fire protection system in the station is activated. The Designer shall include conduit, embedded where necessary, from escalator control panel to nearest kiosk.

14 .13.3 Fire Department Standpipe System

The standpipe system is to be designed per the latest release of NFPA 14, design drawings to identify release.

14 .13.4 Fire Department Standpipe System in Subway (below ground) Stations

All underground stations are to have a wet standpipe system serving fire equipment cabinets and platforms, and the system shall be connected to the municipal water system. Fire line mains shall be not less than four inches in

diameter. A 2-1/2 inch angle hose valve shall be provided in each fire equipment cabinet and at 200-foot intervals under the platforms with a valve within 100 feet of each end of the platforms). Access to angle hose valves under the platforms) shall be through manholes marked "Standpipe." These manholes shall not open up into underplatform exhaust plenums. Provide fire water line ~~surveillance~~ valve at interface of building water service and fire line piping. Locate these valves so as to be readily accessible to fire department personnel and are to be clearly identified. Valve shall be OS & Y type locked in open position. ~~of indicating type and supervised with tamper switch. The switch shall be connected to the station fire alarm system as a separate zone.~~

Coordinate with local jurisdiction as to whether fire service (wet) is to be metered.

A fire department Siamese connection shall be located near each station entrance and within 100 feet of a vehicular access. The fire line piping between the fire department siamese connection and the wet standpipe shall normally be kept dry by use of a check valve with ball drip valve. Fire line piping shall not be embedded or encased in concrete and shall be located so as to be readily removed and replaced. In multi-platform level (cross-over) stations, each level is to be considered as a separate station insofar as standpipe systems are concerned, but the systems shall be interconnected with not less than 4-inch diameter line. Piping shall be galvanized steel, sch. 40 and sized ~~Size piping~~ to provide minimum flow of 500 GPM at 100 psig at farthest angle hose valve (on the hose side of the valve) based on 200 psig at the fire department Siamese connection, using C=120 ~~100~~ (Hazen - Williams Formula) for galvanized pipe ~~or equivalent~~. Pressure calculations to include a factor of 10% to account for unforeseen losses. Piping shall be pitched to allow for draining after use or testing.

If fire department Siamese connection is more than 15 feet above the ball drip check valve, a manual drain is also required on the upstream side of the check valve.

14 .13.5 Fire Department Standpipe System in Surface Stations

All surface stations to have a dry standpipe system serving fire equipment cabinets and station platforms. Fire line mains shall not be less than 4 inches in diameter.

A 2-1/2 inch angle hose valve shall be located at 200-foot intervals under the platforms with a valve within 100 feet of each end of the platforms. Access to these valves shall be through manholes marked "Standpipe".

A fire department Siamese connection shall be provided near each station entrance and within 100 feet of a vehicular access. If there is multi-level access to the station, provide additional fire department connections as required by fire authority having jurisdiction. These connections should be located such that fire hose between hydrant and the connection will not be subject to rail traffic. If necessary, extend connection across tracks. Piping shall be galvanized steel, sch. 40 and sized to provide minimum flow of 500 GPM at 100 psig at farthest angle hose valve(on the hose side of the valve) based on 200 psig at the fire department Siamese connection, using C=120 (Hazen - Williams Formula) for galvanized pipe. Pressure calculations to include a factor of 10% to account for unforeseen losses. Piping to be pitched to allow for draining after use or testing.

~~Fire department Siamese connection, fire lines and standpipes shall be pitched so as to be readily drainable after use or testing.~~

Neither thermal insulation nor heating tracers shall be used on fire department lines, valves, fittings, etc. ~~Size piping as for a wet system.~~

Provide high-capacity, automatic air release valves on main fire lines at end(s) of system opposite from fire department Siamese connections with sufficient capacity for air release time not to exceed three minutes.

Fire line piping shall not be embedded or encased in concrete and shall be located so as to be readily removed and replaced.~~(Pipe shall not be encased in concrete.)~~

14 .13.6 Fire Department Standpipe System in Vent Shafts, Fan Shafts and Rail Tunnel Areas.

All fan and vent shafts shall contain a dry standpipe system. This system shall consist of a fire department Siamese connection at the surface; a fire pipe line down the shaft; and fire pipe lines branching horizontally into the tunnel(s) in both directions to a point within 200 feet of the end of adjacent standpipe system(s). The fire department Siamese connection and fire pipe line mains shall be not less than 4 inches in diameter. The standpipe systems shall be designed for Class I service, i.e., for use by fire departments and those trained in handling heavy water streams in 2-1/2 inch hose, and a capacity of 500 GPM at 200 psig at the fire department Siamese connection with not less than 100 psig at the farthest angle ~~last~~ hose valve (on the hose side of the valve) at the end of the line, using C=120 ~~100~~ (Hazen - Williams Formula) for galvanized pipe. Pressure calculations to include a factor of 10% to account for unforeseen losses. When straight vertical runs of piping of 50 feet or more are required, special attention shall be given to the piping supports and or anchors at the base of these runs to assure the support is adequate for the piping under both static and flowing conditions. First horizontal support beyond the base of the vertical run is to be located as required by the loading but in no case more than five feet from the vertical run for six-inch pipe or six feet for four-inch pipe. To assure against possible violation of the maximum train car dynamic outline, the design shall include typical cross sections of each type of tunnel within the limits of the design contract. These cross sections shall reflect, as a minimum, the maximum dynamic outline of the car and the minimum clearance between this outline and the closest point of the standpipe system (refer to Section 8, Design Policies).

Fan/vent shafts terminating at the surface in an area where ~~accidental~~ vehicular traffic is possible shall have the fire department siamese connection located near a shaft wall just beneath the shaft grating so as to be readily accessible for connecting of fire hoses from outside the shaft. A plate identifying Siamese connection location is to be installed on the hatch leading to the connection. Fan/vent shafts terminating in areas not subject to pedestrian or vehicular traffic shall have the fire department Siamese connection extended above finish grade/grating to a height of between 18 and 36 inches. The design shall indicate sidewalk widths and location of tree space or boxes in the immediate vicinity of the fire department Siamese connection.

Fan/vent shafts terminating in an area subject to pedestrian traffic only shall have the fire department Siamese connection extended above finish grade unless the ~~as for areas not subject to pedestrian traffic, except that if the~~ connection ~~will greatly~~ obstructs pedestrian traffic.~~,~~ Otherwise locate connection ~~it shall be located~~ below grade as for an area subject to vehicular traffic.

A 2-1/2 inch angle hose valve shall be provided at the base of each shaft at track level and at not more than 200-foot intervals along the horizontal fire lines in the tunnels.

Fire lines are to be routed so that a clear head room of at least 6'-8" is provided along all paths of egress. Fire lines are not to encroach on stairways, ladders, etc., unless there is no practical alternative.

~~An in-line cut-off~~ A control valve shall be provided within the fan or vent shaft or in the cross over ~~adit~~ for each horizontal branch fire line extending into the tunnel(s) more than 200 feet.~~, except none~~ A valve is not required where only a single horizontal fire line is required. These valves shall be located so that they are accessible ~~from, but clear of, stairways and ladders and are also accessible~~ without entering the train tunnels (i.e. not on tunnel side of dampers or fans).

Automatic ball drip valves in addition to manual drain valves are to be provided at all low points in the system. Automatic air release valves are to be provided at the ends of each branch line, sized as follows:

14 .13.6.1 For tunnel standpipe branch lines of 1,000 feet or less, provide sufficient air release capacity to permit clearing the line to its furthest point in not more than three minutes.

14 .13.6.2 For tunnel standpipe branch lines over 1,000 feet, provide sufficient air release capacity to permit clearing the line to its furthest point in not more than five minutes.

All mechanical pipe joints shall be electrically bonded for stray current control (see Standard Drawings ST-E-301, ST-E-302, ST-E-303 and ST-E-304.).

14 .13.7 Fire Equipment Cabinets

Fire equipment cabinets shall be provided on the station mezzanine level and both platform ends of subway stations and on the station mezzanine level and one platform end of surface stations.

Each fire equipment cabinet shall ~~provide~~ be sized for:

14 .13.7.1 One 2-1/2 inch angle hose valve.

14 .13.7.2 Two ~~dry powder, stored pressure,~~ portable fire extinguishers, Type 10A

14 .13.7.3 One portable fire extinguisher, type 40B: C~~, suitable for use on Class A, B and C fires as defined by the National Fire Code, supplied and fitted by the Authority~~.

14 .13.7.4 Monitor Fire Equipment Cabinet from Fire Alarm Control Panel which is centrally monitored. ~~Fire equipment cabinet doors shall have intrusion detectors.~~

14 .13.8 Fire Protection for Escalators (Underground Stations)

All escalators shall be provided with a fire suppression system per NFPA 130 the ~~A fire suppression~~ system shall be provided within the truss space of exterior entrance escalators ~~where there is only one entrance to the station~~. The system is to discharge shall be designed in accordance with NFPA 13 ~~5 GPM/50 ft. of~~

~~wellway length~~ in each escalator wellway and will be furnished and installed by the contractor, including fire ~~water~~ line control. ~~surveillance valve. Water for this system may be from the wet standpipe system or from the domestic water system if it is sized to handle the sprinkler system, whichever is most feasible. Arrange system to ensure that the fire water line surveillance valve is located within a heated and lighted ancillary space.~~ Fire lines shall be galvanized steel sch. 40.

14 .13.9 Fire Extinguishers

Portable fire extinguishers~~, where required by fire code standards,~~ shall be of the dry powder, stored pressure type, Type 4A: 40B: C, suitable for use on Class A, B, and C fires; or alternate type consistent with the degree of hazard, except as follows:

Train Control, and selected Communications Rooms~~, Traction Power Substations and Tie Breaker Stations~~ -- Carbon dioxide or Clean Agent (CF_3CHFCF_3), 10B: C.

Fire extinguishers in traction power substations and A.C. switchboard rooms are to be located such that the maximum travel distance to any extinguisher will not exceed 50 feet. ~~Extinguisher locations are to be identified on the plans with extinguishers furnished and installed by the Authority.~~

14 .13.10 Fire Hydrants

~~Assure or provide~~ A fire hydrant shall be located within 100 feet of fire department Siamese connection~~,. within public right-of-way if possible, and in a~~ location shall ~~that will~~ not necessitate running fire hoses across a major or heavily-trafficked thoroughfare. ~~Advise the Authority if no hydrant exists within the 500 feet limit or if a hydrant is required to comply with access criteria.~~ Coordinate hydrant ~~specific~~ location with the local jurisdiction. Fire hydrants located in public right-of-way will be provided by the local jurisdiction. Water line of adequate size will be extended to the WMATA property line by the responsible jurisdiction.

14 .13.11 Fire Walls

The integrity of all fire walls shall be maintained at all penetrations of whatever sort, as for piping, conduits, ductwork, air intake, air exhaust or air relief openings, etc. Walls or floors that separate ancillary rooms from public areas or train tunnels shall be treated as fire rated; additionally, certain other walls may be designated fire wall in order to comply with applicable codes.

Fire dampers complying with the SMACNA Fire Damper Guide and all other applicable codes and standards shall be installed at all duct penetrations and at all other openings provided for the passage of air in fire walls except in the ductwork serving under platform exhaust system. The location of fire dampers shall be indicated on the contract drawings. Where fire dampers are installed in ducts, access panels will be provided to permit inspection and resetting of the fire dampers.

Where pipes or conduits penetrate a fire wall, the space between the sleeve and pipe or conduit shall be tightly packed with an approved noncombustible material of a rating equivalent to the wall or better. In all cases, there shall be full closure of the penetration in a manner as to preserve the fire rating of the fire wall.

14 .13.12 Fire Protection for Cleaner's Rooms, Toilet Rooms and All Ancillary Rooms Used for Operational/Office Areas

These rooms shall be provided with a sprinkler system for materials storage, NFPA ordinary hazard, Group 1. Sprinkler pipes are to be galvanized steel sch. 40. Use one ½" sprinkler head for floor area of 130 square feet or less and two or more sprinkler heads for greater area.

Sprinkler heads shall be uniformly located within the space, midway of the width of the room in cases where a single sprinkler head is required, and equally spaced where two or more sprinkler heads are required.

Sprinkler heads are to be of the fusible link type with temperature rating of 165 ^{0}F. An unmonitored OS&Y shut-off valve, a swing check valve and a flow detector switch are to be provided in the branch line to the sprinkler heads. OS&Y valve shall be easily accessible, be readily viewed from the room door, and sealed in the open position. A flow detector shall be located between the OS&Y valve and check valve. A ½" bronze angle hose valve is to be installed at the end of the sprinkler pipe. The flow switch is to be connected into the fire alarm circuit for the fire zone in which the room is located.

14 .13.13 Clean Agent Suppression Systems

Where fire suppression systems in ~~electrical~~ rooms with mission critical electrical equipment are required by the local jurisdiction or in rooms where the value of the asset warrants, Clean Agent (FM-200 / CF_3CHFCF_3) systems shall be provided in accordance with NFPA 2001 Standards and as follows:

~~**14.13.13.1** Each protected room shall be served by an independent system.~~

~~**14.13.13.2** Systems shall be sized on a 7% total flooding basis.~~

14 .13.13.1 Reserve supplies shall not be provided unless required by local jurisdiction.

14 .13.13.2 Clean Agent (FM-200 / CF_3CHFCF_3) storage shall be located near the protected room (storage may be in protected room if conditions make it necessary).

14 .13.13.3 Each system shall be cross zoned for activation ~~have a dual zone panel~~.

~~**14.13.13.4** Ionization detectors will be provided and transmit a zone 1/zone 2 signal to panel.~~

14 .13.13.4 Clean Agent System panel shall activate audible alarm, close dampers and shut off fan if either zone signal is received.

14 .13.13.5 When the second zone signal is received, Clean Agent System panel shall:

14 .13.13.5.1 Activate ~~second (different)~~ audible alarm.

14 .13.13.5.2 Start timer (O to 60 sec.).

14 .13.13.5.3 Discharge Clean Agent when timer times out.

14 .13.13.5.4 Activate "Clean Agent" visual alarm outside of each entrance to the room when Clean Agent is discharged.

~~**14.13.13.6** Clean Agent shall discharge in 10 sec. maximum.~~

14 .13.13.6 A manual by-pass fan switch shall be provided outside the protected room (for Fire Department use).

14 .13.13.7 ~~A~~ Provide a manual Clean Agent release switch for the fire department use only ~~shall be provided to function as if a zone 1/zone 2 signal had been received~~.

14 .13.13.8 Provide backup b~~B~~attery power ~~shall be provided~~ for the Clean Agent panel. Batteries shall be equipped with a trickle charger in accordance with NFPA 72.

14 .13.13.9 A remote reset switch shall be provided at a station supervising the system.

14 .13.13.10 Protected room doors shall swing out.

14 .13.13.11 Panic hardware shall be provided for protected room door latches.

14 .13.13.12 A standby clean agent storage tank connected to the system shall be provided where required by the local jurisdiction.

14 .13.13.13 In rooms where the equipment does not warrant a clean agent suppression system and a sprinkler system is not used due to the potential of leaks or faulty activation ruining equipment, a fire detection system shall be installed which is connected to a centrally monitored fire alarm control panel.

14 .14 PLUMBING

14 .14.1 Pipe and Fittings

14 .14.1.1 Soil pipe within the structure shall be pitched at 1/4" per foot, except soil pipe in invert running the length of the station shall be pitched at 1/8" per foot with one pipe size larger pipe.

14 .14.1.2 Domestic hot and cold water piping in the structure shall be copper tubing.

14 .14.1.3 Drainage pipe (for track drains and seepage drains) shall be perforated or un-perforated as required.

14 .14.1.4 Force mains shall be mechanical joint, ductile iron pipe.

14 .14.1.5 Pipe for water service entrance shall be ductile iron, mechanical joint.

14 .14.1.6 Floor drains in Mechanical Equipment rooms may be connected to the track drains without venting.

14 .14.1.7 Minimum waste pipe size underground or in structural slab shall be 2".

14 .14.1.8 Electrolytic separation shall be provided for dissimilar metals.

14 .14.1.9 Cathodic protection for buried pipe shall be provided as required.

14 .14.1.10 Unless otherwise approved by the Authority, water, sewer and drainage pipes shall not be run through electrical equipment spaces.

14 .14.2 Roughing-in

Sleeves shall be provided in the structure to accommodate plumbing installations. Sleeves shall be provided in structural walls for the extension of the force main from the sewage ejector. Piping shall be run as directly as possible. All piping shall be run parallel to and at right angles to walls and partitions. Multiple pipes shall be grouped in parallel lines.

14 .14.3 Water Service

14 .14.3.1 At least four (4) inch diameter water service connection shall be provided to each passenger station, except where the fire protection standpipe system, including fire equipment cabinet connections, is completely dry. In this case, size for domestic service requirements with a minimum service connection of two inches. Each domestic service shall have a main shut-off valve immediately inside the structure wall.

14 .14.3.2 ~~Required load, in GPM, shall be estimated from fixture unit values as follows:~~

~~Flush valve water closet~~	~~-~~	~~10~~
~~Flush valve urinal~~	~~-~~	~~5~~
~~Lavatory~~	~~-~~	~~2~~
~~Mop Service Basin~~	~~-~~	~~3~~

Fixture demand in GPM can be estimated from data in The ~~Model~~ International Plumbing Code, Washington Suburban Sanitary Commission Plumbing Code, or ~~BOCA Code~~ International Building Code (IBC), whichever is applicable.

The demand for outlets, (hose connections, cooling tower, make-up, etc.) which are likely to impose continuous demand, shall be estimated separately and added to the fixture demand GPM to determine the total demand.

14 .14.4 Hot Water Service

Hot water shall be supplied to all toilet and cleaner's rooms. Hot water shall be supplied by electric heaters. Heaters shall be installed at least six inches above floor. See Section 13.7.5 for electrical characteristics. Heater capacity shall be based on 100°F recovery and shall be sized in conformance with the fixtures installed which are to be served by the heater.

Provide relief valves in accordance with code requirements. Relief valve shall be piped to indirect waste.

Provide a reticulation system if supply piping is more than 100 feet long.

14 .14.5 Insulation and Freeze Protection

The following shall be insulated:

Water piping.

Portions of all water piping subject to freezing. Condenser water piping exposed to freezing temperatures shall be drained after the cooling

season. Any remaining exposed sections which are not drained shall be heat traced to prevent freezing.

Portions of drainage and cold water piping subject to sweating.

Hot water heater, if not factory insulated.

Where freeze protection is required, use electric heating cable.

14 .14.6 Plumbing Fixtures

Provide number and types of fixtures as required by the applicable local plumbing code. One set of fixtures and accessories in each men's and women's washrooms shall be suitable for use by the physically handicapped and in compliance with local codes and ADA.

Mop service basins shall be of the floor-mounted type.

Provide one electric water cooler per station in heated area such as ancillary space. Electric water coolers shall be wall-mounted and hand-operated and ADA compliant.

Water supplied to lavatories and flush valve fixtures shall have water shock absorbing provisions.

Vacuum breakers shall be installed on all outlets with hose bib connections and submerged inlets.

In addition to the features listed above, plumbing fixtures shall also meet the following requirements:

Lavatories:	Self closing outlet devices 0.5 GPM Outlet temperature, ~~110~~ 110 °F maximum Maximum hot water, 0.25 gallon/actuation
Showers:	3 GPM per shower head

All water supplies to fixtures shall have key operated service valves. Each connection shall carry the pressure recommended by the fixture manufacturer but not less than 15 psi for flush valves and 8 psi for other fixtures.

PLUMBING FIXTURE SCHEDULE

Symbol	Fixture	Soil or Waste	Trap	Vent	HW	CW	Remarks
WC	Water Closet	4"	Integral	2"	No	Yes	Wall hung
UR	Urinal	2"	Integral	1-1/2"	No	Yes	Wall hung
LAV	Lavatory	1-1/2"	1-14" x 1-1/2"	1-1/2"	Yes	Yes	Set on floor slab
MSB	Mop Service Basin	3"	3"	1-1/2"	Yes	Yes	Wall hung
EW/BS	Eye Wash (Fountain and Body Spray)	1-1/2"	*	*	No	Yes	Wall hung
EWC	Electric Water Cooler	1-1/2"	1-1/2"	1-1/2"	No	Yes	

* Required only where connected to sanitary sewer.

Minimum Fixture Supply Pipe Sizes

Flush Valve Water Closet	1"
Flush Valve Urinal	3/4"
Lavatory	3/8"
Mop Service Basin	½"
Hose Bib	3/4"
Eye Wash Fountain and Body Spray	½"
Electric Water Cooler	½"

Where city water pressure is above 60 psi at water service room, provide reducing valve assemblies consisting of reducing valve, three-valve bypass, and strainer.

Emergency eye wash and body spray facilities shall be provided in chilled water plants, battery rooms, traction power substations, tie breaker stations, car wash buildings, and in any other areas where corrosive materials are handled or stored. Portable eye wash and body spray facilities will be furnished and installed by the Authority; however, their locations are to be designated and a clear wall space of not less than 30" wide and 6'-0" high provided. Shields will be provided at both permanent and portable facility locations as required to protect electrical equipment from water spray. A minimum of 20 psi water flow pressure is to be provided to the permanent eye wash fountain and body wash facilities.

14 .14.7 Sewage Ejector Stations

Sewage Ejector stations shall utilize either sewage pumps or pneumatically operated pots.

14 .14.7.1 Pumping System

Sewage ejector pumping stations shall be of the duplex ~~triplex~~ type and utilize vertical dry pit sewage pumps. Each pump shall have a capacity of 100 percent of the design load, minimum capacity of 50 gpm, and a total dynamic head (TDH) to suit the location. ~~Dry pits shall be provided with ladder access and covered with grating.~~ A sump pit and pump shall be provided in the dry pit and shall discharge to the wet well. Wet wells shall be sealed and vented per local codes. Wet well access shall be through a gas tight manhole. ~~Each pump shall have a capacity of 100 percent of design load and as follows:~~ Sewage ejector pumping stations shall be controlled by a PLC with ModBus protocol, interfaced through a Human Machine Interface (HMI) with Ethernet communication for remote monitoring and e-mail server for alarm notification. Level detection shall be performed by ultrasonic level sensor with float switch backup. The pumps are to be cycled through an alternate duty assist algorithm. The controller shall record the number of pump starts, pump run time, volume discharge, and pump efficiency.

14 .14.7.2 Pneumatic System

Sewage ejectors pneumatic pumping stations shall consist of two stainless steel vessels/pots minimum 50 gallon capacity located in a dry pit. The vessels will be pneumatically operated to discharge sewage at a minimum of 50 gpm to the nearest sewer line with a total dynamic head (TDH) to suit the location. The system shall operate using two air compressors, an ASME air tank 200 gallon min., and a three way control valve. The dry pit shall contain a sump pit with a sump pump, pump to discharge into the incoming line on the vessel.

Pneumatic Sewage ejector stations shall be controlled by a PLC with ModBus protocol, interfaced through a Human Machine Interface (HMI) with Ethernet communication for remote monitoring and e-mail server for alarm notification. Level detection shall be performed by dual conductivity probes or sonar. The system shall operate by upon reaching a high level set point, the PLC will signal the three-way control valve to close off the tank vent and allow the stored air to fill the sewage receiver/pot and empty the contents. Receivers shall be regulated by a self contained pressure reducing valve. When the level reaches the lower level set point the three-way control valve shall close off the air supply and open the vent. The PLC shall allow only one receiver to be pressurized and discharged thereby allowing the other receiver to receive sewage from the system.

14 .14.7.3 Dry Pits

Dry pits shall be provided with ladder access and covered with grating. Grating to be in sections to allow for one or two person removal. Ceiling mounted hoisting apparatus such as hook, beam, etc to be provided for sewage equipment removal and installation, hoisting apparatus capacity to be

clearly identified. Float tree, sonar mounting, etc to be accomplished above pit in order to eliminate confined space requirements.

Electrical Characteristics — See Section 13.7

Ejector Discharge — Ejector discharge to the nearest sanitary or combined sewer shall be minimum four-(4) inch cast iron pressure pipe - mechanical joint. Discharge velocity shall be 2.5 feet per second minimum, 7 feet per second maximum.

~~Sewage ejector station controls shall utilize float switches such that the lead pump is energized after the lead pump float switch rises to the pump start position and de-energized after the pump off float switch falls to the off position. If the sewage level continues to rise after the lead pump is energized, additional float switches shall energize the first lag pump and a high level alarm. If sewage level still continues to rise, additional float switches shall energize the second lag pump and a second high level alarm. An alternator shall be provided to alternate lead and lag pumps after every cycle.~~

14 .15 AUTOMATED ENERGY MANAGEMENT SYSTEM

14 .15.1 General

The Automated Energy Management System (AEMS) utilizes Remote Terminal Units installed for transmission of data between field supervised and controlled facilities and a central location. Interface cabinets will connect field AEMS installation with Central Control Center thru RTU. Interface cabinets, accessories, sensors, transmitters, power supplies, instruments, piping and all interconnection wiring from each status, control and analog telemetry point to the AEMS interface cabinet shall be installed under station and line contracts. AEMS Interface panels shall be located in a manner which consolidates the greatest number of functions per cabinet and minimizes the total number of cabinets required.

AEMS status, control and analog telemetry points shall be in addition to the central control points identified as Data Transmission System (DTS) except for points associated with the Chiller Plant, which shall be connected only to the AEMS interface cabinet located in the Chiller Plant.

14 .15.2 Scope Station and Tunnel Sections

The AEMS shall provide the following functions in station and tunnel sections:

14 .15.2.1 ANALOG POINTS (4-20mA):

ACU Chilled Water Supply Temperature	DEG F
ACU Chilled Water Return Temperature	DEG F
ACU Chilled Water Flow	GPM
ACU Supply Air Temperature	DEG F
ACU Return Air Temperature	DEG F
Station Ambient Temperature	DEG F

14 .15.2.2 EQUIPMENT STATUS POINTS (Contact Closure):

ACU Fans	ON/OFF
Under Platform Exhaust Fans	ON/OFF
Dome Exhaust Fans	ON/OFF
Tunnel Ventilation Fans	ON/OFF
Unit Heaters, (larger than 10 kW)	ON/OFF
ACU Air Pressure Drop Across Filter	NORMAL/ ABNORMAL
ACU Air Pressure Drop Across Coil	NORMAL/ ABNORMAL

14 .15.2.3 HOA SWITCH STATUS POINTS (Contact Closure):

ACU Fans	AUTO/HAND
Unit Heaters (larger than 10 kW)	AUTO/HAND

14 .15.2.4 CONTROL POINTS (Contact Closure):

ACU Fans	ON/OFF
Unit Heaters (larger than 10 kW)	ON/OFF

14 .15.3 Scope Chilled Water Plants

The AEMS shall provide the following functions in chilled water plants:

14 .15.3.1 ANALOG POINTS (4-20mA):

Chiller Oil Temperature	DEG F
Chiller Chilled Water Supply Temperature	DEG F
Chiller Chilled Water Return Temperature	DEG F
Chiller Condenser Water Return Temperature	DEG F
Chiller Condenser Water Supply Temperature	DEG F
Chiller Chilled Water Flow	GPM
Chiller Refrigerant Purge Air Pressure	PSI
Chiller Condenser Refrigerant Pressure	PSI
Chiller Evaporator Refrigerant Pressure	PSI

	Chiller Condenser Water Flow Diff. Pressure	PSI
	Chiller Oil Pressure	PSI
	Outdoor Temperature	DEG F
	Outdoor Humidity	0 -100%
	Chiller kW Demand	KW
	Chiller Plant Space Temperature	DEG F
	Chiller Voltage	V
14 .15.3.2	STATUS POINTS (Contact Closure):	
	Chiller Motor	ON/OFF
	Condenser Water Pump	ON/OFF
	Chilled Water Pump	ON/OFF
	Cooling Tower Fan	ON/OFF
	Chiller Refrigerant Purge Air Pump	ON/OFF
	Chiller	NORMAL/ ABNORMAL
	Chiller Condenser Water Flow	NORMAL/ ABNORMAL
	Control Air Pressure	NORMAL/ ABNORMAL
	Chiller Plant Space Temperature	NORMAL/ ABNORMAL
	Condenser Water Pumps HOA Selector Switch	AUTO/HAND
	Chilled Water Pumps HOA Selector Switch	AUTO/HAND
	Cooling Tower Fans HOA Selector Switch	AUTO/HAND
14 .15.3.3	CONTROL POINTS (Contact Closure):	
	Chiller Motor	ON/OFF
	Condenser Water Pumps	ON/OFF
	Chilled Water Pumps	ON/OFF
	Cooling Tower Fans	ON/OFF
14 .15.3.4	ANALOG CONTROL POINTS (4-20mA):	

Chiller Demand Limiting	0 -100%
Chiller Chilled Water Temperature	DEG F

14 .15.3.5 PULSE ACCUMULATOR POINTS (Contact Closure):

Chiller Digital Power Meter	kWH

14 .16 SUPERVISORY CONTROL

14 .16.1 General

The Mechanical Supervisory Control System utilizes the Data Transmission System (DTS) installed by the Contractor / Train Control Sub Contractor for transmission of all data between field supervised and controlled facilities and the Command Center Room. The Central Supervisory Display and Control Console is also designed and installed under the Train Control stage contract. The design of the mechanical and train control systems must be closely coordinated, particularly with respect to interface details and locations.

14 .16.2 Scope

The mechanical systems shall be provided with remote surveillance and remote control capability. These systems shall be provided by the Contractor/Mechanical Sub Contractor with the specific items of electro mechanical equipment, as specified. The Contractor will furnish and install terminal strips in each AC Switchboard Room of every station, at each chilled water plant; and, if more than 300 feet from station limits including ancillary rooms, at each sewage ejector, at each drainage pumping station, at each tunnel fan shaft, and at each vent shaft if remote from the station, and jet fans in the tunnel sections. This terminal strip shall interface the mechanical work with the DTS. The Contractor/ Mechanical Sub Contractor shall provide connections from one side of the terminal strip to the equipment under surveillance or control and provide the necessary items including sensors, contactors, relays, analog to digital converters, external sinks, water level indicators and wiring to perform the indicated functions. The DTS functions shall be replicated and Ethernet communication be made available to the RTU for current and future transition to an Ethernet based system.

The contacts of the items connected to the DTS System shall be of the dry contact type which meets the requirements included in the Train Control and Mechanical Specifications.

The conditions which are measured and values transmitted shall be processed through analog-to-digital converters which shall transmit an updated seven-bit binary code signal to the appropriate terminals on signal from DTS for transmission to the control center.

The Remote Surveillance and Control Systems shall provide the following functions:

14 .16.2.1 The following items shall be remotely controlled from OCC:

Tunnel ventilation fans
Vent shaft dampers
Underplatform exhaust fans
Ceiling (dome) exhaust fans

Jet fans

14 .16.2.2 The following items shall be supervised and abnormal conditions shall be alarmed:

Tunnel ventilation fans and dampers, and jet fans
Underplatform exhaust fans
Ceiling (dome) exhaust fans
Platform and mezzanine air conditioning unit filters
Vent shaft dampers
Track drainage pump wet wells
Sump pumps in operationally critical locations
Fire water shut-off valve
Battery Room exhaust fan
Fire water flow
Sprinkler water flow
Station temperature (high limit only)
Tunnel temperature (high and low limit)

14 .16.3 Standards

The supervisory control equipment for mechanical functions shall embody modern designs which provide the highest degree of safety and reliability. Wherever applicable, design of equipment for these functions shall be in accordance with ANSI, NEMA and IEEE Standards and Specifications. The principles of these criteria shall be maintained where new devices or techniques are developed, even though the technicalities of the specifications do not envision these new devices and techniques.

14 .16.4 Equipment and System Interfaces

14 .16.4.1 Control Center Console:

The Operations Control Center located in the operations Control Center Building will contain a Control Console which will give immediate alarm and visual indication of status changes or other abnormal conditions associated with the mechanical systems. This Control Console will be further equipped to provide the operating attendant with the capability of control. The specific mechanical systems indicate the scope of these criteria.

(Note: Additional functions of the Control Console are described in other sections of these-criteria.)

14 .16.4.2 Remote Terminals and Interface to DTS - Mechanical Facilities:

The Mechanical Sub Contractor shall be required to route and connect all supervisory control cabling from the devices to the interface terminal cabinets. The interface terminal cabinets will be located where indicated in the scope of this section of criteria.

14 .17 ELEVATORS

14 .17.1 General

Dual street elevator access and dual center platform elevators shall be provided -- a minimum of one elevator per mezzanine or two per station, whichever is greater.

There are several elevator types used in the system. The following classification of elevators are in use:

Hydraulic (Types I-IV)

Vertical rise up to 50'-0"
Machine room can be remote from elevator if necessary
- Electronic soft-start shall be used on the pump motor.

Traction (Types VI-VIII)

Vertical rise over 50'-0"
Machine room must be overhead or adjacent to elevator
Traction elevators shall use closed-loop, AC variable voltage, variable frequency drive for 350 feet per minute (FPM) and below, closed-loop SCR drive with variable voltage D.C. full wave controller for speeds greater than or equal to 350 FPM.

All are similar in appearance, but the doors vary to meet the different relationships that exist between surface, mezzanine, and platform. The cab shall have center opening door meeting ADA requirements.

Elevators will be furnished and installed by contractor. The Contractor will be responsible for the complete installation including the car, machinery, hoistway and car appurtenances including hoistway door framing and door, landing controls and indicators, buffers, hydraulic jacks and lines, car and counter weight, guide rails, rail brackets, car control and signal systems, car lighting and communications, car ventilation, provisions for fire/smoke sensor in car and intrusion alarm sensors on surface entrance hoistway doors.

The Designer shall design the ancillary spaces, hoistway (including pits and overhead structures), structural supports, machine rooms, electric services, and conduits for installation of the elevators.

14 .17.2 Codes and Regulations

The elevators, hoistways and machine rooms shall conform in all respects to the requirements of the latest issue of the American National Standard Safety Code for Elevators, Dumbwaiters, Escalators, and Moving Walks - ASME A17.1, ADA and local codes.

14 .17.3 Number of Elevators

The number and types of elevators at each location will be as per Design Criteria and the project specification requirement provided by the authority.

14 .17.4 Location and Access

Generally, elevator entrances at the surface shall be located so that patrons will have direct access from public spaces.

Elevator landings at mezzanines and platform levels shall be located to permit as direct access as possible to entrance passageways, mezzanines or train platforms. Connecting corridors between elevator landings and passageways, mezzanines, or train platforms are to be avoided if possible. Where possible, elevator landings shall be designed so that patrons will be required to pass

through the normal fare collection facility between the free area and paid area at the mezzanine level when entering or leaving the station. Direction signs and barrier free access paths leading to and from the elevators shall be provided in all cases.

14 .17.5 Elevator Environment

14 .17.5.1 Machine Room

Machine room entrances shall be sufficiently wide enough to allow installation and removal of the equipment.

The temperature shall be 50 ^{0}F, minimum. No heat is required in underground machine rooms. Where heat is provided, temperature controls shall be automatic, turning on at 50^{0}F DB and off at 55 ^{0}F DB. Exhaust ventilation shall be based on a capacity of one hundred (100) CFM per driving machine motor horsepower. Exhaust fans shall be automatically controlled, turning on at 90^{0}F DB and off at 85^{0}F DB. For planning purposes, design for 15 horsepower motors for electric elevators, 30 horsepower for hydraulic elevators up to 20 feet of rise, and 35 horsepower for hydraulic elevators of more than 20 feet of rise. Machine room ventilation ducting passing through adjacent occupied areas shall be protected in these areas with a two-hour (higher if the category of the area required) fire-rated construction. The ventilation fan shall be located in the machine room and shall discharge through the exhaust opening or ducting. Minimum head room clearance of 7'-0" shall be provided under the fan and ductwork. Where possible, the supply and exhaust ventilation system for the machine room shall be free of obstructions except for necessary grilles, screens or dampers. Fire dampers shall be provided at pierce points (openings) in the machine room walls, floor or ceilings. No water piping shall be allowed to run in any elevator machine rooms. Where possible avoid locating elevator machine room under the platform.

14 .17.5.2 Car

The cabs shall be stainless steel, and the interior surfaces mar-resistant.

Cab and hoistway sills shall be heavy-duty nickel silver.

Cab subfloor frame shall be hot-dipped galvanized.

Cab floor cover shall be resistant to urine absorption and deterioration.

The cab shall be equipped with a CCTV camera for monitoring.

The cab shall utilize spring tensioned roller guides.

An exhaust fan rated at 350 CFM will be provided by the Elevator Contractor in the ceiling of the car to provide car ventilation. It will be so connected as to operate continuously when the elevator is in an operational mode.

14 .17.5.3 Hoistway

Hoistway in underground stations, from surface to mezzanine and/or Platform, shall be provided with mechanical ventilation intake and exhaust air vents where practical (one at the top and one at the bottom) with a minimum of three (3) square feet of free area for ventilation of hoistway to the outdoors.

All hoistway structural members, glass and bronze cladding shall be in the station contract except for a portion of the entrance way as shown on the Design drawings.

All interior elevator glass and bronze hoistway designs will maintain a minimum dimension of 7'8" from the finish paver tile to the underside of the horizontal structural steel tubing above the door header.

All exterior elevator hoistway designs shall maintain a minimum of 7'0" to the underside of the roof overhang and 7'2" to the underside of the horizontal structural steel tubing above the door header from the finished granite surface.

Exterior elevator hoistway designs will maintain 4'2" minimum horizontally between structural verticals. The station contractor shall affix temporary safety closure full width and height of hoistway opening.

Concrete hoistways within stations will maintain "alcove" ceiling heights of horizontal structural members above the door header at 7'8" minimum from the finished paver tile as noted. For this hoistway configuration, all door surrounds and all structural supports will be provided by the contractor/ elevator sub contractor. The contractor shall be instructed to affix temporary safety closure full width and height of hoistway opening until the time elevator installation start.

All paver tile and granite floor finishes will be completed by the contractor. The contractor will caulk the completed sides of the hoistway.

The Designer shall ensure that any structural projections on the hoistway interior are shown to be finished with appropriate angled projections per ASME A17.1 requirements.

The contractor will provide elevator pit and headhouse lights and receptacles and the pit ladder.

For parking garages where the hoistway are enclosed by glass and bronze cladding, a mechanical ventilation system with an exhaust fan and an air intake louver shall be provided to maintain 10 air changes per hour of ventilation. The fan shall be controlled by a thermostat located in the hoistway.

14 .17.6 Weatherproofing

All elevator installations and/or components exposed to the elements shall be provided with weather protective features such as:

Waterproof construction
Wind and rain screening
Rust resistant properties or coatings
Non-slip paving surfaces
Weatherproof electric wiring

14 .17.7 Duty

Elevators will be designed for continuous duty with a 3,500 pounds capacity.

Electro hydraulic elevator operating speed will be one hundred fifty (150) feet per minute. Electric elevator operating speed will be three hundred (300) feet per minute. minimum rated load for the car will be determined from the inside net platform areas shown by the Contract Drawings and the application of National Standard Code formula rules.

In addition, the mezzanine-to-platform elevators will be designed to support a 1260 pound cart, with the load distributed on four (4) wheels.

14 .17.8 Space and Physical Requirements

14 .17.8.1 Space - Space provisions and dimensions for elevator penthouses, hoistways, hoistway enclosures, and machinery rooms shall be as shown on Design Drawings. Queuing areas, building set-backs, foyers, and corridors (where necessary) serving the elevators shall be as shown on architectural drawings and as required by local jurisdictions. See Section 9.5.19.

14 .17.8.2 Hoistways - All hoistways shall be vertical unless specifically approved otherwise. Hoistways and hoistway pits shall be designed to accommodate elevator appurtenances (*ladders*, overhead beams, hoistway doors, car guide rails and rail brackets, buffers, hydraulic cylinder installations, pit ladders, sump pump, etc.) and to provide sufficient support for the various static and impact loads which may occur.

14 .17.8.3 Machine rooms - machine rooms for electric type elevators shall be located above the elevator or immediately adjacent to the top of the hoistway unless this location is not feasible in which case the machine room may be adjacent to the bottom of the hoistway. Overhead machine rooms may be located immediately adjacent to and near the bottom or top of the hoistway. Approval of the Authority shall be obtained for such installations requiring the machine room to be below. Machine rooms for hydraulic type elevators shall be located as close as practicable to the hoistway and should be located under escalator inclines, if possible, but not as a separate room on the train platform. Machine rooms for electric and hydraulic elevators may be built to accommodate the machinery for more than one elevator. In all cases, access means shall be provided to machine rooms for maintenance services and for equipment installation. machine room doors shall open in and shall be hollow metal, 1-1/2 hour fire rated doors with a Class B label, self-closing and locking. Locks are to be always operable from the inside without a key.

14 .17.8.4 Hydraulic lines - In all cases, design means for passage (embedded conduit, sleeves, trenches, etc.) of rigid hydraulic pipe lines from the elevator machine room to the hoistway pit shall incorporate features which will permit the initial installation of the hydraulic pipe line by the Elevator Contractor, also allowing for periodic piping inspections as well as the subsequent removal and replacement of the entire line or any portion thereof. Design shall provide that the hydraulic line not run exposed in public areas, train rooms, or train tunnels.

14 .17.8.5 Structures - For structural design and construction of elevators and related structures such as hoistways, pits, and machine rooms, etc., see Section 15.15 - Structural, of this Manual and Structural Design Drawings.

14 .17.8.6 Travel - In general, Electro hydraulic elevators will be used in cases where the elevator travel is fifty (50) feet or less. Exceptions may be made with the consent of the Authority based on economic and design considerations. Electric elevators will be used where the travel of the elevator exceeds a

nominal fifty (50) feet. Electric elevators, unless otherwise noted, shall be overhead traction types with 1:1 roping.

14 .17.9 Car Control and Operation

14 .17.9.1 Elevator Controls - Non-proprietary micro-processor/PLC controllers shall be used. Door control features will include automatic door opening and closing with nudging operation, adjustable door hold-open time, car door electric contacts, and hoistway - unit system hoistway-door interlock. All devices or controls for use by patrons at landing and inside shall be in accordance with ADA requirements. These will be clearly marked and designed so that their function can be identified by all patrons including those with sight impairment. An emergency stop key switch will be provided inside the car for use by authorized personnel only. Code-compliant car-top inspection operation shall be provided.

Elevators shall be equipped with a fault display to automatically show the operation of the elevator and the activation of each safety device. The fault display shall be located on the controller cabinet door.

The electronic controls shall operate in ambient temperatures from +32°F to +105°F and relative humidity of up to 95%.

14 .17.9.2 Elevator Operation

The elevator will be equipped with a selective collective type automatic control system. The car will remain at the last landing served until summoned for service by the next patron. Two-stop elevators shall have an automatic dispatching operation in which the calls for the opposite landing is set when the elevator opens its doors for a hall call. The door to the elevator will normally be closed until the elevator is summoned. All doors will be power operated and controlled by a closed loop, electronic operator with door speed and torque independently adjustable.. Doors will be single-speed, center opening except when limited by dimensions. Two-speed, offset doors may then be used.

14 .17.9.3 Elevator Car and Hall Station Fixtures

Elevator Car Control Panel and Hall Station Control Panel fixtures shall meet all current national fire service codes including ASME A17.1, ASME A117.1, and ADA requirements. Fixtures shall be vandal-resistant with illuminating LEDs on the buttons and hall lanterns. Floor indicator push buttons in Cars and Hall Station call buttons shall be metallic, impact- and pry-resistant with a center illuminating light and a finish that contrasts with the surrounding control panel finish.

Floor push buttons in Cars and Hall Station call buttons that serve only two public levels shall have one of two options:

A separate metallic round contrasting colored disk the same dimension as the call button mounted horizontally adjacent to the call button. The disk shall have a contrasting colored arrow inside indicating the direction of travel. Stainless steel panels shall have a black disk with a stainless or white arrow inside. Bronze panels shall have a white disk with a red arrow inside. The arrow design shall meet the criteria laid out in WMATA's Manual of Graphic Standards.

An arrow indication included in the floor identification plate adjacent to the call button, as shown in FIGURE 14.1. Use manufacturer's standard symbols.

Car Control Panels:

The Car Control Panel layout inside the cab shall be logically configured so that the floor indicator push buttons are arranged in a vertical fashion or in columns for elevators traveling to multiple floors. Upper floor buttons shall be mounted above lower floor buttons.

On the Car Control Panel, floor indicator push buttons for public floors shall be grouped together separate from open and close door buttons, help call buttons, and "Non-Public" buttons such as key switches, staff only floor push buttons and all other fixtures not related to public use.

In Elevator Cars with glass panels adjacent to doors, floor indicator push buttons for public floors shall be located on the panel so they are closest to the elevator door(s), followed next by 1-1/2" of blank panel, then the door controls, then the help call button(s). Non-Public fixtures, controls and buttons shall be furthest from doors. See FIGURE 14.1.

In Elevator Cars without glass panels adjacent to doors, the manufacturer's standard ADA-compliant button arrangement shall be used, with floor indicator push buttons separated visually from other Public buttons and Non-Public buttons by 1-1/2" of blank panel. Additionally, and where possible, use round buttons for Public buttons and square buttons for non-Public buttons, if the manufacturer offers both types as standard. Non-standard buttons shall not be used.

Hall station panels:

Hall station panels with "Up" and "Down" call buttons shall also be arranged with the "Up" button on the top and the "Down" button below it. Call buttons shall be grouped together on the panel separate from other fixtures on the panel and closest to the door opening if applicable.

14 .17.10 Kiosk Control, Indications and Operations

Controls will be provided by the Elevator Contractor at the designated Major Elevator Kiosk to enable placing each elevator out of service; holding each elevator at any given landing opening and holding the doors of the elevator at any given landing; and car override control. Each of the above controls will normally take effect with the same priority as the landing and car controls. If the override control is actuated, the elevator will respond only to the kiosk controls. The override control will not preempt the elevator safety controls. The station Major Elevator Kiosk will be equipped by the Elevator Contractor with an elevator status system which will provide a visual display of elevator car status. The functions shown will be landing stopped at, direction of travel, landing being approached, indication of "Out of Service" due to a malfunction, and "Car Stopped" due to activation of "Stop" control button bar car patron. In addition, the kiosk will be equipped with those display indications specified under Paragraph 12, Detection System.

14 .17.11 Communications

An intercom station will be provided by the Elevator Contractor in each car, at each outside entrance landing and at each platform landing to permit two-way voice communication between the station occupants and the kiosk attendant. Depressing a momentary contact pushbutton at each intercom station will activate both audible and visual indicators in the kiosk. By depressing a pushbutton in the kiosk, a two-way voice communication link shall be established. Communication in the cab must rollover to a 24-hour manned site if the kiosk does not respond to a call.

Conduit shall be provided in surface elevator hoistways to permit the future installation of surveillance CCTV equipment.

14 .17.12 Detection Systems

14 .17.12.1 Smoke and Fire

The elevator and machine room will be equipped with smoke and fire detectors. The Elevator Contractor will connect the smoke and fire detector in the elevator car to an interface terminal panel installed in the elevator machine room. Connections between the interface panel and the Station Fire Detection System will also be connected by the *Station* Contractor. The station kiosk attendant will receive a visual display and audible alarm if any temperature or ionization detector is actuated. Simultaneously, an alarm signal that a fire or smoke condition exists at the station will be transmitted via the data transmission system to the Command Center. See Section 14.13 , Fire Protection. Machine room and elevator lobby alarm signals shall be provided to the elevator controller to allow Code-Compliant Fire Service operation.

14 .17.12.2 Intrusion

The elevator hoistway door at the surface and the elevator machine room door will be equipped with intrusion alarm sensors to detect unauthorized entry. In the event any intrusion alarm sensor is actuated, the kiosk attendant will receive a visual display and audible alarm and an "Intrusion Alarm Signal" will be transmitted to the Command Center via the data transmission system. The intrusion alarm sensor on the hoistway door will be by the Elevator Contractor while the sensor on the machine room door will be installed by the Communications Contractor. The sensors will be connected by the respective contractor to an interface panel installed in the machine room by the Communications Contractor. Connections between the interface panel and the Station Intrusion Detection System will be by the Communications Contractor.

14 .17.13 Safety

14 .17.13.1 Fire Resistant Materials

Fire resistant noncombustible materials and fire resistant construction methods shall be utilized and in all cases shall conform to governing code requirements and recognized standards, except for glass materials.

14 .17.13.2 Car Safeties

Car safeties will be provided in accordance with the requirements of governing codes and standards.

14 .17.13.3 Materials and Construction Properties

The physical properties and related design allowances for all materials and construction of all elements of the elevator installation shall meet or exceed those specified in governing codes and recognized standards.

14 .17.14 Electrical services

See Section 13.7.16, Electrical Services Requirements for Elevators.

14 .17.15 CLEARANCE TO INSTALLATIONS

A minimum of two inches is required between any fixed installations (e.g. pipes, pipe hangers, pipe supports, signals, lighting fixtures, etc.) and the design vehicle dynamic outline. This is defined by the clearance envelop (refer to Section 8, Design Policies). However, installations shall be so dimensioned and located that maximal distances are obtained between these and clearance envelope along tangent and curved alignments.

14 .18 MAINTAINABILITY AND CONSTRUCTABILITY

The design of mechanical systems and equipment installations shall be coordinated with structural, electrical, architectural and other disciplines for the purpose of insuring adequate space, clearances, structural support, and non-interference with other trades during construction. Designs shall take ease of mechanical equipment maintenance into account. Maintenance operations will include inspection, adjustments, cleaning, trouble shooting, servicing, repairs and replacement of mechanical equipment. The selected equipment shall be subject to minimal system component failure.

14 .18.1 Space and Accessibility

Sufficient working space and adequate access shall be provided for the maintenance and replacement of all mechanical equipment. This requirement shall include adequate space for movement of equipment during initial installation, and during subsequent unscheduled maintenance involving removal and replacement of failed equipment.

14 .18.2 Specific Requirements

Mechanical system designs shall be in accordance with the following requirements:

14 .18.2.1 Vent shaft and fan shaft damper assemblies 10 feet or more in height shall be provided with work platforms.

14 .18.2.2 Mechanical equipment mounted 8 feet or more above the finish floor shall be provided with work platforms. The mechanical equipment in this category shall include any items which require frequent servicing or contain large components or require large replacement parts.

14 .18.2.3 Chain operators shall be provided for chilled and condenser water valves mounted 8 feet or more above the finish floor.

14 .18.2.4 Chiller tube pull spaces shall be indicated on the contract drawings.

14 .18.2.5 Filter pull spaces shall be indicated on the contract drawings.

14 .18.2.6 Coil pull spaces shall be indicated on the contract drawings.

14 .18.2.7 Special requirements (e.g. cooling tower drive shaft pull space) shall be considered and called out on the contract drawings as required.

14 .18.2.8 Equipment shall not be suspended over floor mounted equipment or pits in a manner which prevents access to the suspended unit.

14 .19 MECHANICAL REQUIREMENTS FOR BUS FACILITIES

14 .19.1 Fire Protection

14 .19.1.1 General

14 .19.1.1.1 The fire protection systems shall be designed per all local and state codes as is appropriate for the project site. In addition, the systems shall be designed in accordance with the latest versions of the NFPA as they apply to the space and/or application being served. Where the NFPA and, local and state codes differ, the design shall follow the most stringent requirements.

14 .19.1.1.2 Coordinate building systems and services with the Fire Protection and Alarm such that there shall be, where appropriate, automatic shutdown of the affected system(s) or service(s) should any of the fire protection systems be activated. (e.g. fuel dispensing system shutdown where the associated fire protection system is activated.)

14 .19.1.1.3 Coordinate fire protection requirements with WMATA's fire protection underwriter.

14 .19.1.2 Wet Sprinkler Systems

14 .19.1.2.1 The building sprinkler systems shall be designed in accordance with NFPA 13, other appropriate NFPA sections, and the local and state building code requirements. The system shall be designed under the direct supervision of an engineer experienced in the design of such system and shall be licensed within the state or district where the building will be located ~~reside~~.

14 .19.1.2.2 All areas of the building shall be protected by a wet sprinkler system, except as allowed below. The system shall be separately connected to the local municipal water main with connections being in accordance with the water purveyors connection and back-flow prevention requirements.

14 .19.1.2.3 The system shall be completely hydraulically designed to meet the density and flow requirements set-forth in NFPA 13 and 30. Unless otherwise indicated in the NFPA requirement, the areas of the building shall generally fall into the following Hazard Classifications:

14 .19.1.2.3.1 General Areas — Ordinary hazard

14 .19.1.2.3.2 Office Areas — Light hazard

14 .19.1.2.3.3 Fuel Dispensing Areas Ordinary hazard

14 .19.1.2.3.4 Paint Spray Booth Extra hazard

14 .19.1.2.4 The sprinkler head selection shall be made according to the hazard classification and specific requirement of the areas served in accordance with the applicable NFPA standards. The sprinkler system shall be provided with test fittings, inspector test valves and drainage fittings. Test fitting, inspector test valves and drainage fittings shall be provided for in each fire zone. The test fittings and drainage fittings shall be discharged to the exterior of the building so as to avoid water damage. The sprinkler heads shall be the upright type except where ceilings or other obstructions prohibit their use.

14 .19.1.2.5 The sprinkler piping system shall be designed with Schedule 40, black steel pipe. The fittings shall be screwed type joist for sizes below 2 ½" and either screwed or mechanical type for sizes 2 ½" and larger. The building sprinkler piping system shall be design~~ed~~ with sprinkler risers to meet the NFPA 13 area requirements. Each riser shall be provided with appropriate riser trim and a seismic connection and check valve. Coordinate the connection requirements with the local fire department and WMATA's insurance carrier requirements. Each fire zone shall be designed with a manual shutoff valve (with tamper switch) and flow-indicating device. The tamper switches and flow indicating devices shall be tied into the Fire Alarm System. All fittings, valves and devices shall be FM approved. The sprinkler piping system shall be supported in accordance with NFPA 13 requirements.

14 .19.1.3 Foam Systems:

In areas within the building where fuel is dispensed or in Class I, II and III Liquid Storage Rooms, foam-water sprinkler systems ~~shall~~ may be used. In addition to observance of the local and state building codes, these systems shall be designed in accordance with NFPA 30, 30A and other appropriate NFPA sections regard these types of systems. The system shall be designed under the direct supervision of an engineer experienced in the design of such systems and shall be licensed within the state or district where the building will be located ~~reside~~.

14 .19.1.4 System Testing:

After the system has been installed, a pre-test and final acceptance test shall be performed. The testing shall be in accordance with the requirements of the appropriate NFPA sections and local and state requirements.

14 .19.1.5 Fire Protection Guidelines:

Provide types of fire protection for specific areas as indicated below.

Occupancy	Suppression
Battery Storage	FE
Electrical Equipment Areas	FE
Fuel Dispensing	HH
Maintenance and Service Areas	WS

Mechanical Equip. Rooms	WS
Boiler Rooms	WS(165°F heads)
Elevators	WS
Office Areas	WS
Storage: Hazardous	HH
General	WS
Paint Booth	HH

ABBREVIATIONS:

WS	Wet Sprinklers
HH	High Hazard Wet Sprinklers
FE	Fire Extinguishers

14 .19.2 Plumbing / Drainage

14 .19.2.1 General: The plumbing systems shall be designed per ~~all~~ the International Building Code and local and state codes as are appropriate for the project site. The system shall be designed under the direct supervision of an engineer experienced in the design of such systems and shall be licensed within the state or district where the building will be located ~~reside~~.

14 .19.2.2 Municipal Water Service: The plumbing system will be served by a separate municipal water service. The water service shall be separated from the domestic water system by a Reduced Pressure Zone type backflow preventer.

14 .19.2.3 Fixtures: The plumbing fixtures shall be designed in accordance with ADA requirements, where applicable. All fixtures shall be provided with removable handle type stops. The Urinals and Water Closets shall be wall-hung type with flush valves. The locker room areas shall be furnished with stainless steel wash fountains for hand washing. Individual Restrooms shall be designed with wall hung lavatories utilizing single lever faucets. Electric water coolers shall be provided in locker rooms, the maintenance areas, service area, and outside of grouped restrooms. Provide stainless steel kitchen sink(s) with disposal(s) in breakroom(s) or otherwise as requested by WMATA. ~~and~~ Janitor and costodial rooms shall have ~~provide~~ mop service basins with bucket holding supported spout fixture and a short flexible hose connection. ~~in janitor's closets~~

14 .19.2.4 Plumbing Specialties

14 .19.2.4.1 The plumbing system shall include emergency eyewashes and combination eye wash and shower units. These shall be tied to a tempered water loop that shall provide water at the proper volume and temperature, and for the duration necessary to meet OSHA requirements. Combination units will be located in the Shop Areas, Maintenance Repair Bays ~~Area~~, Chasses Wash, Lube/Compressor Room, Pant Booth Area, Service Lane, and the Battery Charging/Storage Area. Provide eyewash units in ~~the Flammable Liquid Storage Room,~~ rooms where hydraulic lift pumps are located and other areas where the potential for eye damage exists and as required to meet local, state and federal requirements.

14 .19.2.4.2 The system shall include shock absorbers, on the cold and hot water distribution system, where the action of quick operating valves could

result in a water hammer condition. Provide dielectric fittings at connections of dissimilar metals.

14 .19.2.4.3 Hose bibbs shall be provided, on the exterior of the buildings and in the interior, and as required by WMATA. Hose reels with 50 feet of 1" hose shall be provided every third bay in the maintenance area, at the beginning and end of the washbays, in the tire bay and in the paint booth area. Freeze proof wall hydrants shall be provided every 100 feet around the perimeter of the building.

14 .19.2.5 Cold and Hot Water

14 .19.2.5.1 The cold and hot water distribution system shall be designed as predominately flush valve systems. The distribution system will serve both the domestic water load and the bus wash system requirements. ~~The domestic hot and cold water flows shall be determined using Hunter's Curve.~~ The Flow required for the bus washer(s) shall be considered a constant demand and be added to the domestics water flow.

14 .19.2.5.2 The water distribution system shall be ~~shall be~~ constructed of the following: ~~type "M" copper piping for sizes up to 2 ½" and of Sch. #40, Black Steel for sizes greater than 2 ½".~~
2 1/2" and smaller - aboveground ASTM B 88 Type L drawn-temper copper tubing with soldered joints or press fit. Below grade or within slabs ASTM B88 Type K annealed-temper copper tubing with soldered joints. 3" and larger - Provide ASTM A53/A53M, type S Grade A or B, sch. 40 galvanized.
The water supplies to the bus washer(s) shall be protected from the backflow of wash water by Reduced Pressure Zone backflow preventer.

14 .19.2.5.3 The design shall include a gas or electric ~~central dual fuel~~ water heater (gas preferred) . The heater will operate on natural gas or electric ~~and No. 2 fuel oil~~. It will be sized to meet the demanded of the domestic hot water load along with any building core area loads resulting from cleaning equipment or wash down requirements. Remote hand sink or similar hot water loads will be met through ~~the~~ point of use ~~of~~ or small tank type electric or gas water heater. Provide cleanouts at the base of risers and wall cleanouts at gang toilets.

14 .19.2.6 Sanitary and Vent System

14 .19.2.6.1 All above grade sanitary piping shall be No-Hub service weight cast iron. All below grade sanitary piping shall be Hub and Spigot service weight cast iron. Provide cleanouts at all changes in direction of 45° or greater, every 50 feet on piping 4" and less, and every 100 feet for piping over 4".

14 .19.2.6.2 The vent system shall be: 2 ½" and smaller above ground DWV copper tube with soldered joints ~~up to 2 ½" and No-Hub service weight cast iron above 2 ½"~~. 3" and larger above ground: Copper DMW tube with soldered joint or Cast-Iron soil piping, stainless steel or cast iron couplings.

14 .19.2.6.3 All below ground pipe shall be cast iron with gasket and gasket joints.

14 .19.2.7 Storm Piping: All above grade storm piping shall be No-Hub service weight cast iron or stainless (304) couplings. All below grade storm piping shall be Hub and Spigot service weight cast iron with gasketed joints. Provide cleanouts at all changes in direction of 45° or greater, every 50 feet on piping 4" and less, and every 100 feet for piping over 4".

14 .19.2.8 Roof Drainage: Unless otherwise stated by local or state code, the roof drainage system shall be designed based on the maximum local hourly rainfall intensity. Provide system with both roof drainage and overflow drainage systems. Direct all downspouts in parking and sidewalk areas underground to storm water to prevent ice and standing water.

14 .19.2.9 Interior Floor Drainage: All floor drainage from the maintenance and Fuel and wash lanes area which have vehicular traffic shall be piped to the oilwater separation system. Provide floor drains at all equipment having condensate drains. Mechanical/Electrical and Compressor Rooms shall all have a minimum of one floor drain. Do not provide drains in shop and parts storage areas due to misc parts getting trapped in drain system, floor scrubber to clean these areas. Provide additional floor drains where required to eliminate horizontal drainage piping from equipment exceeding 10 feet. Battery storage rooms to have no floor drain, floor to be sloped to dry sump. All gratings used to cover trench drains, catch basins, etc shall be hot dip galvanized H-20 load rating. Gratings which are greater than 30 lbs shall be accessible by forklift in order for removal (removal by chain and forklift).

14 .19.2.9.1 Bus Wash Area: A longitudinal trench drain shall be located along the entire length of the bus washers, including the blower/dryer assembly, and shall be centered in the bus wash lane. Each trench drain shall be pitched to accommodate the Wash Water Reclamation System and shall terminate with a sediment trap. The trench drains shall be sloped at not less than 1/8" per foot. The overflow from the Reclamation System shall be directed to the Sanitary Sewer System if permitted by local discharge limits.

14 .19.2.9.2 Maintenance Area and Service Lane

14 .19.2.9.2.1 Trench drains shall be run across the entrance to these areas and be located within 2'~~approximate 5'~~ from the face of the overhead doors. A trench drain shall also be located in the steam clean bay. The trench drains shall be pitched to allow efficient flow of water and terminate with a sediment trap. The trench drains shall be not less than 12" wide to allow cleaning with a shovel and the grating shall accommodate H-20 loading.

14 .19.2.9.2.2 An oil water separator shall be designed as part of the drainage system serving the vehicle entrances described above. The oil water separator shall be capable of removing the petroleum product typically seen in similar applications. The separator shall be designed based on American Petroleum Institute (API) standards, a maximum horizontal velocity of 3 fpm, a maximum depth-to-width ratio of 0.5, and continuous flow operation. The separator shall be additionally designed based on local, state and federal requirements. The local sewer district should be contacted to determine if there are specific requirements and discharge limits.

14 .19.2.9.2.3 The oil water separator shall be designed with: a sediment trap; integral holding tank; a top capable of H-20 loading; and applicable features necessary for the use and installation requirement where it will be installed.

14 .19.2.9.2.4 A catch basin will be installed just upstream of the oil water separator described above. The catch basin shall be not less than 36" in diameter and be used for initial sedimentation of the floor drainage. The outlet of the catch basin shall consist of a vertically oriented tee with a 12" open drop leg and capped top. The bottom of the catch basin will have an invert 24" below the bottom of the open drop leg. The catch basin shall be provided with a manhole cover capable of H-20 loading.

14 .19.2.9.3 Waste water from floor scrubbers and parking lot scrubbers shall be handled in one of the following ways, depending on a cost/benefit analysis, local requirements and WMATA requirements:

14 .19.2.9.3.1 Storage on-site in an above ~~below~~ grade holding tank or floor sump, size to be determined by WMATA, prior to removal by a licensed disposal contractor.

14 .19.2.9.3.2 Pre-treatment on-site prior to discharge into the sanitary sewer system.

14 .19.2.9.4 Oil Separation / Pretreatment System

14 .19.2.9.4.1 The following system description is provided for information only. Final design criteria and requirements shall be confirmed during design and shall:

14 .19.2.9.4.1.1 Meet local discharge requirements.
14 .19.2.9.4.1.2 Meet WMATA requirements.
14 .19.2.9.4.1.3 Meet all other applicable requirements.

14 .19.2.9.4.2 Provide one (1) collection manhole for every three (3) maintenance bays. The collection manholes shall be 24" long, 18" wide and 36" deep (all inside dimensions). Provide the manholes with heavy duty fiberglass grates with an opening to allow a suction pipe installation. Each of the manholes will be accompanied by a air driven double diaphragm pump capable of delivering 25 gpm at the calculated pressure differential.

14 .19.2.9.4.3 The pretreatment system generally consists of ~~a collection~~ manholes, transfer pumps (both from the manholes to settling tank and from settlement tank to the oil separator, filter, membrane filter, holding tank, and automatic chemical treatment system. ~~Refer to appendix B for the system description, P&ID, and components.~~

14 .19.2.9.4.4 The system shall be capable of treating 1000 gallons of solution per day. It shall be capable of maintaining a discharge having a ph of between 5 and 10, oil and grease less than 100 parts per million and filtration to 25 microns.

14 .19.2.9.4.5 The settlement tank shall be installed in the floor. It shall have a 2000 gallon volume and have an invert not deeper than four (4) feet below the floor surface. Provide the settlement tank with a fully removable, heavy duty, steel cover such that each section can be removed by a single individual.

14 .19.2.9.4.6 Above ground transfer piping shall be treaded or mechanical joint, schedule 40 black steel. Provide cleanout at all changes in direct of greater than 45° or at straight runs of pipe greater than 50 feet.

14 .19.2.9.4.7 A 25 gpm double diaphragm pump will transfer the effluent for the settlement tank to and above ground oil/water separator. The oil/water separator shall be sized as described above but in no case have a capacity of less than 20 gpm.

14 .19.2.9.4.8 After passing through the oil/water separator effluent will flow by gravity to a "zero gravity" filter. Backwash from the filter should be returned to the settlement tank.

14 .19.2.9.4.9 Effluent from the filter will flow by gravity to a 25 micron ~~membrane~~ filter and on to final holding tank where the effluent will be chemically treated prior to flowing to the municipal sewer.

14 .19.2.9.4.10 Natural Gas Piping

14 .19.2.9.4.10.1 The natural gas piping shall be designed in accordance with NFPA 54 and the local gas provider's requirements. ~~The gas pressure within the building shall be limited to less than 11" of water column (w.c.) with the piping being sized based on a pressure drop of 0.3" w.c. per 100' of pipe.~~

14 .19.2.9.4.10.2 The natural gas piping shall be constructed of Sch. #40, Black Steel pipe. Piping 2 ½" and below shall utilize threaded fittings and piping greater than 2 ½" shall be welded steel fittings. Gas shutoff valves and drip legs shall be provided up stream of all gas consumers.

14 .19.2.9.4.11 Compressed Air System

14 .19.2.9.4.11.1 The compressed air system shall be furnished with two (2) air compressors, each ~~to be~~ sized for 100% capacity based on a 50% diversity factor at 100 psig. The compressors will have soft starts with cross connectable independent air dryers, preferably regenerative desicant type capable of delivering compressed air at a dew point of 28°F. ~~The compressors shall be furnished with intake filtration, cylinder unloading, automatic blow-down, and after cooler.~~ The sizing of the compressor shall be based on the following:

Impact Hammer:	40 SCFM
Blow Gun:	3 SCFM
Paint Spray:	20 SCFM
Drill:	50 SCFM

Rotary Sander:	30 SCFM
Tire Changer:	2 SCFM
Engine Cleaner:	5 SCFM

~~**14.19.2.9.4.11.2** A mechanical compressed air dryer shall be furnished to meet 100% of the anticipated load. The dryer shall be capable of delivering compressed air with a dew point of 28 F.~~

14 .19.2.9.4.11.2 The overhead compressed air piping system shall be designed based on a working pressure of 150 psig. All valves and fitting shall be class 150. The piping shall be not less than schedule #40 black steel with the branch piping being not less than 3/4" diameter. The size of the branch piping shall be based on most demanding device being served. Each branch shall be furnished with a filter/regulator/dryer and a isolation valve at the branch/main takeoff. Filter/regulator/dryer assemblies shall be per WMATA's standard requirements. Confirm standards prior to installation.

~~**14.19.2.9.4.11.3** The compressed air mains shall be sized based on a 50% diversity factor.~~

14 .19.2.9.4.11.3 See Sections 18 and 19 for system components downstream of the filter / regulator / dryer.

14 .19.2.9.4.11.4 Provide quick disconnects, at air outlets, to meet WMATA's standard tool requirements.

14 .19.2.9.4.11.5 Provide general air outlets every 50 feet along the perimeter of the wash bays, maintenance and service bays. Provide two (2) air outlets in the Tire Service bay and four (4) in the Paint Booth bay.

14 .19.3 HVAC

14 .19.3.1 General

14 .19.3.1.1 The HVAC systems shall be designed per ~~all~~ the International Building Code, local and state codes as are appropriate for the project site. In addition the systems shall be designed in accordance with the latest versions of the ASHRAE, NFPA, SMACNA, ASME and UL standards as they apply to the systems utilized for the facility. In addition, any generally accepted standards which are recognized or generally accepted within the local engineering community for similar projects and/or systems shall apply.

14 .19.3.1.2 The system shall be designed under the direct supervision of an engineer experienced in the design of similar systems and shall be licensed in the state or district where the building will be located ~~reside~~.

14 .19.3.1.3 The facility shall be designed in accordance with the latest version of NFPA 30A and 88B, as they apply to the specific areas of the facility.

14 .19.3.2 Heating: The primary heating system shall be a hot water design. The heating system will be zoned to provide for the varying load requirements of each area.

14 .19.3.2.1 Boilers

14 .19.3.2.1.1 The boilers shall be fire tube type, each design sized to meet 80% of the design day heating load. Design heating load will be based on ASHRAE Winter Design Dry Bulb 95% and 80% of maximum building ventilation load.

14 .19.3.2.1.2 The boilers shall be equipped with duel fuel, modulating type power assisted burners that shall be capable of operation on natural gas and No. 2 fuel oil. The burners shall be designed to swing out allowing full burner face access without having to disconnect fuel piping or wiring. The burners shall have full IRI gas and oil trains and be provided with a combined burner management and flame safeguard system. The burner management system shall be capable of providing lead/lag changeover and fuel selection functions.

14 .19.3.2.1.3 No. 2 fuel oil shall be pumped to the boilers from an exterior underground oil tank capable of storing one (1) month's oil at fully loaded boiler operation. The tank shall be dual wall fiberglass design and be provided with leak detection system. Ancillary tank equipment such as oil fill boxes, vents, manholes, oil level indicators, anti-syphon valves, and alarms shall be provided. The fuel oil transfer pumps shall be skid mounted duplex type each being capable of providing sufficient oil for both boilers operating 100% loaded.

14 .19.3.2.1.4 The boiler flue venting shall be accomplished through a pre-manufactured stainless steel flue system. The flue system shall be designed in accordance with NFPA requirements. Design shall include make-up air to the boiler room to provide for boiler combustion and ventilation requirements.

14 .19.3.2.2 Area Heating Requirements

14 .19.3.2.2.1 Entrances and Exits: Heated air curtains shall be provided at all vehicle entrances and exits. Heated air curtains shall be installed at all service area entrances. All air curtains shall be designed for the local winter wind velocity as identified in the latest version of the ASHRAE fundamentals.

14 .19.3.2.2.2 Bus Maintenance Areas: The bus maintenance areas heating requirements shall be served by air handling units that will be located on elevated mezzanines. The unit shall be designed to maintain a space temperature of 65° F through the use of a hot water heating coil. (see Ventilation below for further related requirements)

14 .19.3.2.2.3 Parts Storage Rooms: The Parts Storage Room shall be ~~served by its own air-handling unit. Space temperature shall be~~ maintained at 65 ~~70~~° F. The hazardous storage rooms shall be

designed to Class I, Division 2 requirements (NFPA 30). Space temperature shall be maintained at 65° F.

14 .19.3.2.2.4 Bus Wash Area: The Bus Wash Area shall be designed unitizing a combination of space air handling and high intensity, infrared, gas fire unit heaters. The system shall be designed to maintain a space temperature of 65° F.

14 .19.3.2.2.5 Offices, Locker Rooms, Training Rooms, Operators Areas: Maintained at 68 ~~70~~° F by the central heating system.

14 .19.3.2.3 Air Conditioning: The Offices, Locker Rooms, Toilet Rooms, Training/Conference Rooms, Day Rooms and other similar areas in the administration and operations areas shall be air-conditioned, maintained at 75°F. The air conditioning of these spaces shall be accomplished through roof top direct expansion air conditioners which will utilize water coils for heating. Consideration should be made for the used of a packaged Variable Air Volume to maintain zone control.

14 .19.3.2.4 Ventilation

14 .19.3.2.4.1 Due to the nature of the operation of these facilities, significant amounts of make-up and exhaust air are required. In addition to local and state requirements the ventilation system shall be designed to meet both NFPA and ASHRAE standards. Where any of the requirements and standards differ, the design shall be in accordance with the most stringent.

14 .19.3.2.4.2 Air handling units servicing the maintenance areas shall be mounted on elevated mezzanines. The supply air shall be ducted, with the ductwork being fabricated of materials appropriate for the environment they are serving. Where air is to be distributed in high bay areas (20'+) the use of high velocity drum type diffusers shall be considered. The ductwork shall be constructed in accordance with SMACNA standards as appropriate for the pressure class of the system and units being served.

14 .19.3.2.4.3 The maintenance area air handling units shall be equipped with variable frequency drives (VFD). The supply fan shall operate at minimum speed and maintain minimum make-up air volume based on the space use. As the space exhaust air demand increases the VFD will increase supply fan speed to maintain space pressurization. The space pressurization shall be monitored through the use of space pressure sensors. The air handling units shall be designed for 100% of the ~~of the~~ heat recovery exhaust fan and 50% of the roof top centrifugal exhaust fan volumes.

14 .19.3.2.4.4 The maintenance area general exhaust shall be accomplished through a combination of heat recovery exhaust fans and roof top centrifugal exhaust fans. The heat recovery exhaust fans shall be sized to handle the minimum ventilation rate of 4 air changes per hour. The roof top centrifugal exhaust fans shall be sized such that their total exhaust volume will provide 8 ~~86~~ air changes per hour. The ductwork from the heat recovery exhaust fans shall be such that 50% of the exhaust air is taken from 6" above the finished floor. The ductwork that is run down to the floor level

intakes shall be attached and run down walls or columns to protect them from being hit by the buses.

14 .19.3.2.4.5 As a result of the large make-up air and exhaust requirements, heat recovery shall be used wherever the exhaust stream allows for its use. The type and application of the heat recovery system selected shall be appropriate for the quality of heat available from and the nature of the exhaust stream.

14 .19.3.2.4.6 Specific Area Ventilation Requirements

14 .19.3.2.4.6.1 Service Lanes - Fuel Dispensing Area: Provide 10 air changes per hour at low speed and 12 air changes per hour at high speed. Provide two exhaust intakes at 6" above finished floor for each fuel island.

14 .19.3.2.4.6.2 Service Lanes - Bus Wash Area: Provide 4 air changes per hour on low speed and ~~8~~ 6 air changes per hour at high speed.

14 .19.3.2.4.6.3 Air Compressor and Electrical Distribution Rooms: A mechanical ventilation system shall provide supply and exhaust air to maintain space temperature below 95° F.

14 .19.3.2.4.6.4 Paint Booth Area: The paint booth will be a cross draft style pre-manufactured system to be erected at the site. The booth walls shall be capable of supporting a three axis manlift capable of traveling the length of the booth. Booth air shall be supplied through the use of a makeup unit, which is mounted on the roof of the building. A fully filtered intake and exhaust air system shall be provided, with exhaust being removed from system and facility by ductwork and plenums. Fall protection for maintanence of fans. ~~The system shall be provided with an exhaust fans and a 80/20 style direct fired make-up air unit. The make-up air unit shall be mounted on the roof of the building. The make-up air unit shall be sized that the total volume is 10025% of the exhaust volume.~~ A low pressure breathing air system shall be provided complete with air compressor, purification system controls and alarms, distribution system with not less than two (2) hook-up stations, portable hoses, vortex air coolers and masks. The system shall be capable of allowing two (2) people to use it simultaneously.

14 .19.3.2.4.6.5 Tail Pipe Exhaust: The tail pipe exhaust system shall be designed to provide 600 cfm per connection with a 50% diversity factor. . The exhaust hoses shall be rated for a temperature of 1500°F. Each maintenance bay will be provided with an overhead, pull down hose reel which will automatically start the exhaust fan when the hose is extended for connection to the bus exhaust. The main header will be design per SMACNA standards with the hose and ductwork being as appropriate for the suction pressure generated at the "dead head" condition. The tail pipe connection shall be attached to the tail pipe through

the use of an inflatable rubber bellows. The bellows shall utilize compressed air to inflate. Provide an end switch that automatically deflates the bellows should the bus be moved prior to disconnecting.

14 .19.3.2.4.6.6 Battery Charging/Storage Room: To the extent practicable ventilation design shall take advantage of passive ventilation to maintain the hydrogen concentration level below 1% and comply with applicable code requirements. Where passive ventilation is not applicable, mechanical ventilation shall be used to maintain the concentration level below 1%. Redundant ventilation shall be provided. Battery Chargers shall be interlocked with the ventilation system, preventing their operation should the ventilation system not be in operation. Rooms to be mechanically ventilated at temperatures above 77°F. Battery rooms dependent on mechanical ventilation require remote monitoring per code. Hydrogen monitoring is not preferred because it requires regular sensor calibration and replacement. ~~The ventilation system shall be sized to 15 air changes per hour. The supply air to the space should be at 90% of the exhaust rate to prevent vapors from exiting the space. An exhaust hood shall be designed that will extend over the batteries being charged to exhaust any hydrogen produced by battery charging. The space electrical equipment and exhaust fan shall be designed per Class I, Division 1 with the chargers being interlocked with the ventilation system, preventing their operation should the ventilation system not be in operation.~~

14 .19.3.2.4.6.7 Locker Rooms / Restroom: Each Locker Room or Restroom shall be designed with a supply air and exhaust system. The space exhaust air shall be designed for 2 cfm per square foot or the sum of 75 cfm per water closet and urinal; 50 cfm per shower; and 15 cfm per locker, which ever is greater. The supply/make-up air shall be design at 90% of the exhaust volume to provide a pressure differential between the Locker/Restroom and the surrounding area. These guidelines or code regulations, whichever requires more cfm, shall be followed.

14 .19.3.2.4.6.8 Office/Training/Operators Areas: The Office, Training and Operators Areas shall be designed to provide a minimum of 15 cfm per person of outdoor air. The spaces shall be zoned such that space with similar use and occupancy are on the same air-handling unit (see Air Conditioning above for further requirements). These areas should be designed to provide a positive pressure relationship as compared to surrounding areas. This will be done to reduce infiltration from the outside and maintenance areas. These guidelines or code regulations, whichever requires more cfm, shall be followed.

14 .19.3.2.4.7 Hood Exhaust: Specific exhaust systems will be provided in the welding shop and for the individual brake lathes and grinders. Movable direct capture hoods will be provided at the welding

bench and at each grinding and cutting device. Hoods shall be designed to provide a capture velocity of not less than 150 feet per minute over the cross sectional area. Each hood shall be provided with a blast gate to allow balancing and shutoff. The exhaust duct system shall be designed to the SMACNA pressure class which the suction of the exhaust fan will generate at the "dead head" condition but in no case less than 5" w.g.

14 .19.3.2.5 HVAC Controls

14 .19.3.2.5.1 The control system shall be based on a distributive type Direct Digital Control (DDC), Building Management System (BMS). The system shall be capable of peer to peer communication on a primary or primary/secondary, BACnet ~~or Lontalk,~~ open protocol network. Access to the network shall be available through; a local workstation; a portable personal computer able to be plugged into the system devises; or remotely through the use of the Internet.

14 .19.3.2.5.2 The Internet access shall be made possible through the creation of a building specific Web Site. The control system shall be furnished with all software, programming, hardware and start-up services necessary for the implementation of the Web Site. The Web Site access shall all full BMS control form a remote personal computer without the need for additional software.

14 .19.3.2.5.3 All microprocessor controlled HVAC equipment shall be furnished with all necessary interface equipment and software necessary for full control and monitoring. This equipment would include but not be limited to boilers, chillers, variable frequency drives, air compressors and rooftop air conditioners.

14 .19.3.2.5.4 It is the intent that insomuch as possible the entire BMS will be electronic. All sensors and controls devises should be electronic. ~~Where torque requirements do not allow for the use of electronic actuators, electric actuators shall be used.~~

14 .19.3.2.5.5 In all areas where bus maintenance or service is to take place electronic diesel specific carbon monoxide (CO) monitoring shall be provided. The monitoring system shall directly initiate high fan speed operation of the space exhaust fans, initiate a local audio/visual alarm, and alarm the HVAC control system should a high CO level be sensed. The monitoring system shall be an aspirated type unless approved by engineering. The intent is to eliminate the need to access sensors at the ceiling and to provide for calibration of the sensors by replacement with pre-calibrated units. All maintenance items in the aspirated type units are at ground level.

14 .19.3.2.5.6 A hydrogen gas detection system shall be provided in the Battery Storage Room. The system shall initiate an audio/visual alarm and send an alarm signal to the BMS.

14 .19.3.2.5.7 A CNG detection system shall be provided in the Bus Garage and shall be connected into the BMS system.

14 .19.3.2.6 HVAC Design Guidelines: As follows:

SUMMARY OF HVAC CRITERIA				
SPACE	**HVAC SYSTEM**	**HEATING DESIGN CRITERIA**	**COOLING DESIGN CRITERIA**	**AIR CIRCULATION AND OUTSIDE AIR**
General office	HWH, RTAC	68 ~~70~~°F	75 ~~78~~°F/50%RH	1.0 CFM/SF circ. 20 CFM/person OA
Operations and Training Areas	HWH, RTAC	68 ~~70~~°F	75 ~~78~~°F/50%RH	1.0 CFM/SF circ. 20 CFM/person
Corridors (in general areas)	HWH, RTAC	68 ~~70~~°F	75 ~~78~~°F/50%RH	0.5CFM/SF circ. 0.1CFM/person OA
Electrical Shop	HWH, RTAC	68 ~~70~~°F	75 ~~78~~°F/50%RH	0.5CFM/SF circ. 0.1CFM/person OA
Locker Rooms	HWH, RTAC	68 ~~70~~°F	75 ~~78~~°F/50%RH	(see Section 14.19.3.2.4.6.7)
Air Conditioning	HWH, RTAC	68 ~~70~~°F	75 ~~78~~°F/50%RH	(see ASHRAE)
Service Lanes & Maintenance Areas	HWH, ADH	65°F	N/A	4 ACH general OA 8 ACH rooftop exhaust
Storage Rooms	HWH	65°F	N/A	6 ACH exhaust
Air Compressor and Electrical Room.	HWH	65°F	N/A	Maintain below 90°F
Battery Charge Room	HWH	65°F	N/A	Maintain 1% or less hydrogen gas ~~15 ACH exhaust~~
Boiler Room	HWH	65°F	N/A	10 CFM/boiler HP
Break Lathe				Industrial ventilation handbook
Welding Room				Industrial ventilation handbook
Paint Booth				100FPM across the cross sectional area
Repair Shop				Std. 15
Tail Pipe Exhaust				600 cfm per connection

ABBREVIATION LIST

HWH	Hot Water Heat
RTAC	Rooftop Air Conditioning
ADH	Above Door Heater (Hot Water)
RH	Relative Humidity
CIRC	Circulation
OA	Outside Air
ACH	Air Change Per Hour
HP	Horse Power
N/A	Not Applicable
CFM	Cubic Feet Per Minute
SQ. FT.	Square Foot
FPM	Feet Per Minute

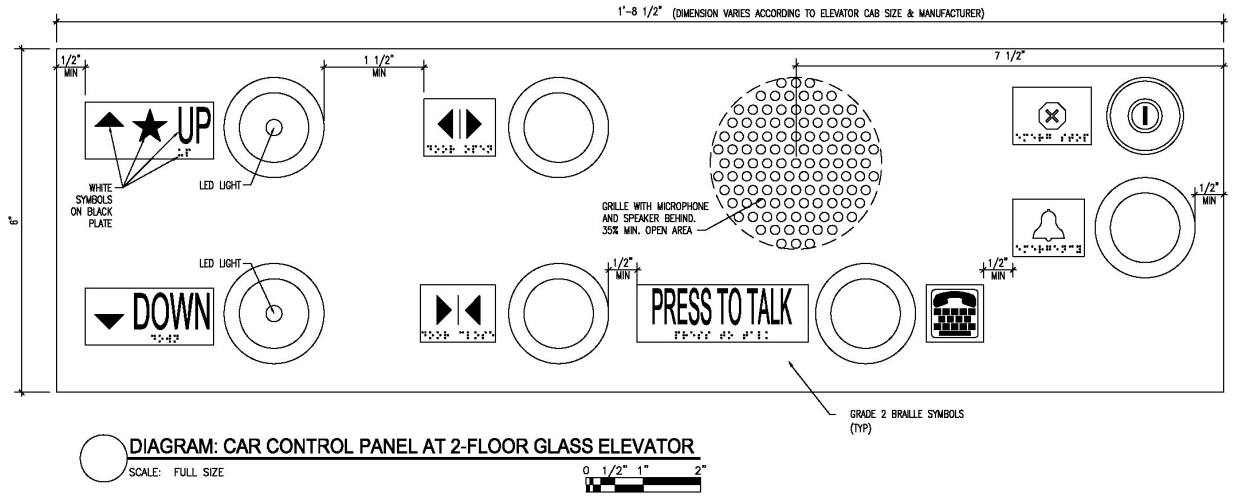

1'-8 1/2" (DIMENSION VARIES ACCORDING TO ELEVATOR CAB SIZE & MANUFACTURER)
1/2" MIN
1 1/2" MIN
7 1/2"
UP
WHITE SYMBOLS ON BLACK PLATE
LED LIGHT
GRILLE WITH MICROPHONE AND SPEAKER BEHIND. 35% MIN. OPEN AREA
LED LIGHT
DOWN
PRESS TO TALK
GRADE 2 BRAILLE SYMBOLS (TYP)
DIAGRAM: CAR CONTROL PANEL AT 2-FLOOR GLASS ELEVATOR
SCALE: FULL SIZE
0 1/2" 1" 2"

FIGURE 14.1

SECTION 15 - STRUCTURAL

15 .1 GENERAL

These criteria shall govern the analysis and design of all structures which are part of the Washington Metropolitan Area Ttransit Authority (WMATA) system, including structures which are auxiliary to the system or support the system.

15 .1.1 DESIGN LIFE - It is the intent of the Authority that all structures provide a minimum design life of 100 years. Prestressed Parking Garage Structures shall have a minimum design life of 50 years. All structural details shall be prepared with these durability requirements. Prediction of life of concrete structures may be performed using the guidelines of American Concrete Institute (ACI) 365.

15 .1.2 INSPECTION AND MAINTENANCE - Structural configuration and details shall permit reasonable access and a fall protection system required for inspection and maintenance consistent with the requirements of the structure in question. Fall protection design shall be in compliance with OSHA requirements.

15 .1.3 DESIGN RESPONSIBILITIES - Design responsibilities shall be as defined in the contract documents. In this section, whenever section designers is mentioned it will also mean the Engineer of Record of the design/build contractor team.

15 .1.4 OCCUPANCY (RISK) CATEGORY OF BUILDING AND OTHER STRUCTURES - All buildings and other structures in WMATA system including auxiliary or supporting structures shall be classified as Occupancy (Risk) category III for Flood, Wind, Snow, Earthquake, and Ice loads per IBC (ASCE 7).

15 .2 DESIGN CODES, MANUALS AND SPECIFICATIONS

In addition to the requirements stipulated in this "Manual of Design Criteria", structural design shall also be governed by the ***Applicable Edition*** of the following codes, manuals or specifications. Unless noted otherwise, most stringent criteria as delineated in the "Manual of Design Criteria" or in the applicable code(s) shall be used. ***Applicable Edition*** of a code shall mean the most current edition published at the time of initiation of design, edition of code per jurisdictional requirement, edition of code required per contract documents, edition of code negotiated with WMATA representative, or edition of code used for design of an existing structure.

15 .2.1 Design Codes

15 .2.1.1 "Manual for Railway and Maintenance-of-Way Engineering" (published by American Railway Engineering and Maintenance-of-Way Association (AREMA)), hereinafter referred to as the AREMA Manual.

15 .2.1.2 American Association ~~for~~ of State Highway and Transportation Officials (AASHTO) Specifications including the Standard Specifications for Highway Bridges (hereinafter referred to as the AASHTO Code), and other pertinent AASHTO codes and specifications.

15 .2.1.3 "International Building Code" (published by the International Code Council) with Local Amendments - hereinafter refered to as IBC or IBC Code.

15 .2.1.4 "Manual of Concrete Practice" published by the American Concrete Institute, hereinafter referred to as ACI, including the "Building Code Requirements for

Structural Concrete (ACI-318) and Commentary (ACI 318R)" hereinafter referred to as the ACI 318 Code.

15 .2.1.4.1 For above ground concrete structures (plain concrete, reinforced concrete, precast concrete, and prestressed concrete), other than bridges or structures subject to railroad, highway or Metro loading, the latest edition of the ACI "Building Code Requirements for Reinforced Concrete(ACI 318)" shall be used.

15 .2.1.4.2 For all underground concrete structures, earth retaining sturctures, ACI 318-99 containing the "Alternate Design Method" shall be used. The proposed design method shall be coordinated with the Authority before starting the design.

15 .2.1.5 "Manual of Steel Construction - Allowable Stress Design" by American Institute of Steel Construction, Inc., hereinafter referred to as the AISC Code.

15 .2.1.5.1 For structural steel structures, other than bridges subjected to railroad or highway loading, the current edition of the "Manual of Steel Construction Allowable Stress Design" of the American Institute of Steel Construction, hereinafter referred to as the AISC Code.

15 .2.1.5.2 For parking structures, composite structural steel and concrete construction shall not be used. Stay in place steel form construction shall not be used. See Sections 15.9.3.2.3 and 15.21 for parking structures.

15 .2.1.6 The current edition of the "American Society of Civil Engineers Minimum Design Loads for Building and Other Structures", hereinafter referred to as the ASCE 7.

15 .2.1.7 In addition to the above "The latest Building Codes of the local jurisdiction, supplemented by any WMATA requirements, shall apply."

15 .2.1.8 Any special applicable requirements or codes, not listed above and in Metro Criteria should be considered only with the approval of the Authority.

15 .2.1.9 "National Design Specification for Wood Construction" of the National Forest Products Association shall apply for timber structures, other than railroad or highway bridge.

15 .2.1.10 Cast Iron - For cast iron structures, the current edition of "The Gray Iron Castings Handbook" of the Gray Iron Founders' Society.

15 .2.1.11 American Welding Society (AWS) Welding Codes D 1.1, D 1.4 and D 1.5.

15 .2.2 Other Design Criteria - For designs not covered by the ~~Building Codes~~ design codes in 15.2.1 above, the following shall be used:

15 .2.2.1 Railroad Bridges - For bridges, which support railroad loading, the design requirements of the applicable railroads. In the absence of such requirements, the current edition of ~~the "Manual for Railway and Maintenance-of-Way Engineering", hereinafter referred to as~~ the AREMA Manual, per Section 15.2.1.1.

15 .2.2.2 Highway Bridges - For bridges, which support highway loading, the design requirements of the applicable jurisdiction. In the absence of such requirements, the current edition of ~~the "Standard Specifications for Highway Bridges" of the~~

~~American Association of State Highway and Transportation Officials, hereinafter referred to as~~ the AASHTO Code, per Section 15.2.1.2.

15 .2.2.3 Earth Embankments - For earth structures, the AREMA Manual.

15 .2.2.4 Concrete - For above ground concrete structures (plain concrete, reinforced concrete, precast concrete, and prestressed concrete), other than bridges or structures subject to railroad, highway or Metro loading, the latest edition of the ACI "Building Code Requirements for Reinforced Concrete(ACI 318)" shall be used. For all underground concrete structures and earth retaining structures, ACI 318-99 containing the "Alternate Design Method" shall be used. The proposed design method shall be coordinated with the Authority before starting the design.

15 .2.2.5 Structural Steel

15 .2.2.5.1 For structural steel structures, other than bridges subjected to railroad or highway loading, AISC Code (see Section 15.2.1.5).

15 .2.2.5.2 For parking structures, composite structural steel and concrete construction shall not be used. Stay in place steel form construction shall not be used. See Sections 15.9.3.2.3 and 5.21 for parking structures.

15 .2.2.6 Timber - For timber structures, other than bridges subjected to railroad or highway loading, the current edition of the "National Design Specification for Wood Construction" of the National Forest Products Association

15 .2.2.7 Cast Iron - For cast iron structures, the current edition of "The Gray Iron Castings Handbook" of the Gray Iron Founders' Society.

15 .3 LOADS AND FORCES

The rapid transit structures shall be proportioned for the following loads and forces when they exist:

15 .3.1 Dead Load (DL)

15 .3.1.1 Structures Constructed by Cut and Cover Methods:

15 .3.1.1.1 The dead load for structures constructed by cut and cover methods shall consist of the weight of the basic structures, the weight of secondary elements permanently supported by the structure, and the weight of the earth cover supported by the top of the structure and acting as a simple gravity load.

15 .3.1.1.2 The design shall consider the application of the dead load to represent all the construction sequence and stages . For example, removal of the earth cover from a prestressed concrete span at some future date may create a serious upward deflection problem and should be analyzed as a separate loading case.

15 .3.1.1.3 The design unit weight of earth, both above and below the groundwater table, shall not be less than 130 pcf. In making calculations with regard to dead weight resisting flotation of the structure, the actual unit weight of backfill placed over the structure shall be used. In those cases where full hydrostatic pressure below the groundwater table is used as a design load, a submerged design unit weight of not less than 68 pcf shall be used for earth below the groundwater table.

15 .3.1.2 Earth and Mixed Face Tunneled Structures - The loads for earth tunnels, mixed face tunneles, and cut and cover structures shall be as given in the Designer's Geotechnical Design Report (GDR) approved by WMATA. For construction and short term loading cases with lesser lateral loads, refer to the GDR and Figure 15.17, whichever governs. The overburden should include any weight of existing structures or other elements, permanently supported by tunneled structure. Also, the unit weight of earth shall not be less than 130 pcf, except the actual weight of earth should be used for buoyancy check .

15 .3.1.3 Rock Tunnel Structures - For construction and long term loading cases, refer to the Geotechnical information and the Designer's (GDR) approved by WMATA and Figure 15.4 thru Figure15.8 and Table 15.1 whichever governs .

15 .3.1.4 Minimum Earth Cover for Design

15 .3.1.4.1 All underground structures other than cut and cover arch roof sections shall be designed for the actual cover depth but not less than 8'-0".

15 .3.1.4.2 Cut and cover arch roof sections shall be designed for actual cover depth. When the actual cover depth is less than 4'-0" at the crown, the arch roof shall be designed for (a) an assumed minimum cover depth of 4'-0" at the crown and (b) a minimum average depth of 8'-0" over the entire cross-section.

15 .3.1.4.3 Unless otherwise instructed, structures under private properties shall also conform to these criteria.

15 .3.1.5 Loads from Adjacent Building Foundations or Other Structures

15 .3.1.5.1 As noted in Section 15.7.3.2., the Contractor shall determine the need for permanent underpinning of all buildings or structures not in Zone A .

15 .3.1.5.2 Designs of all underground structures shall be based on the assumption that Zone B structures will not be underpinned.

15 .3.1.5.3 Considerations shall be given to the maximum and minimum loads which can be transferred to the designed structure and design loads shall be assumed to be as those for which the adjacent structure was designed. In the absence of specific information, provisions in the applicable building code or the actual weights and the heaviest occupancy for which the building is suitable shall be used.

15 .3.1.5.4 Horizontal and vertical distribution of loads from foundations of existing buildings shall be determined in consultation with the Designer's geotechnical consultant.

15 .3.1.6 Above Ground Structures - The dead load for aboveground structures shall consist of the weight of the basic structure and the weight of secondary elements permanently supported by the structure.

15 .3.1.7 Miscellaneous Loads - Consideration shall be given to any system or facility which will apply a permanent load or force to the design structure.

15 .3.1.8 Design Weights of Materials - The design weights of materials shall be as listed in IBC. For those not listed the best available technical information shall be used and its source or reference shown or provided in calculations.

15 .3.2 Live Load (LL) - Live load, excluding impact (for impact see Section 15.3.3) shall consist of any non-permanent gravity load placed on the structure:

15 .3.2.1 Rapid Transit Loading See Figure 15.1 for car dimensions and weights. Any combination of train lengths and loadings which produces the critical design loading shall be used for structural design.

15 .3.2.2 Crane Car Loading - See Figure 15.2 for car dimensions and weights.

15 .3.2.3 Highway Loading for WMATA Structures

15 .3.2.3.1 Highway Loading On WMATA Highway Bridge Structures shall be in accordance with the requirements of the AASHTO . Loading HS 25 for all bridges with spans 35 feet and over. Loading HS 27 for all bridges with simple spans less than 35 feet in length as shown in Figure 15.18. If the bridge is connecting two different jurisdictions, the more conservative requirements shall apply.

15 .3.2.3.2 Highway Loading on Underground Rapid Transit Structures: the roadway live loads on underground rapid transit structures shall be based on the HS25 loading shown in Figure 15.18. HS 25 Wheel loads shall be distributed in accordance with the AASHTO Specifications to a maximum depth of four feet. Between 4 feet and 8 feet a graduated uniform live load of 550 psf to 300 psf shall be used. The depth is to be measured to the top of the underground structure's roof slab. Unless otherwise instructed, structures constructed under private properties shall conform to this criterion. The more severe of the following two conditions shall govern (see Section 15.3.1.4. "Minimum Earth Cover for Design").

15 .3.2.3.2.1 The actual depth of cover plus superimposed HS25 wheel load distributed in accordance with the above requirement.

15 .3.2.3.2.2 An assumed future cover of 8' plus a uniform live load of 300 psf.

15 .3.2.4 Pedestrian Areas including Station platforms, Stairways, Pedestrian Bridge, Pedestrian ramps, mezzanines, and other pedestrian areas shall be designed for a uniform live load of 150 psf (no area reduction factor allowed). Stairs shall also be checked for a minimum concentrated load of 300 lbs (on area of 4 square inches) on stair treads. In the District of Columbia, stair treads only shall be designed for a uniform load of 100 psf plus a concentrated load of 300 pounds.

15 .3.2.5 Storage Space and Machinery Rooms - Electrical equipment rooms, pump rooms, service rooms, storage space and machinery rooms shall be designed for a uniform load of 250 psf, to be increased if storage or machinery loads dictate. The loads for which such rooms are designed shall be stated on the structural drawings.

15 .3.2.6 Escalators and Passenger Conveyors

15 .3.2.6.1 Structures supporting escalators or passenger conveyors shall be designed for the maximum reactions imposed by the equipment installed. The reactions are provided in the WMATA Manual of Design Criteria Facilities, Section 14 .

15 .3.2.6.2 The ~~is~~ design of the structural supporting elements shall be as stipulated in the WMATA Manual of Design Criteria Facilities, Section 14.

15 .3.2.7 Parapets and Railings

15 .3.2.7.1 Concrete parapets in station platform and mezzanines shall be designed for a horizontal load of 150 plf and vertical load of 100 plf at their top. Railings and guardrails in station platform, mezzanines and on enclosed pedestrian bridges shall be designed to resist a load of at least 200 pounds applied in any direction at any point of the top rails or a vertical and horizontal load of 50 pounds per lineal foot applied at the top rails ~~ing~~, whichever produces the worst condition.

15 .3.2.7.2 Railings in other places of public assembly shall be designed in accordance with local codes. Railings in equipment rooms and working areas shall be designed for a 200 pound load applied in any direction at any point except for removable railings in ancillary spaces, which shall be excluded from 200 pound uplift.

15 .3.2.8 Gratings - Ventilation shaft gratings should not be located in roadways, whenever possible. Where unavoidable, vent gratings loacted in a street or in sidewalk shall be designed to carry HS 25 loading in accordance with AASHTO Specifications. Gratings protected from vehicular traffic shall be designed for a uniform load of 250 psf. Gratings which might be subjected to loading from out-of-control vehicles shall be designed for HS 25 loading.

15 .3.2.9 Curbs - A horizontal force of 500 plf shall be applied at the top of curbs on permanent structures.

15 .3.2.10 Safety walks - Safety walks shall be designed for a uniform load of 85 psf of walkway area.

15 .3.2.11 Live Load On Parking Structures - See Section 15.21.1.1.

15 .3.2.12 Other Structures - Structures not listed in Section 15.3.2 shall use IBC live loadings.

15 .3.2.13 Roof Live Load - The minimum roof live load shall be 30 Pound per Square Foot (psf), applied to the horizontal projection of the roof.

15 .3.2.14 Wind Load - The minimum basic (nominal) wind speed shall be 105 mph (3-Second Gust, Vasd=105 mph).

15 .3.3 Impact (I) - Impact loads are statically equivalent dynamic loads resulting from vertical acceleration of the live loads:

15 .3.3.1 Impact considerations for aerial structures supporting rapid transit loading are covered under "Design of Rapid Transit Aerial Structures" in this section.

15 .3.3.2 Design for the top slab of underground rapid transit structures supporting roadway loading shall conform to the following:

15 .3.3.2.1 0'-0" to 1'-0" earth cover I = 30% LL
15 .3.3.2.2 1'-1" to 2'-0" earth cover I = 20% LL
15 .3.3.2.3 2'-1" to 3'-0" earth cover I = 10% LL
15 .3.3.2.4 Greater than 3'-0" earth cover I = 0% LL

15 .3.3.2.5 The depth of cover shall be measured from the top of ground or paving to the top of the underground structure.

15 .3.3.3 Structures supporting special vehicles, equipment, or other dynamic loadings which cause significant impact shall conform to the Building Code of the locality or , if not covered by Code, shall be considered individually using the best technical information available.

15 .3.3.4 Impact shall not be considered for stairways, mezzanines, station platforms, or other pedestrian areas.

15 .3.4 Centrifugal Force (CF) - On curves a percentage of the rapid transit loading per track equal to .0012 x speed^2 (MPH) x degree of curvature (degree) shall be applied horizontally 5 feet above the top of low rail, on all tracks. The degree of curvature is the angle in degrees, subtended by a 100 foot arc.

15 .3.5 Rolling Force (RF) - A force equal to 10% of the rapid transit loading per track shall be applied downwards on one rail and upwards on the other, on all tracks.

15 .3.6 Longitudinal Braking and Traction Force (LF) - A force equal to 15% of the rapid transit loading per track shall be applied 5 feet above the top of rail on all tracks. Consideration is to be given to combinations of acceleration and deceleration forces where more than one track occurs.

15 .3.6.1 For double track structures, three longitudinal loading cases shall be considered:

15 .3.6.1.1 Single track loaded. Train Accelerating or decelerating.

15 .3.6.1.2 Both tracks loaded. One train accelerating, one decelerating. Longitudinal forces from both trains acting in the same direction.

15 .3.6.1.3 Both tracks loaded. Both trains accelerating or decelerating. Longitudinal forces acting in opposite directions.

15 .3.7 Horizontal Earth Pressure (E) - Structures which retain earth shall be designed for side pressure due to earth abutting against the structure, load surcharges resting on abutting earth, and hydrostatic pressure below the groundwater table.

15 .3.7.1 Rapid transit loading ~~may~~ shall be assumed as a uniform surcharge equal to three additional feet of earth. Such surcharge shall be extended uniformly to the face of the retaining wall (between stem walls).

15 .3.7.2 Live and dead loads from adjacent foundations shall be considered in computing horizontal pressures.

15 .3.7.3 Where railroad loading occurs, the surcharges shall be determined by the AREMA Manual, Chapter 8, Part 5.

15 .3.7.4 Hydrostatic pressure shall be computed at 62.5 pounds per square foot per foot of depth below groundwater table. Site groundwater elevation to be established based on field measurements. Groundwater elevation to be used for design to include an additional height to reflect variation likely to occur within the design life of the structure but not less than five feet, subject to Authority review and

approval. Regardless of the presence of sub-drainage systems, structures shall be waterproofed and designed to resist full hydrostatic pressure.

15 .3.7.5 The rock pressure to be used in design shall be established by the designer and approved by WMATA. For loading conditions see Figure 15.4 to Figure 15.8 and Table 15.1.

15 .3.7.6 Lateral earth pressures shall be calculated using At-Rest lateral earth pressure coefficient.

15 .3.8 Buoyancy (B) - Buoyancy shall be considered as it affects the design and construction of any structure. During construction and backfill operations the elevation of groundwater shall be observed and controlled so that the calculated total weight of structure and backfill shall always exceed the calculated uplift due to buoyancy by at least 10 percent.

15 .3.9 Flood (FL) - Floods may add loads to subaqueous structures or structures in the flood plain. Anticipated flood elecation shall be determined by a study of official flood records. Design of the structures should make allowance for this loading as required by the particular type of structure and the conditions affecting each location.

15 .3.10 Other Loads and Forces - Other loads and forces to be considered, including wind loads, shrinkage and thermal forces, friction, seismic and rail/structure interaction loads are covered under Section 15.5 "Design of Rapid Transit Aerial Structures."

15 .3.10.1 Wind Loading of Open-Air Station Roof/Ceilings - The wind loading on open-air ceilings shall be in accordance with the IBC. The elements required to resist the wind uplift load shall be anchored to the foundation. A maximum of two-thirds of the dead load shall be considered in determining the resistance to the uplift load. Uplift in excess of the total reduced loads shall be resisted by foundation anchorage.

15 .4 DESIGN OF ~~PROCEDURES -~~ EARTH RETAINING STRUCTURES

15 .4.1 Earth pressures and other soil constants shall be determined in consultation with the Designer's geotechnical consultant and approved by WMATA. . Unless established by site specific testing and verified with laboratory data, the soil parameters shall not exceed the limits given by the local building code, as applicable, and Section 15.5.1.7 which ever governs.(See Section 15.6 for Soil & Geological Criteria)

15 .4.2 All earth retaining structures shall be classified in one of the categories, along with their design requirements, listed below.

15 .4.2.1 Reinforced Concrete Box and Arch Station - These structures retain earth but are not free to yield significantly. As a minimum, three basic loading cases shall be investigated at working stress levels. Additional permanent, temporary and construction loading cases shall be investigated as required by the particular circumstances.

15 .4.2.1.1 Case I - Full vertical and long-term horizontal load, as recommended by the Designer's geotechnical consultant, and as shown in Figure 15.20 whichever governs.

15 .4.2.1.2 Case II - Full vertical load, long-term horizontal load on one side and short-term horizontal load on the other side, as recommended by the Designer's geotechnical consultant , and as shown in Figure 15.20 whichever governs.

15 .4.2.1.2.1 In underground concrete box structures which could be subjected to unequal lateral pressures, the structural analysis shall consider the top slab as both restrained and unrestrained against horizontal translation in arriving at maximum shears, thrusts, and moments.

15 .4.2.1.3 Case III - Full vertical load with short-term horizontal load neglecting groundwater pressure on both sides, as recommended by the Designer's geotechnical consultant, and as shown in Figure 15.20 whichever governs.

15 .4.2.1.3.1 For stress analysis, variations in the elastic support of the subgrade shall be considered for the different loading cases as appropriate.

15 .4.2.1.3.2 For design, the horizontal earth pressure distribution diagram may be rectangular, giving a total load on the sides of the structure equivalent to the load produced by an assumed trapezoidal pressure diagram.

15 .4.2.1.3.3 Compression forces shall not be considered in shear design of the top and bottom slabs in box section.

15 .4.2.1.4 Use of precast shallow cut-and-cover box tunnel require prior WMATA approval. The following additional requirements shall be satisfied:

15 .4.2.1.4.1 Invert must be designed as cast in place reinforced concrete and fully cured Precast reinforced concrete walls and roof must be match-cast and the segments post-tensioned into minimum 300 feet long units with a minimum uniform pre-compression of 300 psi before permanent connection to the invert .

15 .4.2.1.4.2 Connection to the invert must be tightly grouted and designed to withstand vibrations, uplift and air pressure from running trains (see Section 15.5.1.7).

15 .4.2.1.4.3 All joints must be sealed and entire box must be waterproofed all around with an Authority approved waterproofing membrane.

15 .4.2.1.4.4 In arch sections, compression forces may be considered both in invert and arch.

15 .4.2.1.5 The design of station arch sections shall be directed toward obtaining maximum economy, considering the costs of both the permanent structure elements and the Contractor's proposed method of construction .

15 .4.2.1.6 The Contractor shall be given the option of selecting the arch construction method in his bid. Support of excavation is to be designed by the Contractor to accommodate the arch construction option selected. Arch construction options are shown on Figure 15.3.

15 .4.2.1.7 In Option A, the lower section of the arch is loaded as a cantilever prior to the construction of the upper section . Considerations shall include:

15 .4.2.1.7.1 allowable increase in stresses due to the temporary nature of the loading
15 .4.2.1.7.2 creep in the concrete
15 .4.2.1.7.3 effect of soil arching
15 .4.2.1.7.4 arch flexibility

15 .4.2.1.8 Option B may be implemented by use of tieback support of excavation or, after placement of the slab or grade, by removing struts as necessary to clear the arch, on by strutting the lower section of the arch. The construction specification shall stipulate that if the Contractor proposes strutting of the lower section of the arch, the working drawings he submits for approval must reflect proper consideration of such aspects as magnitude of reload in replacement struts, thermal or stress-induced strain in the struts, crushing of packing, and induced stress and deflection of the permanent structure. The Contractor's proposal shall detail the proposed instrumentation and monitoring to ensure the permanent structure will not be over-stressed or otherwise damaged.

15 .4.2.1.8.1 The Contractor shall submit, , working drawings for the option selected for approval . The working drawings shall include supporting computations for all governing loading cases during construction and the order of procedure proposed. In all cases, the specifications for support of excavation must reflect any limitations inherent in the design of the permanent structure. The Designer shall show on the General Notes sheet/sketch, similar to those shown on Figure 15.3. illustrating construction basis for the design.

15 .4.2.2 Reinforced Concrete Rigid Earth Tunnel Sections

15 .4.2.2.1 The method of driving these tunnels is proposed to be full shield for the circular section. Temporary tunnel support will be provided by precast concrete lining and permanent support by cast-in-place concrete lining.

15 .4.2.2.2 These sections shall be designed as rigid structures using working stress design methods, per Section 15.2.2.4. Horizontal earth pressure shall be calculated using an earth pressure factor established in consultation with the Designer's geotechnical consultant and approved by WMATA.

15 .4.2.2.3 The structural design shall be checked by ultimate strength design methods using a load factor of one. The maximum concrete stress, considering rectangular stress distribution, shall not exceed 85% of the required 28-day concrete strength. Two horizontal earth pressure factors, 0.45 and 1.00, shall be used in these check analyses.

15 .4.2.3 Flexible Earth Tunnel Sections - See Section 15.10.2 ., One Pass System Circular Earth Tunnels

15 .4.2.4 Permanent Retaining Walls

15 .4.2.4.1 Reinforced Concrete Retaining Walls - Retaining walls shall be designed on the basis of specific soils information relating to the backfill material and in accordance with the procedures outlined in the AREMA Manual, Chapter 8, Part 5. The ~~footings of the~~ retaining walls shall be designed using working stress design methods, per Section 15.2.2.4.

15 .4.2.4.1.1 Retaining wall shall be designed with shear key and water stops at expansion, construction and contraction joints.

15 .4.2.4.2 External Stability of Wall System

15 .4.2.4.2.1 Stability of the retention system as a whole must satisfy three conditions: The factors of safety against sliding and overturning must be adequate; the soil pressure beneath the toe of the foundation must not exceed the allowable soil pressure; and differential settlements of the foundation must not be excessive.

15 .4.2.4.2.2 Safety Against Sliding

15 .4.2.4.2.2.1 Sliding of a retaining wall is resisted by the friction between the soil and base and by the passive earth pressure of the soil in contact with the outer face of the foundation.

15 .4.2.4.2.2.2 The factor of safety against sliding is equal to horizontal resisting forces divided by the horizontal component of the backfill pressures, which should be at least 1.5. The friction between the base and clean sand or silty sand is equal to the effective normal pressure on the base times the tangent of the friction angle ∅ between soil and base. The value of ∅ may be taken as 30° for a coarse-grained soil containing no slit or clay, and as 24° for a coarse-grained soil containing silt. The value of ∅ between sand and underlaying clay can be assumed as 20°. The passive resistance in front of the wall shall be disregarded unless approved otherwise by the Authority.

15 .4.2.4.2.3 Safety Against Overturning - The factor of safety against overturning is determined by dividing the sum of moments of forces tending to resist rotation of the wall about the center of rotation of the wall/footing by the sum of moments of forces tending to produce the overturning. A factor of safety of at least 1.5 is required . If walls rest on a highly compressible or cohesive soils, based on the information and the Designer's Geotechnical Design Report, a minimum factor of safety of 2 shall be provided.

15 .4.2.4.2.4 Allowable Soil Pressure and Settlement - The maximum base pressure at the toe of the wall will be limited by the allowable bearing capacity of the soil. The foundation/footing should be designed such that the point of application of the resultant force is within the middle third.

15 .4.2.4.2.5 Overall Stability -where retaining walls are underlain by weak soils (Θ<25º), the overall stability of the mass containing the retaining wall shall be checked with respect to the most critical surface of sliding. A minimum factor of safety of ~~2~~ 3 is required.

15 .4.2.4.3 Reinforced Earth/Mechanically Stabilized Earth: This system may be used only after prior approval of the Authority.

15 .4.2.4.3.1 Reinforced Earth (RE) and Mechanically Stabilized Earth (MSE) walls shall be designed in accordance with the current requirements of the AASHTO Standard Specifications for Highway Bridges and as supplemented by the criteria and requirements below.

15 .4.2.4.3.2 Design Life of walls shall be minimum 100 years; with minimum 5-year warranty period on wall system, during which annual inspections shall be performed by the engineer of record or authorized agent.

15 .4.2.4.3.3 RE/MSE wall supplier shall be the engineer of record for the RE/MSE wall design, and shall be responsible for internal, external and global stability design including allowable bearing capacity. Supplier shall certify that wall installation conforms to approved design.

15 .4.2.4.3.4 RE/MSE wall supplier shall provide the following for WMATA approval:

15 .4.2.4.3.4.1 With Proposal package:

Complete specifications identifying

Design parameters (including minimum required soil bearing capacity)

Materials and design properties

Installation methods

Catalog cuts

Equipment list

Sample calculations for tallest wall section (including internal, external and global stability calculations, and settlement calculations for which design/builder will be fully responsible)

QC Plan and QC Staff

Cost Loaded Bar Chart Schedule showing planned start and finish dates of activities and associated costs

Identification of limit of work and access through site.

Method of controlling differential settlement along the wall based on the available soil boring information. (To include at least the minimum requirements in Section 15.4.2.4.3.7 below.)

Monitoring program to monitor potential settlements and other wall movements.

Schematic design of drainage system to control, collect and discharge water from behind the wall.

Design for corrosion protection of steel elements.

15 .4.2.4.3.4.2 Prior to Construction :

15 .4.2.4.3.4.2.1 Final calculations with P.E. stamp (including internal, external and global stability calculations, and settlement calculations).

15 .4.2.4.3.4.2.2 Shop Drawings

15 .4.2.4.3.4.2.3 Details of drainage system to control, collect and discharge water from behind the wall.

15 .4.2.4.3.5 RE/MSE wall design/constructor must demonstrate the groundwater and soil corrosive properties at the site, including pH, will not affect the performance and service life of the wall.

15 .4.2.4.3.6 Backfill:

15 .4.2.4.3.6.1 Backfill for undercut shall be Virginia DOT Stone No. 57 as specified in the latest edition of Virginia Department of Transportation Specifications, Road and Bridge Specifications, or equivalent.

15 .4.2.4.3.6.2 Backfill for reinforced earth volume: VDOT Stone No. 57 or Select Granular Backfill Material as specified below .

15 .4.2.4.3.6.3 Select Granular Backfill Material shall be free from organic and other deleterious material and conform to the following gradation limits:

% by Weight of Material	
U.S. Sieve Size	**Passing Sieve**
1½ in	100
½ in	25 - 60
No. 40	15 - 30
No. 200	0 - 5

15 .4.2.4.3.6.4 Plasticity Index (PI) for Select Granular Backfill Material shall not exceed 6.

15 .4.2.4.3.6.5 Random backfill beyond the limits of the reinforced earth volume shall meet the requirements for backfill in Standard Specification Section 2320 , Section 2.01.A. The pH for Random Backfill shall be between 5.0 and 8.0 .

15 .4.2.4.3.7 Subgrade Preparation: To control differential settlement along the length of wall, undercut within limits described below, place Tensar Geogrid BX1100 or WMATA approved equal on excavated surface, overlay geogrid with layer of geotextile fabric and fill with VDOT Stone No. 57.

15 .4.2.4.3.8 Limits of undercut:

15 .4.2.4.3.8.1 Length: The entire length of the wall.

15 .4.2.4.3.8.2 Width: Equal to or greater than the length of the reinforcing elements behind the wall, and in front of the wall to a distance

from the edge of the leveling pad equal to or greater than the depth of undercut.

15 .4.2.4.3.8.3 Depth: Minimum 3 feet, but shall be increased in areas of weak soil if shown in soil boring reports, so that differential settlement is eliminated or reduced to a negligible amount. If unstable or poort soil conditions are encountered during excavation, the engineer of record shall propose a solution; any resulting additional work and material, such as undercut, rip rap, fabric and, fill will be paid as a unit price item.

15 .4.2.4.4 RE/MSE wall supplier shall provide the following minimum factors of safety (FOS):

External Stability	Minimum FOS
Sliding	2.0
Overturning	2.7
Global Stability (Overall depth/Deep seated slope stability)	1.7
Bearing Capacity	2.5
Pullout Resistance	2.0

15 .4.2.4.5 Wall face:

15 .4.2.4.5.1 Reinforced Concrete Panels are preferred.

15 .4.2.4.5.2 Minimum concrete strength at installation shall be 4000 psi.

15 .4.2.4.5.3 Alignment of panels and construction of wall face shall provide a true vertical plane with uniform surface after deflection. Precast tolerances and erection tolerances shall be coordinated.

15 .4.2.4.5.4 A minimum of 2 layers of steel reinforcing per panel with maximum vertical spacing of 30" on centers shall be provided. Panels shall be adequately reinforced for flexure.

15 .4.2.4.5.5 All panels shall be keyed to each other (shear connection).

15 .4.2.4.6 Concrete Block Wall may be used as an alternate, with WMATA approval.

15 .4.2.4.6.1 Minimum strength of concrete block at installation shall be 4000 psi.

15 .4.2.4.6.2 Alignment of blocks and construction of wall face shall provide a true vertical plane with uniform surface after deflection. Precast tolerances and erection tolerances shall be coordinated.

15 .4.2.4.6.3 Place steel reinforcement on 16" centers vertically (every other course) for 8" block. Place steel reinforcing in the course of every other block in the horizontal direction. On the course of blocks in between, place an intermediate reinforcing layer of continuous geotextile or geogrid extending a minimum 8 feet length into backfill behind wall. All blocks shall be doweled to each other.

15 .4.2.4.6.4 The steel reinforcing shall be designed to provide the full structural support, neglecting any contribution from the geotextile or geogrid, which shall be assumed to provide the facial stability only.

15 .4.2.4.6.5 Inextensible Reinforcements: RE/MSE walls to be retained with inextensible reinforcement.

15 .4.2.4.6.5.1 Reinforcement Material: Steel, hot-dipped Galvanized after fabrication.

15 .4.2.4.6.5.2 Minimum layers and spacing in accordance with Section 15.4.2.4.6.3 above.

15 .4.2.4.6.5.3 Minimum length > 1.0 x H (wall height)

15 .4.2.4.6.6 Settlement:

15 .4.2.4.6.6.1 No settlement 3 months after completion of the wall. Surcharge wall as needed to accelerate settlement.

15 .4.2.4.6.6.2 Allowable during construction, as long as an approved monitoring and remediation program can be implemented without compromising the project schedule.

15 .4.2.4.6.6.3 Design/Construction documents shall include provisions such as subgrade preparation to limit settlement. See Subgrade Preparation Section 15.4.2.4.3.7 above.

15 .4.2.4.6.7 RE/MSE wall shall be designed to support a traffic barrier and moment slab withstanding AASHTO loading and deflection due to fire truck (WB-50). Traffic barrier shall be capable of accommodating future site lighting pole shown on plans.

15 .4.2.4.6.8 Provide effective permanent drainage including necessary drainage blankets in back of and behind the reinforced zone, and other internal drainage elements, to eliminate seepage from behind the wall. Drainage from behind the wall shall be controlled, collected and discharged from common point(s).

15 .4.2.4.6.9 Detailed design for corrosion protection (100 year minimum) of any steel elements in the system including consideration of stray current, aggressive elements infiltrating from surface flows and groundwater flows. All steel elements in the system must be hot-dipped galvanized.

15 .4.2.4.6.10 Design/Construction shall accommodate installation of planned subsurface utilities, such as ballast drains, cable trenches,

ductbanks, light pole foundations and storm drain pipes; without decreasing wall performance/service

15 .4.2.4.6.11 RE/MSE wall supplier shall provide a full time inspector during wall construction. Inspector shall provide daily reports through the Contractor. Reports shall include, but not be limited to, pre-placement, placement, and post-placement inspection records of precast panels.

15 .4.2.5 Linings for Structures Tunneled in Rock

15 .4.2.5.1 For each rock tunnel construction contract , the Designer shall prepare a Geotechnical Design Report, based on current subsurface information, describing the basis of the design, estimated loads on the lining and lining construction specifications.

15 .4.2.5.1.1 The design shall consider pressure mobilized by the resistance of the rock mass to the outward deflection of the lining. The recommended average properties of the rock elastic modulus are 100,000 psi in compression and 50,000 psi in shear. Crown grouting will be required to fill voids between the rock and the permanent lining. For horseshoe tunnels, crossovers and station structures, satisfactory drainage shall be provided behind the lining and hydrostatic pressures shall be assumed to be relieved. However, in cases where exploratory information indicates complete drainage may be impracticable, the design loading shall include an allowance for exterior hydrostatic pressures or alternatively, grouting will be required to reduce the permeability and expected inflow, and provide drainage . For horseshoe tunnels, crossovers and stations waterproofing shall be provided in the crown and side walls. In A hydrostatic pressure relief system will not be required for circular tunnels. However, full water proofing must be designed in all cases.

15 .4.2.5.2 Where exploratory information indicates drainage is necessary and practical to relieve hydrostatic pressure on the lining , provide drainage, spaced longitudinally as required. At each such location there should be four drains installed to a predetermined pattern. Also, specify the installation of additional drains if required by conditions encountered during construction. Generally, the drain holes shall be 3-inch diameter and be spaced 10 feet apart.

15 .4.2.5.3 The Designer shall specify tunneling method(s) and techniques to be employed based on the WMATA Tunneling Specifications.

15 .4.2.5.4 Tunnel Type

15 .4.2.5.4.1 Depending on size, two basic rock tunnel designs shall be considered:

15 .4.2.5.4.1.1 Running tunnels, including single and double track and crossovers with track centers not exceeding 14'-0".

15 .4.2.5.4.1.2 Station tunnels, including crossovers and transition sections when the crossovers and transition sections have more than 14'-0" distance between tracks.

15 .4.2.5.4.2 Design of Running Tunnel Linings

15 .4.2.5.4.2.1 Initial support are elements provided within the contract design to systematically support the anticipated rock conditions. Local support are additional elements, of a limited extent, required beyond the designed initial support to handle localized conditions as detected in the field. The design of the local support such as rock bolts, steel sets, shotcrete, and combination thereof, shall be specified as the Contractor's responsibility. The initial support shall be installed close to the face as soon as the heading is advanced and tight blocking shall be installed without delay. Assume a degree of rock loosening prior to construction of the permanent lining. In the design of the final lining, consider all loading cases, I, II, III, IV, and V as shown on Figures 15.4, 15.5, and 15.6 apply. Design for case V and check for adequacy in the other four cases. Hydrostatic pressure shall be considered for the design of circular tunnel linings.

15 .4.2.5.4.3 Design of Station Linings

15 .4.2.5.4.3.1 Due to the blocky nature of rock,joint pattern, shallow cover, and the requirement for multiple drift excavation methods, the final lining for stations, transitions, and crossovers shall consist of structural steel ribs or lattice girders encased in reinforced concrete. The concrete may be placed either by cast-in-place or shotcrete methods.

15 .4.2.5.4.3.2 Take into account, in the design of the initial and final lining that the support system will carry loads resulting from different rock excavation stages. For the initial and final lining design, the Designer shall determine the sizes and maximum spacing of rock bolts or steel sets and shall specify the pattern of rock bolts and installation timing to reduce rock movement and loosening.

15 .4.2.5.4.3.3 The design shall specify a multiple drift method when required by anticipated conditions field conditions. The Designer shall consider restrictions imposed by the final lining on the geometry of the initial support, the restrictions imposed by the drainage system, and necessary safety features. The Designer shall design the final lining for loading cases I, II, III, IV, and V, as shown on Figures 15.7 and 15.8.

15 .4.2.5.4.3.4 The Contractor will be responsible to design additional support If field conditions require initial support additional to the final lining.

15 .4.2.5.4.3.5 The Designer shall design the initial support at portal sections and at other critical locations such as intersections of openings. The design shall contain provisions for suitable modifications for conditions disclosed by the excavation.

15 .4.2.6 Slurry Walls

15 .4.2.6.1 Slurry walls may be used for temporary or permanent retaining walls.

15 .4.2.6.2 Design Loadings - Lateral earth pressures for the design of temporary cofferdam walls are shown on Figure 15.15. Lateral at-rest pressure should be used for the design of a permanent slurry wall. Horizontal pressure from surcharge loads should be added to the above loadings. Table 15.2 depicts soil properties for design. Figure 15.16 provides criteria for horizontal pressure due to surcharge loads.

15 .4.2.6.3 Embedment Depth - The depth of slurry wall embedment below the bottom of the excavation is designed based on the depth required to develop adequate resistance to lateral earth and surcharge pressure, provide overall stability, minimize deflections, provide adequate bearing capacity, and limit settlement. Slurry walls can also be designed to provide containment of ground water outside of excavation. Passive resistance provided by the soil in the interior of the cofferdam is computed utilizing the conventional expressions for passive pressures, ignoring vertical wall friction forces on the cofferdam. A factor of safety of 1.5 must be applied to the computed theoretical passive pressures for temporary walls. A factor of safety of at least 2.5 shall be used for permanent slurry walls. Drawing No. DD-S-138 depicts several slurry wall types normally used, as well as typical details.

15 .5 DESIGN OF RAPID TRANSIT AERIAL STRUCTURES

15 .5.1 The Criteria Set Forth in this Section Shall Pertain Specifically to the Design of Aerial Structures Carrying Train Loading and Aerial Stations.

15 .5.1.1 Aerial Structures supporting Stations shall be designed in accordance with ACI or AISC as applicable.

15 .5.1.1.1 Aerial Structures for train loading shall be designed in accordance with AASHTO specifications and the AREMA specifications using the train car loadings and other criteria provided in this Manual of Design Criteria.

15 .5.1.1.2 Structures with spans greater than 150 ft. between centerline of bearing supports will require Authority's prior approval and may require additional modifications to the subject codes.

15 .5.1.2 Loads and Forces - Where applicable, loads and forces listed in Section 15.3 shall be used for the design of rapid transit aerial structures. These loads and other loads and forces to be considered include:

15 .5.1.2.1 Dead Load (DL)

15 .5.1.2.1.1 The dead load of aerial structures shall consist of the gravity loads of the basic supporting girders and structure.

15 .5.1.2.1.2 Trackwork and appurtenances and secondary elements supported by the structure and added after construction of the basic structure shall be considered as superimposed dead load. In areas of tie and ballast construction, the weight of the ties and ballast shall also be considered as superimposed dead load.

15 .5.1.2.2 Live Load (LL) & Derailment Load - Refer to Section 15.3. for live load magnitudes. Transit and crane car wheel loads shall be distributed as follows:

15 .5.1.2.2.1 Non-Ballasted Aerial Structure - Where a wheel load is transmitted to a slab through rail mountings placed directly on the slab, the wheel load shall be assumed to be uniformly distributed on the slab over a 3'-0" length of rail and a 1'-2" width normal to the rail and centered at the rail. In addition, the aerial structure shall be designed to support the derailment loads of Section 15.5.1.2.13.

15 .5.1.2.2.2 Ballasted Aerial Structures

15 .5.1.2.2.2.1 Where an axle load is distributed to a slab through ties and ballast, the axle load shall be assumed to be uniformly distributed on the slab over an area, centered below the axle, of the following dimensions:

15 .5.1.2.2.2.1.1 Width normal to rail - Tie length plus depth of ballast below tie but not greater than the width at the bottom of ballast.

15 .5.1.2.2.2.1.2 Length parallel to rail 3'-0" plus depth of ballast below tie, but not greater than 6'-6".

15 .5.1.2.3 Impact (I)

15 .5.1.2.3.1 Impact shall be applied to the superstructure, and generally those members of the structure which extend down to the main footings. The portion above the ground line of concrete or steel piles rigidly connected to the superstructure as in rigid frame or continuous design is included. Impact shall not be considered for abutments, retaining walls, piles, foundations, footings and safety walks, except the portion of piles (pile bents) rigidly connected to the superstructure.

15 .5.1.2.3.1.1 Vertical impact for aerial structure shall be considered in the design as follows:

15 .5.1.2.3.1.1.1 Non-ballasted Aerial Structures

15 .5.1.2.3.1.1.1.1 Impact force for the design of simply supported longitudinal girders less than 150 feet long:

15 .5.1.2.3.1.1.1.2 I = 30 percent of the total rapid transit vehicle or crane car loading.

15 .5.1.2.3.1.1.2 For structures with longitudinal girders continuous over supports, including cantilever systems:

15 .5.1.2.3.1.1.2.1 I = 40 percent of the total rapid transit vehicle or crane car loading for the girders in regions of negative bending and for the supports where the girders are continuous.

15 .5.1.2.3.1.1.2.2 I = 30 percent of the above loading for continuous girders in regions of positive bending and for the supports where the girders are discontinuous.

~~**15.1.2.3.1.1.3** These constant vertical impact factors apply where the unloaded natural frequency of first mode of vibration of the longitudinal girders is not less than 2.5 cycles per second.~~

15 .5.1.2.3.1.2 Ballasted Aerial Structures - Vertical impact for ballasted rapid transit longitudinal girders shall be equal to 30 percent of the total rapid transit vehicle or crane car loading for both positive and negative moment areas. The vertical impact forces shall be applied as concentrated vertical loads at the axle locations.

15 .5.1.2.4 Stream Flow Pressure (SF)

15 .5.1.2.4.1 Anticipated flood elevations shall be determined by a study of official flood records. Stream flow pressures shall be included in the design of aerial structures where applicable.

15 .5.1.2.4.2 All piers and other portions of structures which are subject to flood forces shall be designed in accordance with sound engineering practice. The requirements outlined in the AASHTO Specification shall be used as a guide, as a minimum.

15 .5.1.2.5 Shrinkage and Creep Forces (S)

15 .5.1.2.5.1 These forces are described under "Reinforced and Prestressed Concrete Design" Section 15.5.1. 5..

15 .5.1.2.6 Thermal Forces (T)

15 .5.1.2.6.1 The largest combination of TRF, DT and FF forces shall be included in load combinations as the loading "T".

15 .5.1.2.6.2 (TRF) Temperature changes which are uniform throughout the structure and which cause stresses in the structure due to restraint of a uniform tendency for thermal expansion or contraction: Provision shall be made for stresses and deformations resulting from uniform temperature changes as follows:

15 .5.1.2.6.2.1 Concrete

15 .5.1.2.6.2.1.1 Temperature Rise 50º deg. F
15 .5.1.2.6.2.1.2 Temperature Fall 50º deg. F
15 .5.1.2.6.2.1.3 Coefficient of Expansion 0.0000060 inch/inch/deg. F

15 .5.1.2.6.2.2 Steel

15 .5.1.2.6.2.2.1 Temperature Rise 60 deg. F
15 .5.1.2.6.2.2.2 Temperature Fall 60 deg. F
15 .5.1.2.6.2.2.3 Coefficient of Expansion 0.0000065 inch/inch/deg. F

15 .5.1.2.6.3 (DT) Temperature gradients within the structure which are due to variations in solar and atmospheric heating and cooling at the structure's surfaces:

15 .5.1.2.6.3.1 Provision shall be made for stresses and deformations resulting from the following temperature distributions:

15 .5.1.2.6.3.1.1 Concrete

15 .5.1.2.6.3.1.1.1 See Figure 15.14a. This is based on a simplified adaptation of ACI 435.7R. Alternately, it is permissible to follow the procedure of ACI 435.7R using U.S. Weather Service Climatological Data applicable to the site of the structure. The AASHTO Guide Specification for Thermal Effects in Concrete Structures may be used for temperature effects in statically indeterminate concrete box girders.

15 .5.1.2.6.3.1.2 Steel

15 .5.1.2.6.3.1.2.1 See Figure 15.14b. This variation from the treatment for concrete is due to the fact that the gradient is small in steel compared with concrete, since the thermal diffusion/conductivity of steel is almost 30 times that of concrete.

15 .5.1.2.6.3.2 (FF) Frictional forces due to temperature changes shall be considered in the design of structures with bearings.

15 .5.1.2.7 Wind Load on Structure (W) - ~~The forces and loads given herein are based on wind velocity of 90 miles per hour, as recommended in the final report (1961) of the ASCE Task Committee on Wind Forces.~~ The minimum basic (nominal) wind speed shall be 105 mph 3-Second Gust, Vasd=105 mph). Exposure C for the wind exposure category shall be used.

15 .5.1.2.7.1 Wind Load on Superstructure

15 .5.1.2.7.1.1 A horizontal uniform wind load shall be applied simultaneously at the centroid of all exposed areas.

15 .5.1.2.7.1.2 For girders and beams: ~~40~~ 50 psf in the traverse direction and ~~10~~ 12 psf in the longitudinal direction, with a minimum of 240 plf, in the transverse direction and 60 plf in the longitudinal direction.

15 .5.1.2.7.1.3 In addition to the horizontal wind loads, an upward load shall be applied at the windward quarter point of the transverse width of the superstructure. This vertical load shall be 20 psf on the plan area of the deck and walkway.

15 .5.1.2.7.2 Wind Load on Substructure-The substructure shall be designed to withstand the preceding loads applied to the superstructure as they are transmitted to the substructure. In addition a horizontal wind load of 35 psf in any direction shall be applied simultaneously at the centroid of the exposed substructure area.

15 .5.1.2.7.3 Loads and pressures (MWFRS or C/C) determined by wind tunnel testing shall be limited to not less than 80 percent of those calculated by other (analytical/envelope) procedures in ASCE 7.

15 .5.1.2.8 Wind Load on Live Load (WL)-Design shall include a transverse horizontal wind load of 320 plf and a longitudinal horizontal wind load of 80 plf for the entire length of track supported by the element being designed. The transverse load shall be applied to the train as concentrated loads at the axle locations, in plane 7 feet above the top of the low rail and normal to the track. The total load for double track shall be the same as for single track.

15 .5.1.2.9 Rail/Structure Interaction Force (RS)

15 .5.1.2.9.1 Non-Ballasted Aerial Structures. During the design of non-ballasted aerial structures, an analysis shall be made of the forces resulting from continuously welded rail (CWR)/structure interaction. This analysis shall be coordinated with the Authority.

15 .5.1.2.9.1.1 The design of the deck, girders, bearings, frames, pier caps, piers and foundations shall include the forces resulting from the interaction between the rails and the structure when:

15 .5.1.2.9.1.1.1 The superstructure expands and contracts beneath the rail,

15 .5.1.2.9.1.1.2 One rail breaks,

15 .5.1.2.9.1.1.3 The structure restrains the rail from displacing radially on horizontal curves,

15 .5.1.2.9.1.1.4 Combination of the above.

15 .5.1.2.9.1.1.5 Maximum allowable rail break gap is 3 inches.

15 .5.1.2.9.1.2 The design shall include the forces imparted to the structure as the superstructure moves beneath the rail due to thermal variations.

15 .5.1.2.9.1.2.1 The thermal load criteria shall be the same as Section 15.5.1.2.6., Thermal Forces. The rail shall then be considered attached to the deck at 30 inch intervals with a mechanism which mobilizes 3 kips of longitudinal force per fastener resisting the movement of the deck, girders, pier caps, and piers relative to the rail (See Figure 15.13 for range of load vs. deflection of the fasteners). The rail beyond the abutments of the structure shall be considered, if direct fixation track, to have the same restraint characteristics as the track on the deck (i.e. 30 inch spacing of fasteners, 3 kips restraint per fastener) and if ballasted track, 27 inch tie (fastener) spacing with a restraint of 1500 lbs/rail/tie (equivalent spring rate of 15000 lbs/inch per rail per tie). In general, in order to keep the structure interaction balanced, piers shall alternate between those having fixed bearings for the

superstructure and those having expansion bearings. On either side of piers with the fixed bearings, the superstructure should be of approximately equal length.

15 .5.1.2.9.1.2.2 The design shall include the forces mobilized in the structure to restrain a broken rail when the rail has a 100°F temperature differential from rail neutral temperature. Each mechanism which attaches the rail to the deck at 30 inch intervals mobilizes 3 kips of restraint between the broken rail and the superstructure until the thermal rail force is developed.

15 .5.1.2.9.1.2.3 The design shall include the loads mobilized in the structure which provide lateral restraint to the rail when the structure is located on a horizontal curve. The analysis shall consider a 100°F temperature differential in the rails from rail neutral temperature.

15 .5.1.2.9.1.3 Special Trackwork. The layout of the aerial structure shall be such that there will be a minimum relative movement due to the thermal conditions between the rails and the superstructure at switch locations in turnouts and at derails.

15 .5.1.2.9.1.3.1 The force in the rail resulting from interaction shall not exceed 132 kips.

15 .5.1.2.9.1.4 Ballasted Aerial Structures. No interaction loads need be considered.

15 .5.1.2.10 Prestressing Forces (PS)-Prestressing creates forces within the structure include:

15 .5.1.2.10.1 Primary forces occurring in any prestressed structure and secondary forces occurring due to restraint of deformations resulting from the primary effect of prestressing.

15 .5.1.2.10.2 Forces arising during construction due to temporary restraint of post-tensioning shall be considered under Erection Loads During Construction. However a movement due to shortening during prestressing should never be obstructed.

15 .5.1.2.11 Foundation Settlement (FS)-Aerial structures shall be analyzed for a minimum of ½ inch vertical differential settlement between adjacent pier foundations. If a greater value of differential settlement is permitted per Section 15.5.1.7, that value shall be used .

15 .5.1.2.12 Seismic Forces (EQ) - Seismic forces for aerial structures supporting rapid transit loading shall be in accordance with the AASHTO specifications. At least 50% live loading from rapid transit shall be included in the seismic load combination.

15 .5.1.2.13 Derailment forces (DRF)

15 .5.1.2.13.1 The aerial structures shall be designed for a vertical derailment load caused by a misdirected car oriented with its longitudinal axis

parallel to the track, and transversely positioned a minimum of 1.5 feet to a maximum of 3 feet from the centerline of the track.

15 .5.1.2.13.2 The derailment load shall consist of standard vehicles with a modified impact factor.

15 .5.1.2.13.3 A derailment impact equal to 100 percent of the axle load shall be applied to any two adjacent axles at a time, with a normal impact factor applied to the remaining axles. The 100 percent impact axles shall be selected to produce the critical loading condition for the structure.

15 .5.1.2.13.4 When checking any component of a superstructure or substructure that supports two or more tracks, only one train on one track shall be considered to have derailed, with the other track being unloaded and loaded with a stationary train.

15 .5.1.2.13.5 When investigating derailment loads, the percentage of basic unit stress may be increased to 150 percent. For prestressed concrete members, the steel tendon stress shall not exceed 85 percent of the ultimate tensile strength (0.85 f's) and the concrete stress shall not exceed 60 percent of the 28-day compressive strength (0.60 f'c).

15 .5.1.3 Loading Combinations and Unit Stresses

15 .5.1.3.1 The basic unit stresses for various materials in structures supporting the rapid transit system are defined in their respective sections. The following combinations of loadings shall be considered in design:

	Allowable Percentage of Basic Unit Stress
Group I = DL + LL + I + CF + RF +E + B + SF + PS	@ 100%
Group II = DL + LL + I + CF + LF + T +S + B + SF + PS	@ 100%
Group IIa = DL + LL + I + RF + CF +T + RS + PS	@100%
Group III = DL + E + B + W + SF + PS	@ 125%
Group IIIa = DL + PS + E + B + SF + S + DT	@ 100%
Group IV = Group 1 + 30% W + WL + FS	@ 125%
Group V = Group II + 30% W + WL +RS + FS	@ 125%
Group VI = Group III + EQ - W	@ 133%
Group VII = DL + CF + LF + RS + DRF	@ 150%

Where : DL = Dead Load
LL = Live Load
I = Impact
CF = Centrifugal Force
RF = Rolling Force
LF = Longitudinal Braking and Traction Force

E = Horizontal Earth Pressure
B = Buoyancy
SF =Stream Flow Pressure
S = Shrinkage and Creep Force
T = Thermal Force, Total
DT =Forces due to Thermal Gradient
W = Wind Load on Structure
WL = Wind Load on Live Load
RS = Rail/Structure Interaction Force
PS = Post-tensioning Forces
FS = Foundation Settlement Forces
EQ = Seismic Force
DRF = Derailment Force

15 .5.1.4 Special Design Considerations

15 .5.1.4.1 Vibration Limitations

15 .5.1.4.1.1 To limit potential dynamic interaction between aerial structure girders and rapid transit vehicle and amplification of deformations from resonance, the aerial structure shall be designed so that the unloaded natural frequency of the first mode of vibration of the longitudinal simple span girders is not less than 2.5 cycles per second.

15 .5.1.4.1.2 For continuous spans girders the natural frequency of the first mode of vibration shall be not less than 3.0 cycles per second.

15 .5.1.4.1.3 Concrete rail plinths shall not be considered in the cross section properties.

15 .5.1.4.2 Fatigue-Consideration shall be given to the effect of change of stress levels caused by passage of rapid transit trains over structures. Over the life of the structure, 3 million cycles of maximum stress shall be used in estimating the number of repetitive maximum stress cycles.

15 .5.1.4.3 Uplift shall not be allowed for any loading combinations. However, provision shall be made for adequate attachment of the superstructure to the substructure should any loading or combination of loading, increased by 100% of the live load, produce uplift at any support

15 .5.1.4.4 Friction (FF)-Frictional effects shall be considered in the structural design.

15 .5.1.4.5 Track Girders shall follow WMATA Structural Design Drawings (DD Drawings) showing box girder configurations, unless a special exception is approved by WMATA .

15 .5.1.4.5.1 Access to Interior of Box Girders and Future Bearing Replacement Details:

15 .5.1.4.5.1.1 Provide access openings in the box girder large enough to allow personnel to enter the inside of the box girder for inspection and maintenance. The opening shall be located in an area of the span which shall make it easily accessible, and would not impair the structural adequacy of the girder. Also design sealed access openings from the box girder's deck. Provide details and

procedure for future bearing replacements. Replacements should be made possible from the inside of box girders using access from the Metro track. Opening size shall be 2'-6" x 2'-6" as shown on drawing DD-S-128.

15 .5.1.4.5.1.2 Design and provide removable water tight cover .

15 .5.1.4.5.1.3 An access opening shall be provided for every box girder. If the proposed access opening is provided on the top of the deck, a ladder shall be installed to access inside the box girder. The access ladder shall be made up of non-corrosive material.

15 .5.1.4.5.2 Span length for Precast pre-stressed AASHTO Bulb Tee girders shall be limited to 100 feet maximum.

15 .5.1.4.6 Drainage and Water Infiltration

15 .5.1.4.6.1 Superstructure should be designed such that no water leaks inside the box girder. Deck joints should be sealed and made water-tight. Runoff shall be directed to drain inlets, into drainage pipes, which are mounted on the outside face of the aerial structure and against the piers down into a proper outfall.

15 .5.1.4.6.2 2" minimum diameter weep holes shall be provided at the low spots on the box girder bottom flange to ensure that box girder remains dry at all times. Weep holes should be lined with PVC pipe and firmly secured to prevent corrosion and staining of the concrete. The weep hole inlet should be covered with a suitable screen.

15 .5.1.4.7 Operational and Maintenance Preferences

15 .5.1.4.7.1 Provide ballasted track bridges along ballasted alignment on bridges with a total length of 600 feet (8 rail car lengths) or less.

15 .5.1.4.7.2 Provide separate aerial structures for each track to enable maintenance work on one span to proceed independent to the other span.

15 .5.1.4.7.3 Achieve super-elevation by rotating the cross section and adjusting rail plinth height.

15 .5.1.5 Reinforced and Prestressed Concrete Design - Reinforced and prestressed concrete members for rapid transit aerial structures shall conform to the requirements of Section 15.9 except as modified below.

~~**15.5.1.5.1** Crack control-All concrete aerial structure for any span shall be prestressed to control cracks.~~

15 .5.1.5.1 Camber and Deflections

15 .5.1.5.1.1 Non-Ballasted Aerial Structures-As a guide in design, the total long term predicted camber growth shall be limited to 1/2000 of the span length for unballasted, prestressed concrete aerial structures. The short term camber growth prior to Trackwork construction shall be limited to 1/4000 of the span length. A minimum 2-month period

between structure construction and trackwork installation is assumed.

15 .5.1.5.1.2 Ballasted Aerial Structure

15 .5.1.5.1.2.1 The Designer shall consider the stress conditions and effect of camber growth in prestressed concrete, ballasted, aerial structures for the simple dead load condition prior to placement of superimposed dead load. Girder members shall also be checked on the assumption that superimposed dead load may be removed at any time during the life of the structure.

15 .5.1.5.1.2.2 Long term deflections under dead load plus superimposed dead load conditions shall be limited to 1/3000 of the span length.

15 .5.1.5.2 Live Load Deflections

15 .5.1.5.2.1 Girders of simple or continuous spans shall be designed so that deflections due to live load plus impact shall not exceed 1/1000 of the span length. The deflection of cantilever arms due to live load plus impact shall be limited to 1/450 of cantilever arm.

15 .5.1.5.2.2 For deflection calculations only, normal loading of the rapid transit vehicle may be considered. Live load shall be assumed as 132,000 lb. distributed equally to four axles.

15 .5.1.5.2.3 The minimum concrete cover for reinforcement in the platform slab (cast-in-place, precast or prestressed concrete) shall not be less than 1½ inches in any cases.

15 .5.1.5.3 Longitudinal Tensile Stresses in Prestressed Aerial Structure Members

15 .5.1.5.3.1 Longitudinal tensile stresses shall not be permitted under any combination of loads, except in the bottom fibers where tension will be permitted as $3\sqrt{f'_c}$ maximum for impact loading only.

15 .5.1.5.3.2 Reinforcing bars shall be added to resist the tension stresses resulting from impact loads.

15 .5.1.5.3.3 In no case tension stresses are allowed at the joints in precast segmental post tensioned concrete and for post-tensioned cast-in-place concrete structures. Maintain a minimum compressive stress of 50 psi minimum, under all loads and loading combinations at the joints, at all locations, in precast segmental posttensioned concrete.

15 .5.1.5.4 Shrinkage and Creep

15 .5.1.5.4.1 Model for predicting shrinkage and creep in concrete structures shall be ACI 209.

15 .5.1.5.4.2 Stresses and movements resulting from concrete shrinkage and creep shall be considered in the design and included in all load combinations.

15 .5.1.5.4.2.1 The shrinkage coefficient shall be assumed to be 0.0002 inches per inch for both prestressed and reinforced concrete.

15 .5.1.5.4.2.2 To minimize creep problems, it is suggested that the average prestressing compression stress after losses should not exceed 1000 psi.

15 .5.1.5.5 Structure Deformations and Settlements-All structure deformations, including foundation settlement, shall be considered, not only for their effect on structural behavior, but also for their effect on track work. The control of deformations through proper structural design is of paramount importance in obtaining acceptable riding quality of the rapid transit trains.

15 .5.1.6 Structural Steel Design

15 .5.1.6.1 Structural steel and composite steel-concrete flexural members for rapid transit aerial structures shall conform to the requirements of Section 15.8.

15 .5.1.6.2 The requirement governing live load deflections and structure deformations and settlements as outlined for Reinforced and Prestressed Concrete Design shall also apply to Structural Steel Design.

15 .5.1.7 FOUNDATIONS

15 .5.1.7.1 Foundations for girder spans up to 150 feet in length shall not have total settlements greater than 1" nor differential settlements greater than 1/4", however, the design shall be based on a minimum ½" differential settlement. For spans over 150 feet in length, the Designer shall develop settlement values subject to Authority approval .

15 .5.1.7.2 Allowable foundation bearing capacity shall be determined in consultation with the Designer's geotechnical consultant, and approved by the Authority.

15 .5.1.7.3 The type of foundation shall depend on local soil conditions and are classified into three types as follows:

15 .5.1.7.3.1 Spread Footings-The design shall keep the maximum soil pressure within the maximum allowable bearing values shown in TABLE 15.2 (Soil Properties for Design) or as indicated within the WMATA approved Geotechnical Design Report, with soil pressures as nearly uniform as practicable.

15 .5.1.7.3.2 Pile Footings

15 .5.1.7.3.2.1 Pile footings Pile foundations for aerial structures shall be designed in accordance with the requirements of AASHTO Specifications. However, uplift shall not be permitted in bearing piles or combination bearing and friction piles

15 .5.1.7.3.2.2 Deleted.

15 .5.1.7.3.2.3 Drilled Caissons

15 .5.1.7.3.2.3.1 The design shall keep maximum soil pressure at base of caisson below allowable soil bearing value.

15 .5.1.7.3.2.3.2 Bearing values shall be established and verified by independent testing as approved by the Authority.

15 .5.1.7.3.2.3.3 Permanent steel casing shall not be considered for both structural and geotechnical designs. Caisson Foundation for aerial structures shall be designed with multiple caissons. Single caisson foundation shall not be used. Caisson foundations for straddle bent structures shall be designed with minimum of four caissons per column.

15 .5.1.7.3.3 Rammed aggregate pier foundation shall not be used in Metro facilities or aerial guideway structures.

15 .5.1.8 Bearings

15 .5.1.8.1 Pot bearings shall not be permitted.

15 .5.1.8.2 Elastomeric bearings for Aerial Stations:

15 .5.1.8.2.1 Criteria for the design shall be governed by AASHTO Section 14 "Elastomeric bearings". Method A or B is to be used as applicable. The compressive strain should not exceed 7%.

15 .5.1.8.2.2 If at one end of girder or structure sliding bearing is used, the bearing assemblies shall be the sliding plate type bearing which allows translation by sliding of a self lubricating surface across a smooth hard solid stainless steel mating surface.

15 .5.1.8.2.2.1 The assembly is to have solid stainless steel bearing plate on the upper unit with sole plate and a preformed fabric pad with a rigidly confined PTFE bearing surface in the lower unit with masonry plate.

15 .5.1.8.2.2.1.1 The preformed fabric pad shall meet AASHTO Specifications 10.3.12 “Preformed Fabric Pads” and capable of withstanding loads of 10 ksi perpendicular to the plane of lamination.

15 .5.1.8.2.2.1.2 The metal bearing plate shall be fabricated from minimum of 13 gage stainless steel, and have a mirror finish with a minimum 20 micro inches RMS on the PTFE bearing side.

15 .5.1.8.2.2.1.3 The coefficient of friction between the steel plate and the PTFE surface shall be no greater than .06 at 800 psi compressive loading.

15 .5.1.8.3 Bearings for Aerial Line Sections

15 .5.1.8.3.1 Bearing assemblies used in the line sections of the aerial structure with span lengths of 80 feet or more, shall be self lubricating bearing assemblies to provide rotation and longitudinal movement as

needed for expansion joints. The bearing assembly shall be an integral unit composed of:

15 .5.1.8.3.1.1 Spherical bearings plates - A convex solid stainless steel plate with surface of woven PTFE fabric mechanically interlocked to the substrate plate, and a mating solid stainless steel concave plate with finished bearing surface. The spherical interface shall provide rotational movement in any direction.

15 .5.1.8.3.1.2 Flat bearing plates - A flat plate with the PTFE material similarly fixed on the sliding surface, and a solid stainless steel concave mating plate, as described in Section 15.5.1.8.3.1.1 above with a flat finished sliding surface, to provide longitudinal translation movement. The relative movement between these two flat surfaces is to be restricted to the longitudinal direction. Such a flat bearing plate assembly is required along with Spherical bearing plate assembly only at the expansion end.

15 .5.1.8.3.1.3 The PTFE fabric shall have a minimum thickness of 1/16" and is to meet the following requirements:

15 .5.1.8.3.1.3.1 Hardness at 78°F per ASTM D676 - 50-65 Durometer D

15 .5.1.8.3.1.3.2 Tensile strength per ASTM D638 - 2800 psi (Min. Avg.)

15 .5.1.8.3.1.3.3 Elongation per ASTM D1708 - 200% (Min. Avg.)

15 .5.1.8.3.1.3.4 The coefficient of friction between the steel plate and the PTFE surface shall be no greater than .06 at 800 psi compressive loading.

15 .5.1.8.3.1.4 The stainless steel surfaces shall have a finish of 20 RMS.

15 .5.1.8.3.2 Expansion bearings shall be sized and set at the time of construction to allow for the following:

15 .5.1.8.3.2.1 The maximum temperature movement based on the mean 48 hour prior temperature.

15 .5.1.8.3.2.2 The anticipated rotation and movement due to creep, shrinkage and elastic shortening from time of setting through day 400. These computed rotation and movements shall be increased by a factor of 1.3.

15 .5.1.8.4 Materials and fabrication for all type bearings, shall be in accordance with AASHTO's Section 18. Division II, and with the contract specifications.

15 .5.1.8.5 All types of bearing assemblies installation, shall have provisions for:

15 .5.1.8.5.1 future bearing replacement and inspection indicated on the design drawing.

15 .5.1.8.5.2 The reactions for the jacking forces required for removal of the bearings shall be included in the contract drawings.

15 .5.1.8.5.3 Provision for Inspection and future replacements of bearings should be made possible from inside box girders.

15 .5.1.8.5.4 Furthermore, design shall provide inspection and maintenance manual for the aerial structures indicating

15 .5.1.8.5.4.1 all critical items and area for periodic inspections such as bearings, tie-downs, end & deviation blocks, connections, fracture critical members locations and connections, etc

15 .5.1.8.5.4.2 inspection flow charts, frequency and procedures.

15 .5.1.8.6 Anchor bolts subject to tensile fatigue loading shall be torqued in accordance with AREMA Manual.

15 .5.1.8.7 Bearing pads shall be non-shrink grout. Minimum 28 days compressive strength for non-shrink grout shall not be less than 7000 psi.

15 .5.1.9 Precast Box Girder Segment for Aerial Structures - Casting and Erection:

15 .5.1.9.1.1 Minimum strength prior to lifting segments or lowering forms: 2500 psi.

15 .5.1.9.1.2 Minimum concrete strength prior to stressing vertical and transverse post-tensioning: 4000 psi

15 .5.1.9.1.3 Minimum age of segments at time of erection: 14 days

15 .5.1.9.1.4 Minimum concrete strength prior to stressing longitudinal post-tensioning: ~~4000~~ 6000 psi

15 .6 SOILS AND GEOTECHNICAL CRITERIA

15 .6.1 The Authority will provide site specific Geotechnical Information (GI) .

15 .6.2 The Designer of Record/Design-Builder may perform additional geotechnical investigations, as he deems necessary.

15 .6.3 The Design-Builder's Geotechnical Consultant shall investigate and summarize the geotechnical information provided with existing and newly obtained data, identify subsurface strata and recommend properties for design in a separate Geotechnical Design Report (GDR).

15 .6.4 Soil and rock properties given in Table 15.2 (pages 1 trough 5) are the allowed limits required for design. The Designer may use values for design provided in the GDR if obtained through site-specific testing and verified by laboratory results, and approved by WMATA.

15 .6.5 The Designer of Record/Design-Builder will be responsible for the certification / sealing of the design and the design drawings, by a professional engineer registered in the jurisdiction of the work location.

15 .7 SUPPORT AND UNDERPINNING OF EXISTING STRUCTURES

15 .7.1 All Designs for support and underpinning of existing structures shall be coordinated with the Authority . The economics and feasibility of various underpinning and dewatering methods for structures influenced by excavation or tunneling shall be investigated by the Design/Builder and recommendations shall be made as to the method best suited to the particular structure.

15 .7.2 Special Provisions shall be made in the contract documents requiring the construction contractor to maintain, protect and be responsible for the safety, stability and integrity of all buildings and structures which may be affected by the work. These provisions shall be coordinated with the Authority.

15 .7.3 All Structures, within the WMATA zone of influence shall fall into one of the following two categories:

15 .7.3.1 Zone A Structures

15 .7.3.1.1 Sructures within Zone A (see Figure 15.19) require underpinning design, detailed drawings and specifications prepared by the Designer for Authority approval. In identifying Zone A structures the Design/Builder shall investigate all structures over or adjacent to the work Zone A shall include:

15 .7.3.1.1.1 Buildings or structures which extend over transit structures to an extent requiring support during construction and permanent underpinning.

15 .7.3.1.1.2 Buildings or structures immediately adjacent to the transit structures, which must be carried on underpinning braced to act as retaining elements supporting the sides of the excavation.

15 .7.3.1.1.3 Underpinning walls or piers supporting buildings or structures and forming a portion of the excavation support system shall be extended to a minimum depth of 4'-0" below subgrade elevation to the underground rapid transit structure.

15 .7.3.1.2 Methods used to underpin or protect these buildings or structures shall depend on local soil conditions and shall be designed to eliminate differential settlement.

15 .7.3.2 Zone B Structures

15 .7.3.2.1 Structures located within the WMATA zone of influence but not requiring underpinning, in accordance with Figure 15.19 and as determined by the Designer/Builder, subject to Authority approval. Such structures shall not be listed in the contract documents. The need for protection, temporary support or permanent underpinning of Zone B structures shall be the responsibility of the construction contractor, who shall be required to submit designs and computations prepared by an engineer registered in the locality of the work.

15 .7.3.2.2 Zone B includes structures which may be affected by groundwater lowering.

15 .7.3.2.3 All underground construction shall be designed on the assumption Zone B structures will not be underpinned.

15 .8 STRUCTURAL STEEL DESIGN

15 .8.1 Consideration shall be limited to the following Types of Structural Steel. Other types may be used only with the approval of the Authority.

15 .8.1.1 Structural Steel-For normal use: ASTM A36; ASTM A709, Grade 36.

15 .8.1.2 High Strength Structural Steel

15 .8.1.2.1 For uses requiring higher strength steels or where economically justifiable use: ASTM A242, A514, A588, A572, A709 and A992 (for structures not carring train loading).

15 .8.1.2.2 For elevators for the physically disabled, hoistway framing ASTM A500. Grade B. modified to 50,000 psi minimum yield strength if necessary. Architectural metal cladding as shown on the directive drawings.

15 .8.1.3 Connections

15 .8.1.3.1 Shop connections shall be welded or bolted. All welding shall be in accordance with the applicable requirements of the American Welding Society Structural Welding Code as described in Section 15.2.1.11. Design of welded aerial structures shall also comply with the applicable provisions of fracture control plan as required by the AASHTO Standard Specifications for Highway Bridges, latest edition. Special consideration shall be given to welded connections for addressing Fatigue to alleviate future cracks Each aerial structure design shall be evaluated to determine the location of any non-redundant fracture critical member or member components that may exist and their location shall be clearly delineated on the contract plans.

15 .8.1.3.2 Functionality shall be considered as well as strength in determining whether failure of a structural element is critical, and appropriate measures up to or including those for a fracture-critical member, shall be prescribed to avoid failure of such an element. In particular, it is possible that an aerial structure supporting tracks may promote derailment when load resistance is transferred from a failed element to another element, even though the structure is redundant.

15 .8.1.3.3 Field connections shall be designed for high-strength bolts unless otherwise approved by the Authority. The use of high-strength steel bolts shall be governed by "Specification for Structural Joints Using ASTM A325 or A490 Bolts". This includes a prohibition of galvanizing for A490 bolts and hot-dip galvanizing for A325 bolts of Type 2. The bolt type to be used shall be identified in the design specifications.

15 .8.1.3.4 Threaded bolts of ASTM A36, A307, galvanized shall be used for anchors and other applications. Swedged bolts shall not be used.

15 .8.1.3.5 End diaphragm between steel girders shall be provided at the bearings.

15 .9 REINFORCED AND PRESTRESSED CONCRETE DESIGN

15 .9.1 Cements

15 .9.1.1 Type I Portland Cement ordinarily shall be specified for concrete mix design; however, consideration shall be given to the use of an approved expansive

type cement, manufactured to compensate for the normal drying shrinkage of Portland Cement concrete.

15 .9.1.2 Type II Portland Cement shall be specified for concrete construction in soils having low pH values or high sulphate content.

15 .9.1.3 Type III Portland Cement may be specified for concrete mix design requiring a high early strength, except where soil conditions make the use of Type II necessary.

15 .9.1.4 Shrinkage Compensating Cement may be used if approved by the Authority.

15 .9.1.5 All of these Portland Cement Mixes (except Type III) may utilize Blast Furnace Slag or Fly Ash as a percentage of Portland Cement content in accordance with WMATA Specification. Corrosion inhibitor with Calcium Nitrite base shall be used in all concrete exposed to elements.

15 .9.2 Reinforcing Steel

15 .9.2.1 All mild steel reinforcement shall be ASTM A706 and ASTM A615, Grade 60.

15 .9.3 Concrete Design

15 .9.3.1 For all underground structures:

15 .9.3.1.1 Cast-in-place concrete fc' = 4000 psi unless otherwise approved by the Authority, and. shall be designed by the "Alternate Design Method" of ACI 318-99, using the following values:

n = 8

fc in flexure = 1,800 psi for station arches

fc in flexure = 1,600 psi for other underground structures

15 .9.3.1.2 fc' for precast members shall not be less than 5,000 psi except that precast tunnel liners shall be not less than 6,000 psi. Use of strengths higher than 7,000 psi concrete will require prior approval of the Authority. Use of concrete with f'_c greater than 7,000 psi shall be limited to columns only. Concrete with f'_c greater than 10,000 psi shall not be used.

15 .9.3.1.3 fc' for prestressed concrete shall be not less than 5,000 psi. Unbonded and ungrouted prestressing steel shall not be used. Use of higher strengths than 7,000 psi will require prior approval of the Authority. Use of concrete with f'_c greater than 7,000 psi shall be limited to columns only. Concrete with f'_c greater than 10,000 psi shall not be used.

15 .9.3.2 For all above ground structures:

15 .9.3.2.1 Cast-in-place concrete f'c = 4,000 psi unless otherwise approved by the Authority. See Section 15.2.2.4 . f'_c for precast members shall not be less than 5,000 psi except that precast tunnel liners shall be not less than 6,000 psi. Use of strengths higher than 7,000 psi concrete will require prior approval of the Authority. Use of concrete with f'_c greater than 7,000 psi shall be limited to columns only. f'_c for pre stressed concrete shall be not less than 5,000psi. Unbonded and ungrouted prestressing steel shall not

be used. Use of higher strengths than 7,000 psi will require prior approval of the Authority. Use of concrete with f'_c greater than 7,000 psi shall be limited to columns only.

15 .9.3.2.2 For precast/prestressed concrete parking structure, refer to Section 15.21.

15 .9.3.2.3 Where existing parking use will be disrupted during construction, precast construction should be considered to minimize disruption. Where construction time is of little consequence or special construction features are required, post tensioned cast-in-place construction may be required and will be accepted.

15 .9.3.3 For all structures:

15 .9.3.3.1 Precast Prestressed Concrete:

15 .9.3.3.1.1 All exposed concrete edges shall be chamfered. Chamfers shall be 3/4 inch by 3/4 inch unless noted otherwise.

15 .9.3.3.1.2 Concrete Strength

15 .9.3.3.1.2.1 Unless noted otherwise, all precast prestressed concrete shall attain 28-day minimum compressive strength (f'_c) of 6,000 psi with a maximum water-cement ratio of 0.40 and contain a corrosion inhibitor as specified in Section 15.21.25.

15 .9.3.3.1.2.2 High performance concrete of strength up to 10,000 psi , for columns only, may be considered with Authority's prior approval.

15 .9.3.3.1.2.3 The compressive strength of concrete at the time of initial prestress (f'_{ci}) shall not be less than ~~3,500~~ 4,000 psi nor less than 0.6 f'_c.

15 .9.3.3.1.2.4 For allowable tensile stresses in rapid transit aerial structures see Section 15.5.1.5.4.

15 .9.3.3.1.3 Concrete Stresses in Structural Members Not Carrying Transit Loads

15 .9.3.3.1.3.1 Extreme fiber stress in tension immediately after prestress transfer (before time-dependent prestress losses) shall not exceed 6√fci even if bonded auxiliary reinforcement is provided.

15 .9.3.3.1.3.2 Extreme fiber stress in tension, in precompressed tensile zone at service loads (after prestress losses) shall not exceed 6√fc'.

~~**15.9.3.3.1.3.3** For allowable tensile stresses in rapid transit aerial structures see Section 15.5.~~

15 .9.3.3.1.4 Connections

15 .9.3.3.1.4.1 The precast manufacturer shall design and provide all embedded items necessary for connections.

15 .9.3.3.1.4.1.1 All exposed and embedded and partially exposed connection hardware shall be hot-dipped galvanized after fabrication or Stainless Steel as required.

15 .9.3.3.1.4.1.2 Galvanized connections which are subsequently field-welded shall be touched up with zinc-rich paint after welding as per Specifications.

15 .9.3.3.1.4.1.2.1 Use ASTM A706 weldable reinforcing for all reinforcing which is required to be welded.

15 .9.3.3.1.5 Full attention shall be given to restrict corrosion of reinforcement, embedded steel and any other exposed steel at connections. Silane penetrating sealers (min 45% solids), on exposed horizontal surfaces, shall be required as well as use of corrosion-inhibitor in concrete. The corrosion-inhibitor shall be calcium nitrite-based admixture, DCI as manufactured by W.R. Grace & Co. or approved equal.

15 .9.3.3.1.6 Provision shall be made to install Fiber Optic Sensors in the precast concrete aerial structures, as required by the specifications.

15 .9.3.3.2 End diaphragm between girders, both precast and cast in place, shall be provided at the bearings, however, 1'-6" clearance shall be provided for bearing replacement lifting devices. End diaphragm depth shall be same as the girder depth. The end diaphragm shall be cast-in-place concrete.

15 .9.3.3.3 Intermediate diaphragms shall be provided between girders at 40' maximum spacing. The depth of intermediate diaphragm shall not be less than one half of the girder depth. The intermediate diaphragm shall be cast-in-place concrete.

15 .9.4 Reinforcing Steel Details

15 .9.4.1 Spacing

15 .9.4.1.1 Temperature and shrinkage reinforcement for aboveground structures shall meet the requirements of the ACI code.

15 .9.4.1.1.1 Temperature and Shrinkage reinforcement for underground concrete structural units not exceeding 50 feet in length shall be at least 0.15% of the gross concrete area, with a maximum of #7 bars at 18" centers in each face except for lower station arch units where it shall be #7 at 12" centers on the outside face and #7 at 9" centers on the exposed face in order to minimize cracking. This steel shall be placed as close to the exposed face as possible and permissible.

15 .9.4.2 Splices

15 .9.4.2.1 All typical splices of main reinforcement shall be indicated on the drawings and the lengths of these lap splices given. Only a statement that all splices shall be in accordance with ACI code is not acceptable.

15 .9.4.2.2 Mechanical tension splices of reinforcing bars shall be made by the use of Cadweld or NMB splices. Other mechanical splices / couplers may be accepted on a case by case basis and this acceptance shall be at the sole discretion of the Authority. All mechanical couplers shall comply with the requirements of the applicable code.

15 .9.4.3 Joints

15 .9.4.3.1 For expansion joints in overlaying members, Of Above Grade Structures see Section 15.9.9.1., and for Precast Prestressed Parking Structures see Section 15.21

15 .9.4.3.2 For tunnel units longer than 50 feet between contraction joints, construction procedures shall be specified and adequate reinforcement shall be provided to reduce cracking to a minimum. The above requirements do not apply to rock tunnels.

15 .9.4.3.3 Rock tunnels may have vertical contraction joints in arch, vertical or sloping construction joints in the invert or may be continuous without joints, with prior approval of the Authority. All construction joints shall be bonded.

15 .9.5 Architectural Considerations - In order to assure uniformity of structural concrete color in public areas of the stations, it will be necessary to standardize concrete mix and strength throughout, as approved by WMATA.

15 .9.5.1 This will apply to all concrete exposed to public view within the stations and for a distance of approximately 100 feet beyond the ends of platforms.

15 .9.5.2 The structural element such as mezzanines within a station requiring the highest strength concrete will determine the single strength to be used for all elements.

15 .9.5.2.1 Deleted.

15 .9.6 Roofs over Station Mezzanines and Mezzanine Structure - These criteria refer to pertinent data in cast-in-place concrete roofs over mezzanines in above ground stations.

15 .9.6.1 Design Assumption

15 .9.6.1.1 Long span of 60 feet and more roof structures shall be two-way post-tensioned with a minimum prestress of 100 psi and not more than 250 psi, longitudinally and transversely to reduce the cracking of concrete.

15 .9.6.1.2 For spans up to 80 feet mezzanine structures may be designed using high strength precast prestressed concrete.

15 .9.7 Architectural Details - Include details of block outs at tensioning points to assure corrosion protection and continuity of architecture features of the structure.

15 .9.8 Roofs, Lightweight Insulating Concrete Fill - Lightweight insulating concrete fill will not be permitted in roof construction.

15 .9.9 Crack Control and Waterproofing of Above-Ground Structures for station mezzanine, platform, track support, ancillary structures and parking structures:

15 .9.9.1 Joints or pour strips shall be used to control concrete cracking, especially where the structure has re-entrant corners, geometrical or loading asymmetry or other features which tend to cause cracking of concrete. Expansion Joints in overlaying members shall always coincide with Structural joints (e.g. station platform setting bed and tile expansion joints must coincide with structural slab expansion joint). Jointing hardware shall ensure complete water tightness.

15 .9.9.2 Maximum spacing of expansion joints 100' - Locate joints judiciously to ensure that the electrical and mechanical rooms are not impacted.

15 .9.9.3 Movement due to shrinkage, temperature variation, prestress elastic shortening and creep, which must be allowed by expansion joints, shall be calculated, taking joint geometry into account.

15 .9.9.3.1 The movement shall be 1" minimum (which may be reduced for spacing less than 100' - minimum allowable movement proportional to spacing).

15 .9.9.3.2 All expansion joints introduced by design must have assured free movement and rotation where applicable, without any obstruction.

15 .9.9.3.3 Expansion joints shall be sealed with either lock-in or extruded strip seal as shown in Drawing DD-S-120.

15 .9.9.3.3.1 The seal shall be neoprene and continuous along the length of the expansion joint.

15 .9.9.3.3.2 Seals shall have a width 115% of the maximum and 250% of the minimum joint opening.

15 .9.9.4 Joint installations shall provide continuous, full-width watertight seals with gutter like terminations which are durable and readily renewable. Design documents shall require the on-site participation and recommendations to the Engineer of a seal manufacturer representative to ensure proper installation and easy replacements in the future.

15 .9.9.5 Expansion joint anchors shall be integrated with the deck reinforcement, and finished concrete in the vicinity of joint surfaces shall be sound.

15 .10 DESIGN OF CIRCULAR SEGMENTAL TUNNEL LINERS

15 .10.1 **For Contracts which include soft-ground tunneling**, the Designer/Builder shall develop a segmental tunnel liner based upon design recommendations provided in the Geotechnical Design Report (GDR). A two-pass system utilizing a PVC waterproof membrane system is preferred. The GDR shall provide recommendations concerning tunneling method and appropriate equipment types. Tunnel liner segments shall be designed to resist individual jack thrust of at least 125 tons spaced at approximately 2'- 6" on centers.

15 .10.2 One-Pass System Circular Earth Tunnels

15 .10.2.1 One-pass tunnel support shall consist of reinforced precast concrete segmental lining with waterproofing gaskets and bolts as depicted on Drawings DD-S-141, DD-S-142, DD-S-143, DD-S-144 and DD-S-145. Precast concrete compressive strength f'c shall not be less than 6000 psi.

15 .10.2.2 For shield driven tunnel construction, segmental linings shall be designed for support of ground loads and shield jacking forces.

15 .10.2.3 The use of 7 segments (6 pieces plus key) is preferred.

15 .10.3 Two-Pass System Circular Earth Tunnels

15 .10.3.1 The two-pass tunnel support system shall consist of a precast reinforced concrete initial liner and a cast-in-place non-reinforced concrete final liner, both designed as permanent tunnel liners. The inside diameter of the final liner shall be 16'-8". A continuous waterproofing membrane must be provided along the entire circumferential surface between the initial liner and the final liner. Details for the membrane, relief drains, and barriers () are provided by Drawings DD-S-123, DD-S-124, DD-S-125, DD-S-126, DD-S-127 and DD-S-129. The Designer shall adopt these details as required and necessary.

15 .10.3.2 The Designer shall specify tunneling machine operational requirements includingtunnel guidance system, alignment tolerances, grouting and stability requirements for the precast rings of the initial liner. The initial liner shall be comprised of segments with a maximum width of four feet. and a minimum thickness of 9 inches. Based on the geological conditions it should be decided if rings should be expanded in place without gaskets or they need to be bolted with gaskets to keep the water out of the tunnel.

15 .10.3.3 Initial Precast Liner

15 .10.3.3.1 The design of the initial precast liners of the two pass system tunnels shall be performed by the Designer. The initial liners shall be designed for the short term loads, as noted below. The liner segments shall be not less than 9 inches in thickness. The minimum compressive strength of concrete f'c of the initial liner concrete shall be 6,000 psi at 28 days, and the design shall be in accordance with the "Alternate Design Method" of the current ACI 318-99. The Designer shall include in the contract specifications and note on the drawings that the Contractor is responsible for verifying and increasing reinforcement of the initial liner as necessary to sustain loads imposed during handling and transportation, erection, jacking and grouting. The contract specification shall include the Contractor submit , working drawings and pertinent design calculations for approval.

15 .10.3.3.2 Lining Installation Method Options

15 .10.3.3.2.1 One installation method is by expanding the lining against the earth. This is a suitable method when it is not necessary to make the initial liner fully waterproof. A single-point or two-point jacking method shall be considered. Use an expansion ring for such jacking scheme. The initial gap before expansion may vary between 4° and 10°. When using two jacks axial thrust shall be produced in the liner segments in the tangential direction along the entire circumference, to maintain proper contact between segments, during expansion. Jacks shall be of adequate capacity - recommended capacity is a minimum of 100 tons each. The expanded gaps shall be supported by steel Dutchman and filled with concrete, to maintain the axial thrust in the ring.

15 .10.3.3.2.2 Another optional method is the use of bolted segments. Gasketed and bolted segments are beneficial in high water table areas. When bolted segments are used the contact between the segment and the surrounding soil is to be achieved by contact grouting.

15 .10.3.3.2.3 All lining installation methods require full grouting of the contract between the segment and the surrounding soil, and within a specified time interval. The construction documents shall require the Contractor to protect utilities, assure face support, prevent settlement, and obtain full contact between the initial liner and the ground.

15 .10.3.3.2.4 The Contractor shall be required to complete the precast tunnel (first pass) and achieve a stable configuration of the rings before the final liner is cast. The Contractor shall be required to prove stability has been achieved and maintained by convergence monitroing.

15 .10.3.3.3 Design Loads and Other Considerations

15 .10.3.3.3.1 WMATA tunnels shall be designed for short-term and long-term loads as shown in Figure 15.17, .

15 .10.3.3.3.2 For the two-pass system, the initial liner is designed for short term loads shown in Figure 15.17 only. Reduction of vertical pressure due to development of side shear in the soil is not permitted. The final liner is designed only for long-term loads.

15 .10.3.4 Final Cast-in-Place Concrete Liner:

15 .10.3.4.1 Final liner design shall be performed by the Designer/Builder. The final liner shall be designed for long term loads shown in Figure 15.17. The Designer/Builder's geotechnical consultant may revise this loading with approval of the Authority. Hydrostatic pressure shall be considered when applicable.

15 .10.3.4.2 The final liner, if not provided with steel reinforcing shall be a minimum of 16 inches thick. To account for possible tunnel misalignment, the tunnel final liner shall be designed as having a minimum thickness of 12 inches. Contraction joints shall be located at a spacing of no greater than 50 foot along the length of the tunnel arch . Contraction joints shall be spaced at no more than 150 foot for the invert . The minimum compressive strength (f'c) of the final liner concrete, at 28 days, shall be 4000 psi. The strength shall be obtained without consideration for added fiber reinforcement. Design of non-reinforced plain concrete shall be based on the requirements of the current edition of ACI 318.1 (Structural Plain Concrete). Plain concrete for the final liner shall have fiber reinforcement added for shrinkage control . The Designer shall consider the case when the tunnel is misaligned and a minimum liner thickness of 12 inches is not possible. If the minimum thickness of the misaligned tunnel liner is less than 12 inches but greater than 9 inches, the Designer shall provide contingency reinforcement. Reinforcement provided in the final liner arch because of contingency requirementsshall be discontinued at each arch contraction joint regardless of invert joint spacing and a water barrier provided . Note that even if the invert may be poured in 150 foot segments the invert

reinforcement shall be made discontinuous at each contraction joint of the arch, and a water barrier shall be provided all around the circumference of the final liner including invert. If the final liner thickness is less than 9 inches due to misalignment, the Contractor shall be required to re-mine to obtain adequate liner thickness.

15 .10.3.4.3 The Designer/Builder shall provide a computer analysis of the tunnel liner design, modulus of subgrade reactions shall be as specified by the Designer's Geotechnical Consultant, and reviewed and approved by the Authority. Use of radial springs for the computer model is recommended. All tension springs on the tunnel models must be released. Selective checks, using hand calculations shall be performed to establish the applicability of the computer analysis.

15 .10.3.4.4 Tunnel/Structure Interface - When non-reinforced final lining is used, the Designer shall provide reinforcement in transition portions at the interface with stiff structures such as, fan shafts, emergency access shafts, etc.

15 .10.4 Investigation of Construction Adjacent to Tunnels

15 .10.4.1 In areas of probable development adjacent to the tunnels, the Designer shall investigate the adequacy of the tunnel liner utilizing Loading Case II, (Section 15.4.2.1.2), Full Vertical Load, with "long-term" horizontal load on one side and "short-term" horizontal load on the opposite side (loading as recommended by the Designer's Geotechnical Consultant), acting on the combined initial and final liner. Such areas in which the tunnel liners are designed for Loading Case II shall be marked on the design drawings.

15 .11 TEMPORARY STREET DECKING SYSTEMS

15 .11.1 Temporary Decking Systems, including decking, beams, piles, lagging, bracing, struts, railings, curbs, sidewalks, and other elements shall be designed by the Contractor, based on information provided on Drawing ST-S-009 and Drawing DD-S-063. The design shall be prepared by an engineer registered in the jurisdiction of the locality of the work.

15 .11.2 Drawing. ST-S-009 and WMATA Standard Specifications require Primary Bracing Members other than slurry walls be prestressed to 50 percent (and 100% when tiebacks are used) of their design load to minimize movement of the retained soils and reduce the possibility of damage to adjacent buildings, utilities, or other structures. In localities where there are no sewers, water lines, or other utilities which could be affectedby the work, the50 percent prestressing requirement may be reduced with Authority approval. The Designer shall investigate prestressing requirements for the site in conjunction with their geotechnical consultant and modify this requirement if approved by the Authority. The requirement for 100% prestressing for slurry wall braces shall be retained in all cases.

15 .11.3 Emphasis shall be placed by the Designer on adequate design and detailing of member connections. Web stiffeners should be specified at all strut to wale connections and other points of concentrated forces.

15 .11.3.1 The Designer shall indicate in the contract drawings and cover comprehensively in the specifications, detailed arrangements for traffic

diversions, allowable restrictions, and necessary construction stages which have been approved by the public authorities.

15 .11.3.2 Acceptable locations shall also be indicated for construction access ramps or any other construction facility which affects the temporary street decking system design.

15 .12 CONSTRUCTION, GENERAL

15 .12.1 Fire Hazard Rating: NFPA 130 and NFPA 220.

15 .12.1.1 In case where no suitable material conforms with these requirements, minor quantities of an accessory material may be permitted if prior approval in writing is obtained from the Authority.

15 .12.1.2 Underwriters' Laboratories, Inc., label or listing, satisfactory test results from the National Institutes of Standards and Technology, or certified report from an approved testing laboratory, will be required to indicate that fire hazard ratings for materials proposed for use conform to the above.

15 .12.2 Ancillary Rooms at Stations

15 .12.2.1 Walls

15 .12.2.1.1 For a distance of approximately 100 feet beyond the ends of the station platform the exposed concrete in the walls and ceiling of the tunnel shall be the same color as that in the station vault. Undamaged forms shall be used to produce a smooth finish as in the station. Reinforced concrete walls shall have a smooth finish but need not be rubbed.

15 .12.2.1.2 Partition walls of ancillary rooms shall have fire ratings in accordance with the following unless otherwise specified in NFPA 130 or the local jurisdiction:

15 .12.2.1.2.1 Traction Power Substation - 3 hrs from all other occupancies

15 .12.2.1.2.2 AC Switchboard, Battery, DC Breaker, Train Control and Communications Rooms - 2 hours from all other occupancies

15 .12.2.1.2.3 Cleaner's Rooms - 2 hours from all other occupancies

15 .12.2.1.2.4 Public areas shall have a 2 hour separation from all non-public areas

15 .12.2.1.2.5 Openings between station public areas and non-transit occupancies shall have a 3 hour separation

15 .12.2.1.3 The partition walls shall comply with the applicable local Code with respect to lateral support if such is necessary.

15 .12.2.1.4 Each Mechanical Equipment Room shall have an 8' x 8' removable panel of concrete block to permit removing the air conditioning equipment from the room into the tunnel. The panel shall have a 2-hour fire rating.

15 .12.2.2 Doors -All door sizes and UL requirements shall be those listed on the Architectural Door Schedule Drawings.

15 .13 EARTH STRUCTURES

15 .13.1 Earth Structures Include Fill Embankments, Cut Slopes, or Combinations Thereof. The design of each earth structure shall be established in consultation with a geotechnical consultant and approved by the Authority. Design considerations and procedures shall be in accordance with, but not limited to, those outlined in the AREMA Manual, Chapter 1, Part 1.

15 .13.2 Slopes

15 .13.2.1 Slopes of cuts and fills shall not be steeper than two horizontal to one vertical unless approved by the Authority.

15 .13.2.2 Shoulders of cut slopes shall be rounded.

15 .13.2.3 Provide interceptor ditches at the top of cut slopes where runoff is anticipated.

15 .13.2.4 An intermediate drainage bench or benches ten feet in width shall be provided for slopes which exceed thirty vertical feet.

15 .13.2.5 Slopes shall be protected from surface erosion by a cover of grass or other vegetation suitable for the particular location and soil condition.

15 .13.2.5.1 Slopes steeper than two horizontal to one vertical, where specifically permitted by the Authority, shall be protected in a like manner.

15 .13.2.5.2 Special consideration shall be given to slopes shaded from light and precipitation.

15 .13.2.6 Where protection by grass or other vegetation is not feasible, grouted field stone rip-rap or other approved form of slope protection shall be provided.

15 .14 TUNNEL PORTAL DESIGN

15 .14.1 Tunnel and Box Section Entrance Portals shall be designed in a manner to minimize the rate-of-change of pressure on a train passing through the portal. The pressure rise is a function of both the cross-sectional area of the portal entrance and the entrance speed of the train (See Figure 15.9).

15 .14.2 Acceptable Design Methods

15 .14.2.1 Provide the entrance with a flared transition so that the increase in cross-sectional area approximates the cross-sectional area of a 6 degree conical flare starting at the constant area section of the tunnel or box and extending to the portal opening as shown on drawing DD-S-064. This flared transition can be formed using any combination of tapers on the top and sides, provided no plane or surface of the transition section is at an angle in excess of 6 degrees relative to the center line of the tunnel and provided the side tapers are symmetrical with the center line. For the required length of the flared transition see Figure 15.10 and for the required cross-sectional area at the portal see Figure 15.11.

15 .14.2.2 Design both the top and vertical sides of the entrance without a flare and provide a tapering slot in the top as shown on drawing DD-S-065. From a one foot minimum width at the constant area section the slot should increase to a maximum at the portal at a taper rate of 12 feet per 100 feet of length. The slot opening should therefore be 13 feet wide at the portal for a 100-foot long transition or 7 feet wide at portal for 50-foot long transition. For the required length of transition, see Figure 15.10.

15 .14.3 Exceptions - Exceptions that do not require special transition portals are:

15 .14.3.1 Tunnels less than 200 feet in length.

15 .14.3.2 Single track horseshoe tunnels with train velocity 45 mph or less.

15 .14.3.3 Box earth tunnels and single track circular tunnels with train velocity 40 mph or less.

15 .15 ELEVATORS

15 .15.1 Surface Structure Design Loadings

15 .15.1.1 The surface structure shall be designed for the following loads. All loads shall be applied simultaneously with allowable stresses increased in accordance with applicable codes.

15 .15.1.1.1 Dead load, 40 psf wind load and 30 psf snow load.

15 .15.1.1.2 In addition, the canopy frame shall be designed for a 100 pound per linear foot live load at the free edges.

15 .15.1.1.3 For traction type elevators, the surface structure shall be designed to support elevator beams. The end reaction of each elevator beam shall be 18,000 lbs. minimum. The locations of elevator beams vary with type of elevator and its relative machine room location. Designer shall coordinate with elevator manufacturers for the elevator beam locations.

15 .16 SOLDIER PILES

15 .16.1 Installation

15 .16.1.1 Soldier piles shall be installed in pre-bored holes unless driven piles are acceptable under the following conditions:

15 .16.1.1.1 The Designer has studied all available soils and cost data and other relevant factors and has made recommendations concurred in by his geotechnical consultant and the Authority. The following are representative of items which should be considered:

15 .16.1.1.1.1 The noise of driving piles will not be objectionable in the given locality or in conflict with local ordinances or OSHA Code.

15 .16.1.1.1.2 The underlying rock is not higher than 5 feet below the bottom of the invert, and the soil characteristics do not make penetration difficult because of boulders or high blow count.

15 .16.1.1.1.3 Driving piles will not result in incorrect pile alignment or encroachment on the neat lines of the structure.

15 .16.1.1.1.4 Driving piles will not alter soil characteristics with resulting damage to existing structures.

15 .16.1.1.1.5 There will be a reduction in cost.

15 .16.1.1.2 Note on the contract drawings where prebored piles are required and where driven piles are permitted.

15 .17 UNDERGROUND STORAGE TANKS

15 .17.1 Underground storage tanks shall be designed and installed in accordance with the following:

15 .17.1.1 40 CFR 280 and the state equivalent regulations
15 .17.1.2 NFPA 30 (latest update)
15 .17.1.3 Local jurisdiction requirements

15 .17.2 Because of the potential presence of stray current in the vicinity of WMATA facilities, only fiberglass-reinforced plastic (FRP) tanks and piping shall be used.

15 .17.3 When a steel tank is encountered during renovation or construction operations, the tank shall be removed or abandoned in accordance with the code and regulations specified in Q.1. Steel tanks shall be replaced with FRP tanks.

15 .17.4 Tanks shall have the appropriate leak detection system in accordance with local jurisdiction requirements.

15 .17.5 Underground storage tanks and related piping shall not be located within 100 feet of a WMATA subsurface structure.

15 .17.6 Vault Tanks: Generally, vault tanks shall not be constructed. When a vault tank is necessary, design and construction shall be coordinated with the Authority.

15 .17.7 New tanks shall be provided as follows:

15 .17.7.1 Tanks material will be FRP.

15 .17.7.2 Tanks shall be of double wall construction, and shall have a minimum 30 year life.

15 .17.7.3 Fiberglass tanks shall be in compliance with ASTM specification 04021-81, and UL 1316-83. Tanks shall bear the UL label.

15 .17.7.4 Tanks shall comply with National Fire Protection Association (NFPA) 30, "Flammable and Combustible Liquid Code" and applicable local requirements.

15 .17.7.5 Tanks shall be installed per manufacturer's recommendations which must include the following:

15 .17.7.5.1 Bedding material

15 .17.7.5.2 Requirements for surface traffic protection

15 .17.7.5.3 Allowable depth of installation

15 .17.7.5.4 Special tank supporting system if required.

15 .17.7.6 The material used in tank construction or lining shall be compatible with the substance to be stored.

15 .17.8 In most cases, corrosion protection will not be required because tank and piping construction will be FRP materials. When required because of steel tank or steel piping construction, corrosion protection shall be accomplished by the following method:

15 .17.8.1 Use of cathodic protection in accordance with the National Association of Corrosion Engineers Standard RP-01-69 (1983 Rev.).

15 .17.8.2 Corrosion protection shall be designed by a qualified corrosion engineer.

15 .17.9 Tanks shall be equipped with a leak detection system. The detection system shall have a master control that will provide both visual and audible alarm when a leak is sensed. A Veeder-Root® or equivalent system (as determined by WMATA) shall be used. As a minimum, detection systems shall comply with the following:

15 .17.9.1 The detection system shall be Underwriter's Laboratory and Factory Mutual approved.

15 .17.9.2 Double wall tanks shall have annular or interstitial space monitoring to detect leakage or break down in either or both inner and outer walls.

15 .17.9.3 Where single wall tanks are located within a concrete vault, external monitoring shall be accomplished by observation wells strategically located around the tanks within the confines of the vault.

15 .17.10 All related piping, valves and fittings of Class I, II and III flammable and combustible liquids shall conform to NFPA Code 30.

15 .17.10.1 Piping shall be UL labeled and corrosion resistant to combustible liquids and corrosive soils.

15 .17.10.2 Piping material shall be FRP. Piping shall be installed in accordance with the manufacturer's instructions, and shall have a minimum 30 year life.

15 .17.10.3 Distribution piping shall be provided with a secondary containment system. A double wall piping system shall be provided. This system shall be tested prior to backfilling to achieve system integrity equal to that of the double wall tank. The piping system shall be designed to as to preclude tank contents from standing in the piping system during non-flow periods.

15 .17.11 No connection (such as venting or drainage) of any storage and related piping of Class I and II flammable liquids to Metro subsurface structure shall be permitted.

15 .17.11.1 All tanks shall be atmospherically vented, in accordance with state and local air pollution codes.

15 .17.11.2 Venting of any Class I, II and III flammable and combustible liquid storage structure shall not be permitted within 30 feet clear of the WMATA surface opening, subway entrance, or emergency opening.

15 .17.12 The surface around pump islands shall be graded to drain away from any Metro grating or other opening in a manner to divert possible spills away from the subsurface and shall be surrounded by a curb at least 6" high. Provisions shall be made for draining of accumulations of ground or rain water or spills of flammable or combustible liquids.

15 .17.13 Excavation operations shall not be performed directly above, below, or within 100 feet (measured horizontally) of any existing tank until the tank is pumped clean and purged of all vapor. Pressure tests of storage tanks shall be performed prior to excavation operations. Combustible gas detection analyzers shall be used during operations.

15 .17.14 Aerial and at-grade structures shall be built in such a manner that their support loads are not transmitted to an adjacent tank. Where this is not possible the tanks shall be removed and, after consideration of soil and bearing conditions, properly placed in a location so that loads on the tank will not occur. The minimum horizontal distance shall be established in accordance with the requirement of NFPA 30, the local authority having jurisdiction and a qualified soils engineer after consideration of the soil bearing conditions.

15 .17.15 Underground vaults and tanks shall be so located with respect to adjacent building foundation and supports that the loads carried by the latter cannot be transmitted to the vault or tank.

15 .17.16 Tanks shall be tested in accordance with the provisions of NEPA 30 and manufacturer's criteria to assure total tank and piping system integrity.

15 .17.17 During pipe pressure testing, piping shall be isolated from tank and pump.

15 .18 METRO UNDERGROUND STRUCTURES DESIGN FOR AIR PRESSURE CAUSED BY RUNNING TRAINS

15 .18.1 The following air pressure shall be considered in addition to other loading:

15 .18.1.1 Fan and vent shaft dampers and ancillary area walls, doors and hardware adjacent to stations and portals shall be designed to withstand a dynamic force, reversible in its direction, of 70 psf pressure.

15 .18.1.2 Normally, no doors or walls shall be constructed in cross-passages separating two tunnels. However, when they must be constructed to satisfy safety or other requirements, the design pressure shall be as defined in Section 15.18.1.1.

15 .18.1.2.1 Doors located in areas stated in Section 15.18.1.1 and used as emergency exits shall be concave pivot doors. If concave doors are not feasible, other suitable doors satisfying the criteria may be used.

15 .18.1.2.2 For retrofit of existing doors in areas defined in Section 15.18.1.1, where replacements with concave pivot doors are not feasible, medium

range blast doors shall be used. All related hardware must satisfy the criteria mentioned in Section 15.18.1.1

15 .18.1.3 Station structures including ceiling and other components shall be designed to withstand the wind load of 40 psf.

15 .19 ROOF DRAINAGE - See Section 3.10.8.

15 .20 WATERPROOFING

15 .20.1 Underground facilities and below-grade portion of structures shall ~~should~~ be designed to prevent water infiltration.

15 .20.2 Design for watertightness shall include but not be limited to the following items:

15 .20.2.1 Provide water stops at expansion, construction and contraction joints.

15 .20.2.2 Provide sloping roof and floor slabs in underground areas to assure positive drainage and prevent surface depressions, i.e., "bird baths."

15 .20.2.3 If a wall is adjacent to earth or rock, provide a waterproofing membrane on the outside face of the wall and provide relief drainage if necessary. Use applicable details of WMATA standard and design drawings (ST and DD-Drawings)

15 .20.2.4 Provide drip shields in all ~~underground areas~~ aboveground structures.

15 .20.2.5 Joints in the floor, ceilings or walls of rooms or buildings containing electrical equipment, such as Traction Power Substations, Tie-breaker Stations, AC Switchboard rooms, Battery rooms, Automatic Train Control and Communication rooms should be avoided~~, but~~ and kept to a minimum where essential. Joint locations in rooms containing electrical equipment shall be coordinated closely with the Authority to insure proper equipment location.

15 .20.2.6 Structures containing electrical equipment shall have continuous waterproofing all around outside face of walls including the bottom slab and roof.

15 .20.3 Waterproofing membrane

15 .20.3.1 Waterproofing membrane shall comply with a minimum of 100 years durability requirements. Testing standards for 100 years durability shall be provided, subject to Authority review and approval.

15 .20.3.2 All seams and lap shall be double wedge welded seams unless otherwise approved by Authority. All seams and lap joints shall be air pressure tested. Visual inspection of seams and lap joints shall not be permitted.

15 .21 PRECAST PRESTRESSED CONCRETE PARKING STRUCTURES: - In addition to the requirements of this design criteria , the structural design of the precast prestressed parking structure shall also satisfy the following requirements Precast and Prestressed Concrete Institute (PCI) Design Handbook and Building Code Requirements for Masonry Structures (ACI 530/ASCE 5) and Specifications for Masonry Structures (ACI 530.1 /ASCE 6) and ,ADAAG: ADA Accessibility Guidelines for Buildings and Facilities.

15 .21.1 Loads: - The following loads shall be the basis for structural design:

15 .21.1.1 Live:

15 .21.1.1.1 Parking Roof - 80 PSF (which includes 30 PSF snow load),

15 .21.1.1.1.1 or two 4 kip concentrated loads, each acting on an area of 4.5 inches by 4.5 inches, at a spacing of 6'-0". The distribution of the concentrated load on the cantilever portion of double tees, shall be based on a 45 degree angle. ~~a minimum 3 kips concentrated load acting on an area of 4.5 inches by 4.5 inches plus a 30 PSF snow load.~~

15 .21.1.1.1.2 For roofs without car access use roof loads per IBC

15 .21.1.1.2 Typical Parking - ~~50 PSF and a minimum 3 kips concentrated load acting on an area of 4.5 inches by 4.5 inches.~~ 50 PSF or two 4 kip concentrated loads, each acting on an area of 4.5 inches by 4.5 inches, at a spacing of 6'-0". The distribution of the concentrated load on the cantilever portion of double tees, shall be based on a 45 degree angle

15 .21.1.1.3 Stairs & Elevator Lobby shall be designed for a uniform load of 150 psf (no area reduction factor allowed). Stairs shall also be checked for a minimum concentrated load of 300 pounds (on an area of 4 square inches) on stair treads. In the District of Columbia, stair treads only shall be designed for a uniform load of 100 psf plus a concentrated load of 300 pounds.

15 .21.1.1.4 Car Impact - 10 kips (Ultimate) Horizontal. Load at 18 inches above driving surface.

15 .21.1.1.5 Elevator Machine Room- 150 PSF or Actual Weight of Mechanical or Electrical Equipment Whichever is Larger.

15 .21.1.1.6 Wind:

15 .21.1.1.6.1 Basic Wind Speed - The minimum basic (normal) wind speed shall be 105 mph ~~110 MPH~~ (3 second gust~~s~~, V_{asd}=105 mph).

15 .21.1.1.6.2 Wind Exposure "C"

15 .21.1.1.7 Snow:

15 .21.1.1.7.1 ~~(Not including drift) 30 PSF~~ A minimum of 30 psf snow load shall be applied on parking roofs without drifting load. The parking roof live load includes this 30 psf snow load. See Section 15.21.1.1.1.

15 .21.1.1.7.2 ~~(note: included in Parking Roof load above)~~Other snow loads such as partial loading, unbalanced roof snow loads, drifts, sliding snow, rain-on-snow surcharge load, ponding instability shall be calculated as per ASCE-7.

15 .21.1.1.8 Seismic

15 .21.1.1.8.1 In accordance with IBC and information from the soils report.

15 .21.1.2 Dead Load:

15 .21.1.2.1 Dead Loads shall be in accordance with IBC.

15 .21.1.2.2 Provisions shall be made for an uniformly distributed superimposed load of ~~10~~ 5 psf for roof level and 5 psf for all ~~other~~ levels as a contingency load .

15 .21.1.2.3 In addition, dead load of other miscellaneous cast-in-place (CIP) concrete for such items as raised walkways, wheel stops in accessible parking spaces, etc., shall be included in the design.

15 .21.2 Loading combinations shall be in accordance with the IBC

15 .21.3 Limits on the Concrete Stresses:

15 .21.3.1 Extreme fiber stress in tension in concrete immediately after prestress transfer (before time-dependent prestress losses) shall be as noted in Section 15.9.3.3.1.3. Increase in the depth of the members, and/or the use of draped tendons or a judicious use of additional tendons can be used to maintain stresses within the above-mentioned recommended limits. Bonded auxiliary reinforcement if used, shall consist of many small bars distributed uniformly over the face rather than a few large bars .

15 .21.3.2 Extreme fiber stress in tension, in precompressed tensile zone at service loads (after prestress losses) shall be as given in Section 15.9.3.3.1.3.

15 .21.4 Unless noted otherwise, all cast-in-place concrete shall be air entrained normal weight concrete.

15 .21.5 Concrete Strengths:

15 .21.5.1 Cast-in-place concrete placed on precast concrete elements shall attain 28 day minimum compressive strength of 6,000 psi and shall have a water-cement ratio of 0.38 or less. This concrete shall be fiber reinforced concrete with a minimum of 0.1 % by volume of Fibermesh 300 or approved equal. All other cast-in-place concrete shall have a compressive strength of 4,000 psi, at 28 days, with a water-cement ratio of 0.45 or less. ~~Cast-in-place concrete used compositely with precast prestressed concrete shall attain 28 days minimum compressive strength of 5,000 psi and shall have a water-cement ratio of 0.38 or less. All other concrete shall be 4,000 psi minimum, with a water-cement ratio of 0.45 or less.~~

15 .21.5.2 Unless noted otherwise, all precast prestressed concrete shall attain 28-day minimum compressive strength of 6,000 psi with a maximum water-cement ratio of 0.38 and contain a calcium nitrite-based corrosion inhibitor as specified in Section 15.21.25.

15 .21.6 Double Tees:

15 .21.6.1 For a 60 feet clear span parking bay a column grid of 62 feet by 45 feet is recommended. For such a bay the normal length of the DT is considered as 60 feet. As shown on drawing DD-S-PF-004, the minimum depth of the DT shall be 34 inches. For serviceability and longevity, in addition to the maximum allowable stresses, limit the maximum deflection of double tees to **7/8** inch at roof and **1/2** inch at other levels at the center under live load including snow load at the roof level. In an unusual situation if longer DT has to be used, then the DT spans of over 60 feet, limit the minimum natural frequency of the beam

system to 3 Hz. as flexural members. See drawing DD-S-PF-004 for the dimensions of the 10 ft., 12 ft. and 15 ft. wide DT's. Avoid dapping the DT's as much as possible. Flanges of double-tees shall be connected with stainless steel hardware as shown in Design Drawing DD-S-PF-003 at 4'-0" spacing maximum, or use of stainless steel Vector Connectors at an average spacing of 3'-6" . All other structural steel connections and associated components shall be hot-dipped galvanized after fabrication.

15 .21.6.2 For expansion joints between the DT flanges see Section 15.21.13.

15 .21.6.3 Galvanized connections that are subsequently field-welded shall be touched up with zinc rich paint after welding, as per the Technical Requirements/Specifications.

15 .21.7 **Concrete Reinforcement**: All reinforcing steel for concrete shall conform to ASTM Specifications A615, Grade 60 for bars (A 706 where required for welding) and A185 for welded wire fabric. Reinforcing details shall be in accordance with current ACI "Manual of Standard Practices for Detailing Reinforced Concrete Structures". Bar laps shall be Class "B" tension laps. Provide concrete cover over reinforcing bars in accordance with ACI 318 (unless noted otherwise). Hooks shown shall be standard hooks unless otherwise dimensioned

15 .21.8 **Mechanical Tension Splices** of reinforcing bars made by the use of Cadweld or NMB Splices. All mechanical couplers shall comply with the seismic requirements of ACI 318 latest edition or ACI 318-99 when designing by the Alternate Design Method. Other mechanical splices/couplers may be accepted on a case by case basis at the sole discretion of the Authority.

15 .21.9 **The Shop Drawings**, prepared by the fabricator or the pre-caster, shall include the precast foundation reactions for all the loading combinations. All column connections to the piers, and all light wall connections to the foundations about their minor axes shall be hinged connections. All column connections to the piers, for parking garages having a maximum of three levels may be designed as fixed at the foundation and detailed accordingly, with the prior approval of the Authority.

15 .21.10 **Lateral Loads** shall be transmitted to shearwalls and light-walls through the roof and floors acting as horizontal diaphragms. Any torsional effects due to unsymmetrical location of the shearwalls and the lateral loads shall considered in the design. Minimum 5% eccentricity shall be assumed in design.

15 .21.11 **Connections:** The precast manufacturer shall design and provide all embedded items necessary to adequately anchor the precast member to the foundation including anchor bolts. Any additional foundation details required for proper transfer of forces between the precast members and the foundation not already shown in the design shall be submitted with the shop drawings by the precast manufacturer

15 .21.12 **The Inverted Tee Beams (ITB):**

The Inverted Tee Beams (Itb) shall be at Least 44 Inches Deep, with a minimum stem width of 22 inches at the top and 38 inches at the bottom. For ITB spans over 45 feet, the span to depth ratio shall not exceed 12.5. Provide embedded steel bearing plates at both ends of ITB's. Provide adequate protection of the prestressing strands after they are cut off. The design of the bearing of ITB's shall consider the effect of eccentric loading during construction. Also as a minimum, closed ties in the lower section of the beams as shown in the

Standard/Project Drawings shall be provided. The minimum shear reinforcement shall be as shown on the Standard/Project Drawings. Provide inverted U-shaped bars, in the IT stem, extending into the wash strip on top level and at all other levels.

15 .21.13 For the precast concrete parking structure, the expansion (isolation) joint shall be placed at a location not farther than 150 feet from the center of restraint. If the center of restraint is at the middle of structure, the expansion joint could be placed at 150 feet on each side providing a total length of 300 feet with out expansion joint. If however the structure is longer or wider than 150 feet, say 252 feet, and the restraint is located at the outer edge of the building, an expansion joint would be required at a distance not to exceed 150 feet. If circumstances warrant extending this limit, prior approval of the Authority's Representative shall be obtained and documented in the design calculations and be noted on the Final Design Drawings. The spacing for the sliding connections at expansion joints shall be designed for the loads specified and to make sure that double tee beams on both sides of the expansion joint work together as a unit when a wheel either passes along the expansion joint on one double tee or crosses the joint from one beam to another. ~~When the expansion joint is between side by side flanges of double tees (DT), along the length of the DDS, the maximum spacing of the sliding connections shall be 3'-0". These sliding connections would limit the differential deflection between the flanges.~~

15 .21.14 **Expansion Joints** shall be placed where area floor systems are graded with washes constructed cast in place concrete (only, not precast) such that water will not pass over an expansion joint, except the sealed expansion joints in ramps.

15 .21.15 **Inverted Tee or Expansion Joint** washes shall be graded so that water does not flow over the wash.

15 .21.16 At the expansion Joint between the flanges of Double Tees (DTs), a flange support system shall be used to transfer the moving load from the flange of one DT to the flange of the other DT to eliminate a bump at the expansion joint, see drawing DD-S-PF-003, for a recommended 'Flange support at Expansion Joints. ~~Deleted.~~

15 .21.17 **Cast-in-place Concrete Wash Strips** at Inverted Tee Beams and cast-in-place concrete wash areas at Ell Beams and any other wash areas: The minimum thickness of concrete in these cast-in-place concrete washes shall be a minimum of - one and one half inches. The concrete in these wash areas shall be adequately reinforced with epoxy coated WWF or reinforcing epoxy coated bars.

15 .21.18 Deleted.

15 .21.19 **The Bearing Pads** shall be either Fabreeka, Capralon or Masticord per Authority's approval (see drawing DD-S-PF-001). Galvanized steel plate support or embedded galvanized steel plates shall be provided under the bearing pads .

15 .21.19.1 The design of bearing pads shall take into account the effect of beam camber, deflected shape, and the slope of the floor beams and double tees.

15 .21.20 **The Support for the Itb's**, spandrels, Ell-beams shall be designed for the maximum load acting as an edge load acting at any place along the bearing pad. When the beams are supported on corbels or brackets, the moment at the corbel column interface will be maximum when the load is at the farthest edge of the bearing pad. Effect of torsion, if any, shall also be considered.

15 .21.21 **The Corbels and Brackets** shall be designed for the maximum load noted above and the maximum lateral load due to thermal, wind and seismic effects.

15 .21.22 **The Effect of Lateral Movement** of the structure due to wind and seismic effects, including effects on bearing pads and bearing connection shall be considered in the design.

15 .21.23 **The Connections of Horizontal Diaphragms** with the vertical members transferring horizontal loads shall be such that there will not be any distress due to deformation of the bearing pads.

15 .21.24 **Full Attention Shall Be Given to Restrict Corrosion** of reinforcement, embedded steel and any other exposed steel at connections. Silane penetrating sealers as specified previously shall be required as well as use of corrosion-inhibitor in concrete. The corrosion-inhibitor shall be calcium nitrite-based admixture DCI or approved equal.

15 .22 **For Precast Concrete Elements** and for cast-in-place concrete overlay topping over inverted tee beams on top level and for cast-in-place concrete in wash strips and wash areas on all levels, use four (4) gallons per cubic yard of the corrosion inhibitor when the water-cement ratio is 0.40 or less and use three and a half gallons (3-1/2) per cubic yard when water-cement ratio is 0.38 or less. To increase the service life of the structure, use epoxy coated Welded Wire Fabric (wwf) and reinforcing bars in the double tee flanges on the top level, in cast-in-place concrete overlay topping on top level, and all inverted U-shaped bars in the cast-in-place concrete wash strips (over inverted tee beams) and all wwf in cast-in-place concrete wash areas on all levels. No other epoxy coating of reinforcement is required unless so directed.

15 .22.1 **Provide Lateral Prestressing in the Flange Slab at Each End of Double Tees**, to prevent cracking and other damage during handling and transportation. Two full loops of prestressing strands (each 360°) at each end shall be provided. This can be accomplished by using one continuous strand or two strands.

15 .22.2 **The Fabricator (Precaster)** shall participate in the Precast/Prestressed Concrete Institute (PCI) Certification Program and be designated as a PCI certified plant for product categories A1 and C3. The fabricator shall have continuous experience and is to be regularly engaged in the fabrication of precast/prestressed concrete products as per the requirements of the RFP and as stated in the Technical Proposal as finally accepted.

15 .22.3 All structural steel, unless otherwise noted, shall conform to ASTM A36, ASTM A709 and A992, and all anchor bolts shall conform to ASTM A307, unless approved otherwise by the Authority.

15 .22.4 All structural steel used for connections shall be hot-dip galvanized after fabrication except as noted otherwise.

15 .22.5 Unless otherwise shown, all bolted framing connections shall be 3/4-inch diameter bolt ASTM A325 bolts designed and detailed as slip-critical connections in accordance with the AISC specifications. For structural joints using ASTM A325 or 490 bolts (surface condition shall be Class A or better and fastener tension in accordance with Table 4). Connections not shown shall be designed for a minimum shear capacity of 55-percent of maximum beam carrying capacity under uniform load for the span indicated. All welded framing connections shall have a capacity, no less than that for the span indicated

15 .22.6 All welding electrodes shall conform to E70XX except for stainless steel. Welding electrodes for stainless steel shall be in accordance with AWS and shall be approved by the Authority's Representative prior to use.

15 .22.7 Tee Beams Ending at Skewed Walls/Column Lines: If skewed deck plan has to be used, it is recommended that the Designer should consider the use of flat precast panels to span relatively short spans. However, for long spans with skewed ends the Designer shall pay particular attention to the details required where the tees end at skewed wall/column lines including but not limited to, use of diaphragms and added reinforcing to assure superior strength and durability and to avoid the potential for concrete cracking. The design shall account for constructability, uneven stiffness of double tees, and special details at the bearings.

15 .22.8 Column and wall footings shall be designed based on the proposed precast building systems components, configurations, loads and locations shown. The Designer/Builder shall coordinate all precast details and dimensions to insure that the proposed foundation system is compatible with precast system used.

15 .22.9 It is the Designer/Builder's responsibility to insure the stability of the structure during construction by providing temporary supports, bracing and other means as required. Where temporary connections are to be used, they shall be noted on the shop drawings along with the anticipated forces.

15 .22.10 It is also the Designer/Builder's responsibility to ensure that the erected portions of the structure, part or full, do not deform or deviate from their installed positions, after the temporary supports, bracing etc. are removed . The general erection scheme should be submitted to the Authority, for review and approval.

15 .22.11 Masonry:

15 .22.11.1 Concrete masonry units shall conform to ASTM C90 –1 and shall have minimum compressive strength of 2,000 PSI on the net area. Masonry mortar shall be type "S".Provide 9-gauge truss-type joint reinforcing at 16 inches O.C. in all masonry walls.

15 .22.11.2 All masonry accessories shall be hot-dipped galvanized or stainless steel to meet Standard Specifications.

15 .22.11.3 The masonry shall be designed and constructed in accordance with applicable codes and standards.

15 .22.12 GEOTECHNICAL DESIGN:

15 .22.12.1 The design criteria for the geotechnical portion of the Work shall be in accordance with the Designer's geotechnical evaluation or the following, whichever is more conservative

15 .22.12.2 Soil Parameters:

15 .22.12.2.1	Unit Bulk Weight	130 PCF
15 .22.12.2.2	Submerged Unit Weight	68 PCF

15.21.40.2.3 Coefficient of Friction Between Concrete and the Foundation Soils – 0.35

15 .22.13 Foundations:

15 .22.13.1 Foundation design shall be based on subsurface exploration and recommendations provided in the Designer's Geotechnical Design Report (GDR) prepared by an Authority-approved Geotechnical Engineer registered as a professional engineer in the jurisdiction of the work.

15 .22.13.2 Spread footings, piles or caissons may be used as foundations The maximum settlement of any column shall not be greater than 1 inch nor the differential settlement between any two adjacent columns greater than ½ inch.

15 .22.13.3 Not Used

15 .22.13.4 Caissons must be designed by and fully justified by Designer's approved Geotechnical Engineer registered as a professional engineer in the Jurisdictionof the proposed Parking Structure .

15 .22.13.5 Any variations to the approved design shall be reported to the Authority Representative in writing before the construction of the foundations.

15 .22.14 Compacted Structural Backfill:

15 .22.14.1 Placement requirements and material properties for compacted structural backfill against interior ramp walls and retaining walls shall be in accordance with the Technical Requirements.

15 .22.14.2 Only hand-operated compaction equipment (less than 2,000 pounds) shall be used within ten feet of any structure.

15 .22.14.3 All subgrade surfaces shall be proof-rolled with at least two passes of a fully loaded 10 wheel dump truck prior to placement of previous material or backfill within the building area and at least five feet beyond the outer edge of the footings.

15 .22.15 Slab-On-Grade

15 .22.15.1 A 6" thick concrete slab on grade pavement reinforced with epoxy coated Welded Wire Fabric (WWF) shall be used on the base floor.

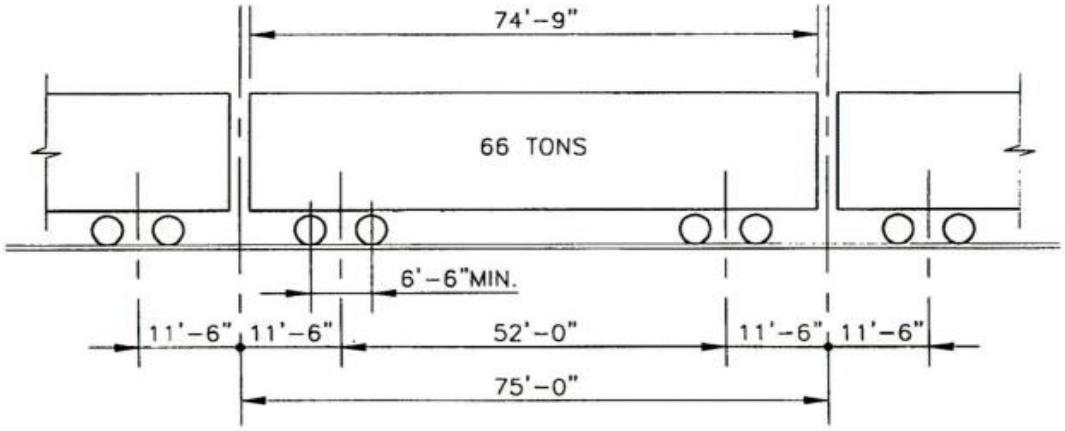
15 .22.16 The criteria set forth herein shall be treated as minimum requirements. The responsibility for production, and erection of structurally adequate and sound precast members without structural cracks or damage lies with the Designer/Builder.

TABLE 15.1

AVERAGE VERTICAL LOAD (P_R) ON ROCK TUNNELS

TUNNEL TYPE		Single Track	Double Track	Station
Excavated Dimensions		20' Wide 18' High	35' Wide 24' High	70' Wide 40' High
Type I Lining: Minimum Cover of "Relatively Sound or Sound Rock" required for Type I lining. (see Note 4)		10'	15'	30'
Type II Lining: Type II lining is used for the following conditions		AVERAGE VERTICAL LOAD P_R		
(A)	Portal Sections, or where rock cover of any quality is $\leq$ 0.4 of minimum rock cover for Type I lining, or where thicker rock cover is highly jointed and weathered.	Full Overburden ΣV	Full Overburden ΣV	Full Overburden ΣV
(B)	Rock cover "relatively sound or sound" is $\geq$0.4, but is $\leq$0.6 of minimum rock cover for Type I lining.	(0.15)x(ΣV)	(0.30)x(ΣV)	(0.60)x(ΣV)
(C)	Rock cover "relatively sound or sound" is $\geq$0.6, but is $\leq$0.8 of minimum rock cover for Type I lining.	(0.10)x(ΣV)	(0.20)x(ΣV)	(0.40)x(ΣV)
(D)	Rock cover "relatively sound or sound" is $\geq$0.8, but is $\leq$1.0 of minimum rock cover for Type I lining.	(0.05)x(ΣV)	(0.10)x(ΣV)	(0.20)x(ΣV)
(E)	Rock cover $\geq$ 1.0 of minimum rock cover for Type I lining, but is not "relatively sound or sound" at tunnel top.	0.5 ksf	1.0 ksf	2.0 ksf

Notes:
(1) ΣV = Total pressure of overburden, soil plus rock, above tunnel top.
(2) Rock described in D. U. Deer report of November 1, 1967 as "good to excellent"' with RQD values greater than 65 to 75 percent generally qualifies as "relatively sound or sound" rock cover.
(3) Rock described on the geological sections in the WMATA soils reports prepared by MRCE, as "relatively sound or sound", with RQD values greater than 60 to 70 percent generally qualifies as "relatively sound or sound" rock cover.
(4) No vertical load is considered for the design of the tunnel lining, in "relatively sound or sound" or better rock and is called Type I lining.
(5) These are the minimum values of P_R. Higher values may be used if ascertained by the Designer's Geotechnical Consultant.



1.	DESIGN Loads	VEHICLE	82,000 LB.
		PASSENGERS	50,000 LB.
		TOTAL RAPID TRANSIT LOADING (LL)	132,000 LB.
2.	AXLE LOAD		33,000 LB.
3.	IMPACT		AS SPECIFIED
4.	CENTRIFUGAL FORCE		[0.0012 x SPEED ^{2} (MPH) x DEGREE OF CURVE (DEG)] % LL
5.	ROLLING FORCE		10% LL
6.	LONGITUDINAL BRAKING AND TRACTIVE FORCE		15% LL
7.	LOADING COMBINATIONS		FOR COMBINATIONS OF ABOVE LOADS REFER TO SECTION E

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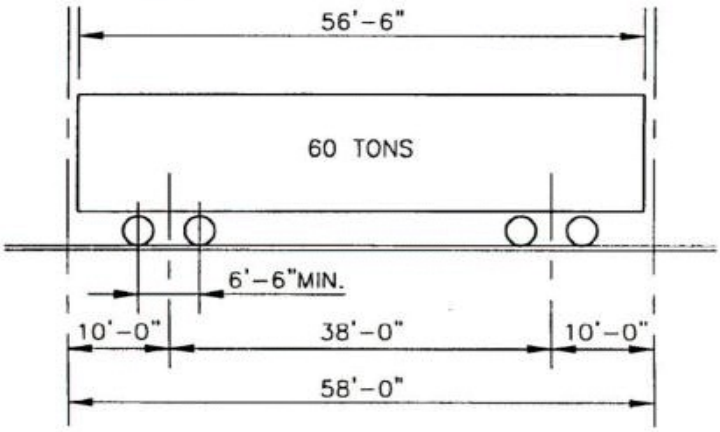
RAPID TRANSIT VEHICLE DESIGN LOADING

FIGURE 15.1



1.	DESIGN Loads	CAR	80,000 LB.
		PAYLOAD	40,000 LB.
		TOTAL CRANE CAR LOADING (LL)	120,000 LB.
2.	AXLE LOAD		30,000 LB.
3.	IMPACT		AS SPECIFIED
4.	CENTRIFUGAL FORCE		[0.0012 x SPEED^2 (MPH) x DEGREE OF CURVE (DEG)] % LL
5.	ROLLING FORCE		±10% LL
6.	LONGITUDINAL BRAKING AND TRACTIVE FORCE		15% LL
7.	LOADING COMBINATIONS		FOR COMBINATIONS OF ABOVE LOADS REFER TO SECTION E

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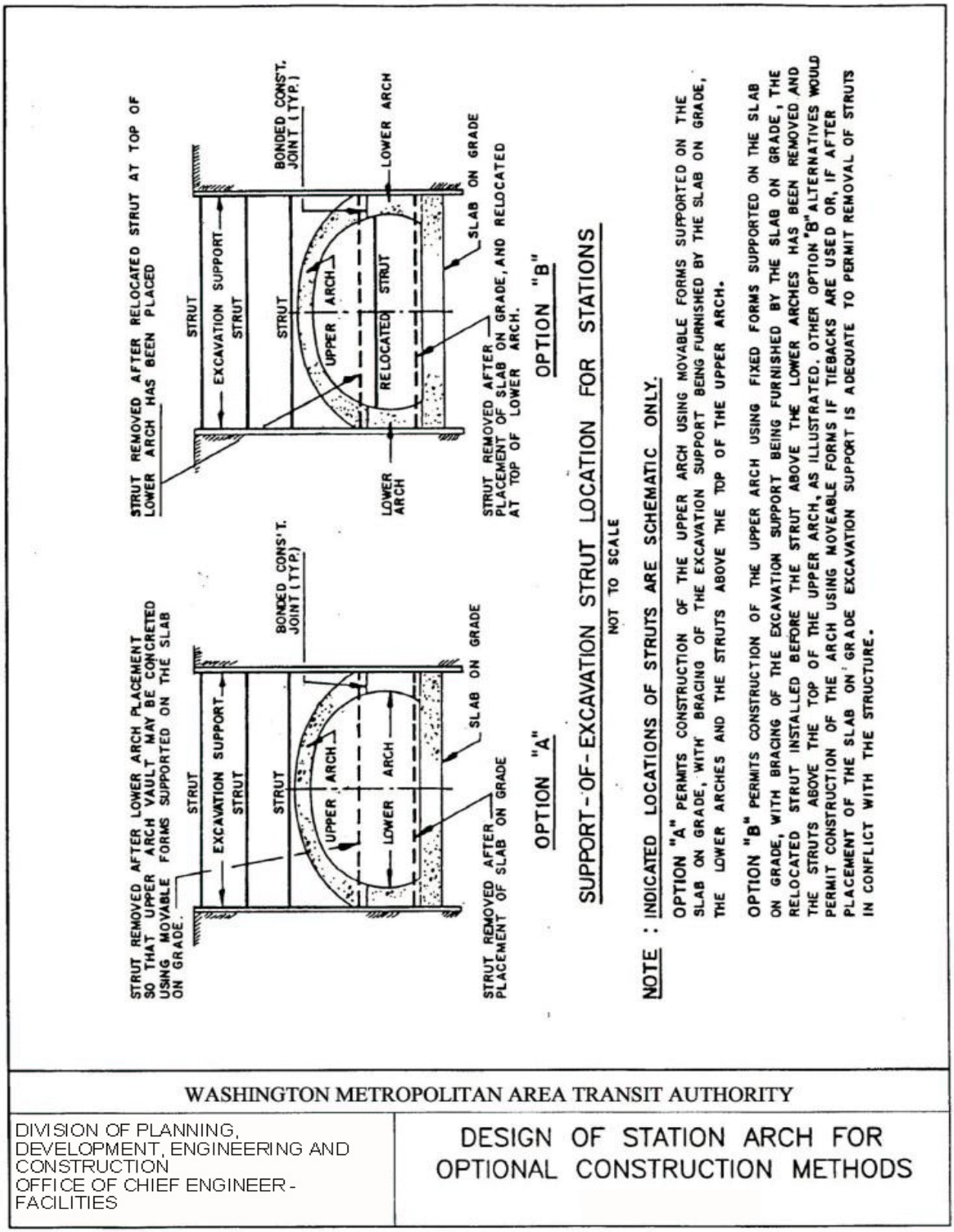
CRANE CAR
DESIGN LOADING

FIGURE 15.2


STRUT REMOVED AFTER RELOCATED STRUT AT TOP OF LOWER ARCH HAS BEEN PLACED
STRUT
EXCAVATION SUPPORT
STRUT
STRUT
BONDED CONST. JOINT (TYP.)
LOWER ARCH
SLAB ON GRADE
UPPER ARCH
RELOCATED STRUT
LOWER ARCH
STRUT REMOVED AFTER PLACEMENT OF SLAB ON GRADE, AND RELOCATED AT TOP OF LOWER ARCH.
OPTION "B"
STRUT REMOVED AFTER LOWER ARCH PLACEMENT SO THAT UPPER ARCH VAULT MAY BE CONCRETED USING MOVABLE FORMS SUPPORTED ON THE SLAB ON GRADE.
STRUT
EXCAVATION SUPPORT
STRUT
STRUT
BONDED CONS'T. JOINT (TYP.)
SLAB ON GRADE
UPPER ARCH
LOWER ARCH
STRUT REMOVED AFTER PLACEMENT OF SLAB ON GRADE
OPTION "A"
SUPPORT-OF-EXCAVATION STRUT LOCATION FOR STATIONS
NOT TO SCALE
NOTE : INDICATED LOCATIONS OF STRUTS ARE SCHEMATIC ONLY.
OPTION "A" PERMITS CONSTRUCTION OF THE UPPER ARCH USING MOVABLE FORMS SUPPORTED ON THE SLAB ON GRADE, WITH BRACING OF THE EXCAVATION SUPPORT BEING FURNISHED BY THE SLAB ON GRADE, THE LOWER ARCHES AND THE STRUTS ABOVE THE TOP OF THE UPPER ARCH.
OPTION "B" PERMITS CONSTRUCTION OF THE UPPER ARCH USING FIXED FORMS SUPPORTED ON THE SLAB ON GRADE, WITH BRACING OF THE EXCAVATION SUPPORT BEING FURNISHED BY THE SLAB ON GRADE, THE RELOCATED STRUT INSTALLED BEFORE THE STRUT ABOVE THE LOWER ARCHES HAS BEEN REMOVED AND THE STRUTS ABOVE THE TOP OF THE UPPER ARCH, AS ILLUSTRATED. OTHER OPTION "B" ALTERNATIVES WOULD PERMIT CONSTRUCTION OF THE ARCH USING MOVEABLE FORMS IF TIEBACKS ARE USED OR, IF AFTER PLACEMENT OF THE SLAB ON GRADE EXCAVATION SUPPORT IS ADEQUATE TO PERMIT REMOVAL OF STRUTS IN CONFLICT WITH THE STRUCTURE.
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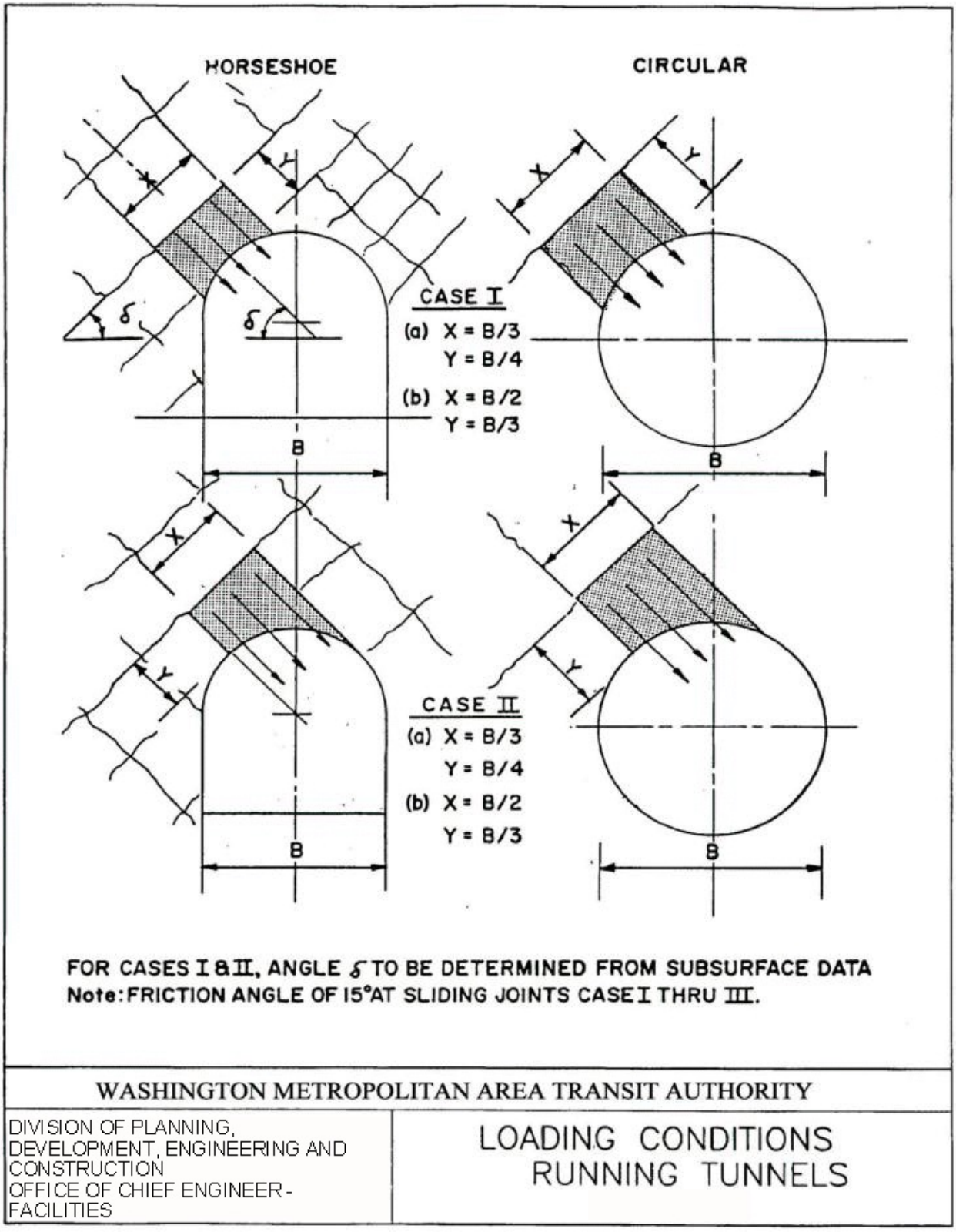
DIVISION OF PLANNING, DEVELOPMENT, ENGINEERING AND CONSTRUCTION
OFFICE OF CHIEF ENGINEER - FACILITIES
DESIGN OF STATION ARCH FOR OPTIONAL CONSTRUCTION METHODS

FIGURE 15.3


HORSESHOE
CIRCULAR
CASE I
(a) X = B/3
Y = B/4
(b) X = B/2
Y = B/3
CASE II
(a) X = B/3
Y = B/4
(b) X = B/2
Y = B/3
B
FOR CASES I & II, ANGLE δ TO BE DETERMINED FROM SUBSURFACE DATA
Note: FRICTION ANGLE OF 15° AT SLIDING JOINTS CASE I THRU III.
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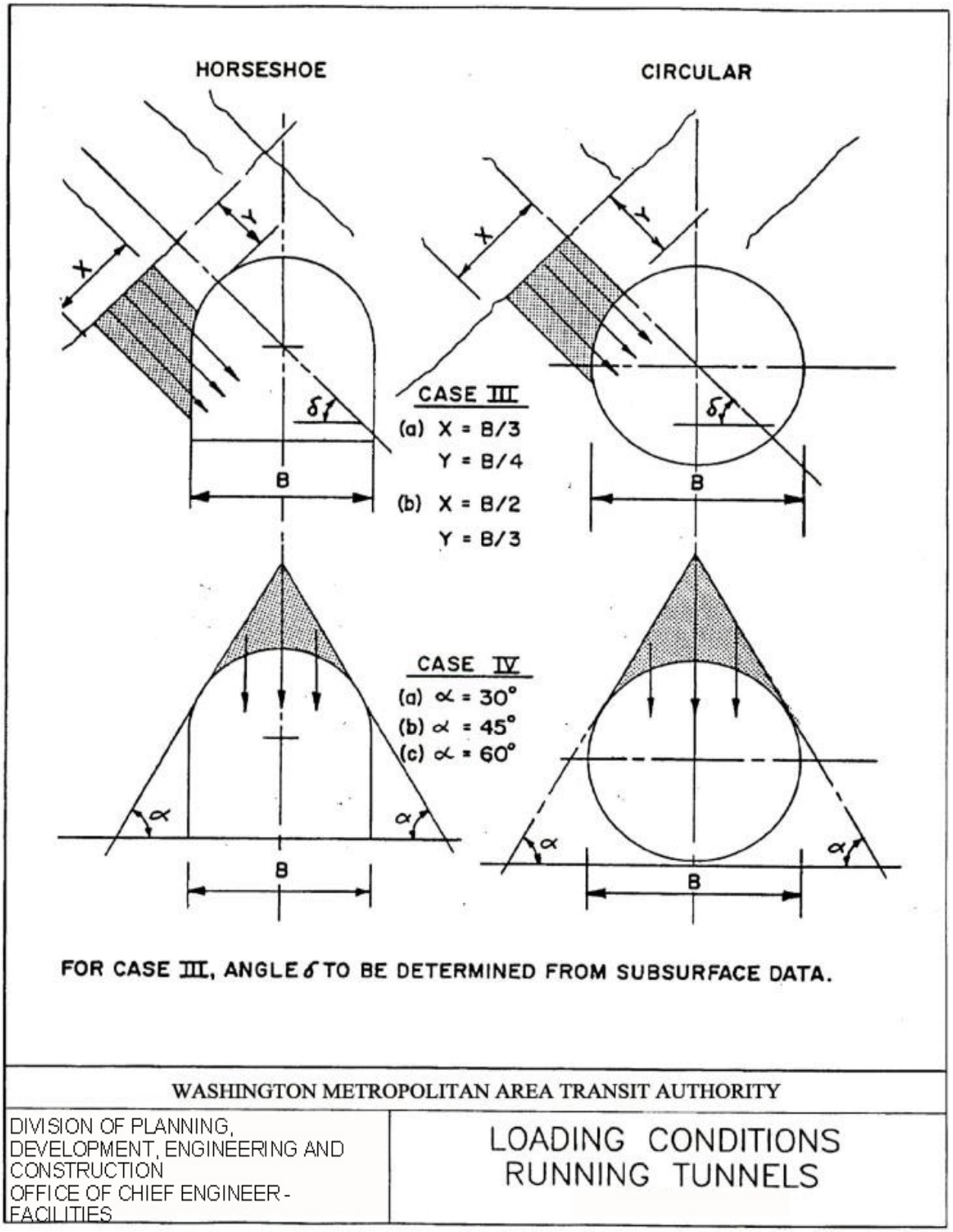
OFFICE OF CHIEF ENGINEER - FACILITIES
LOADING CONDITIONS
RUNNING TUNNELS

FIGURE 15.4


HORSESHOE
CIRCULAR
X
Y
δ
B
CASE III
(a) X = B/3
Y = B/4
(b) X = B/2
Y = B/3
CASE IV
(a) α = 30°
(b) α = 45°
(c) α = 60°
α
FOR CASE III, ANGLE δ TO BE DETERMINED FROM SUBSURFACE DATA.
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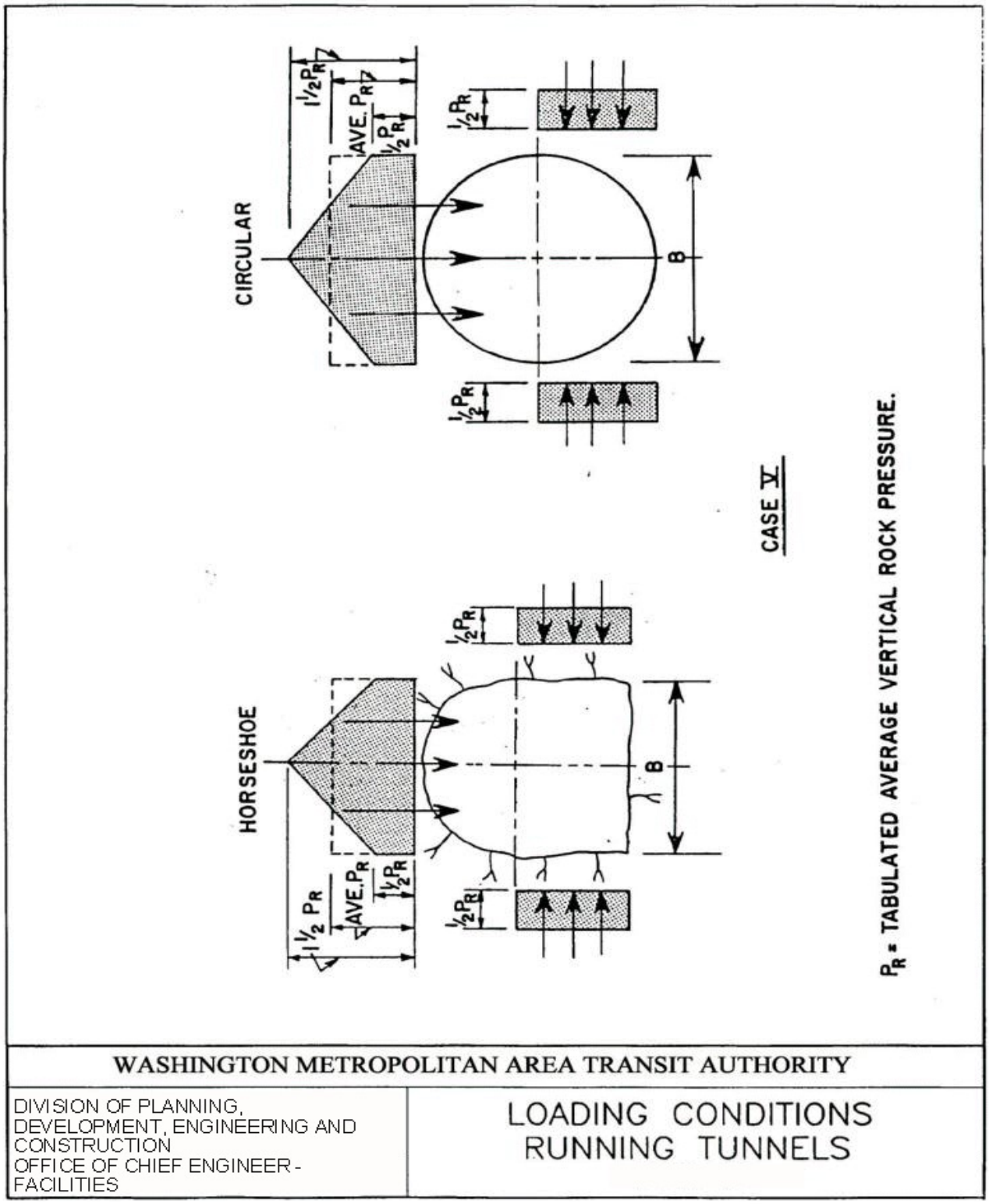
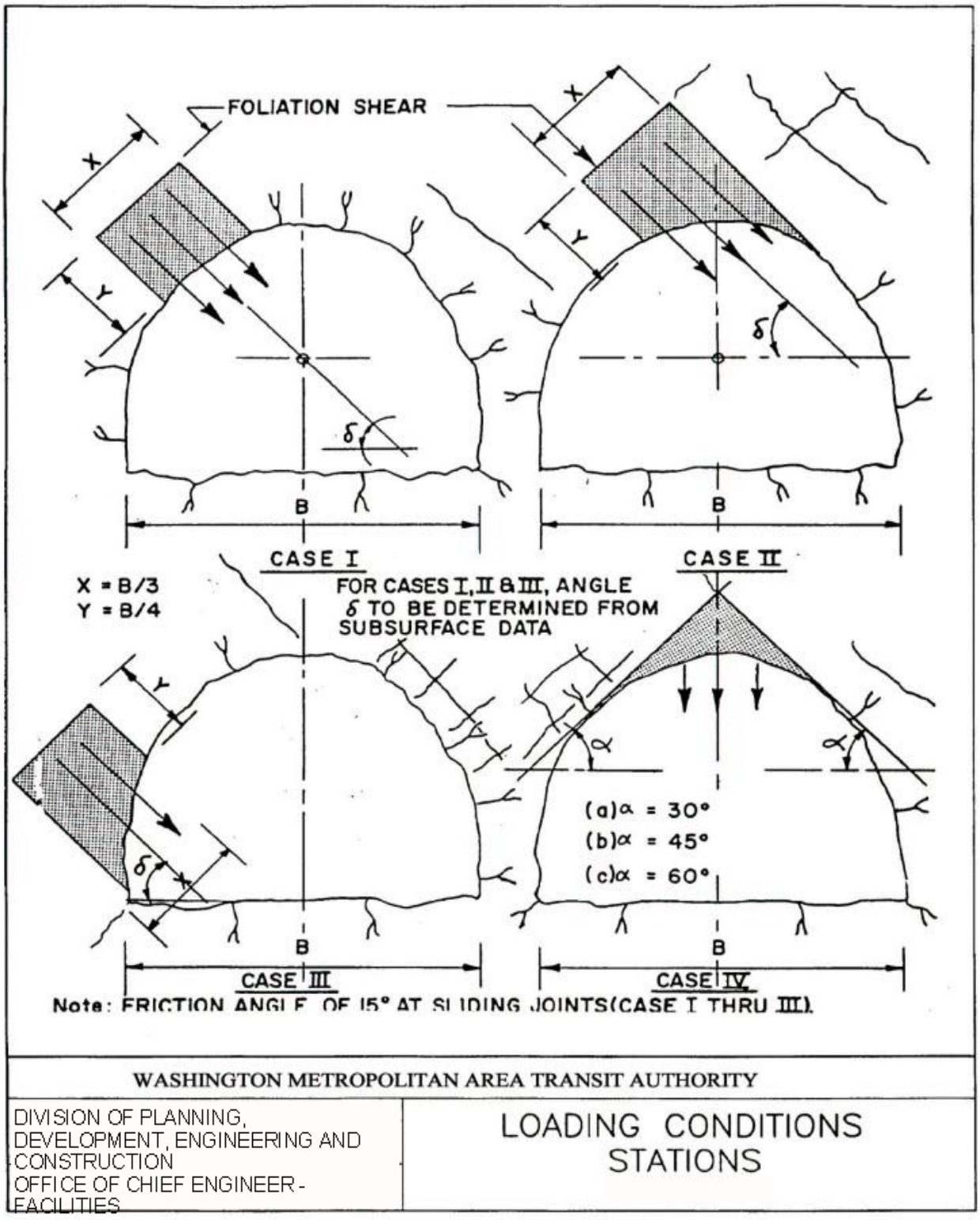
OFFICE OF CHIEF ENGINEER - FACILITIES
LOADING CONDITIONS
RUNNING TUNNELS

FIGURE 15.5



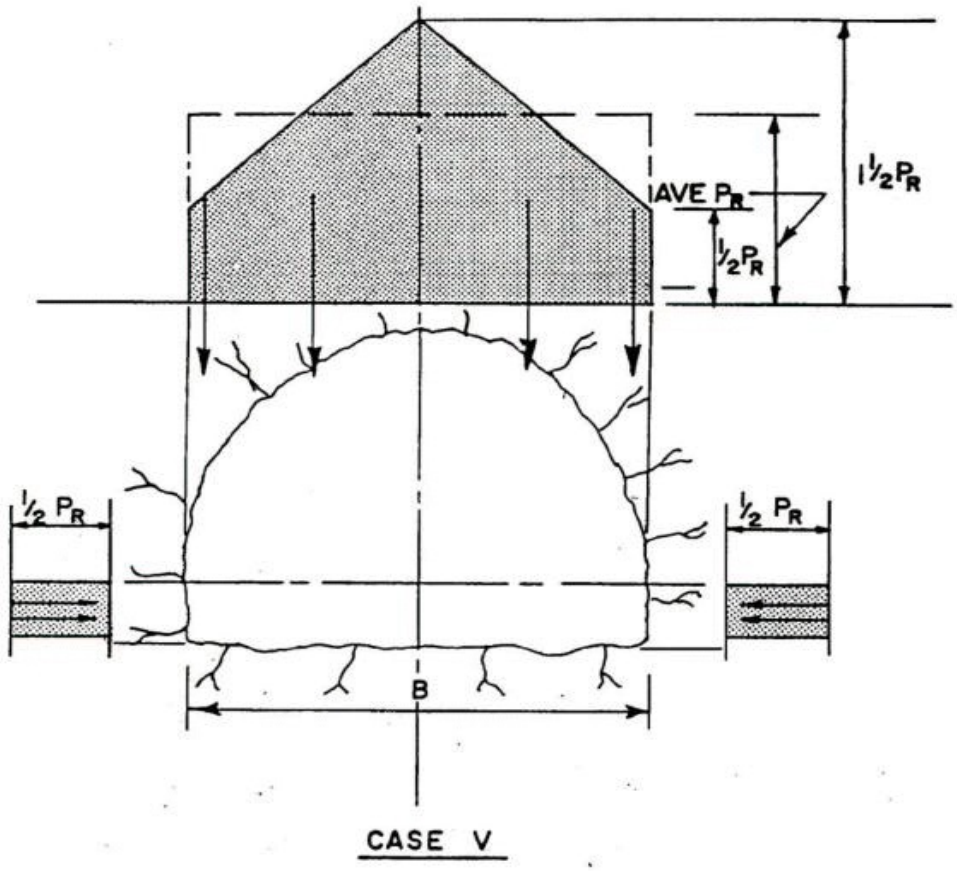
See Table 15.1

FIGURE 15.6



See Table 15.1

FIGURE 15.7

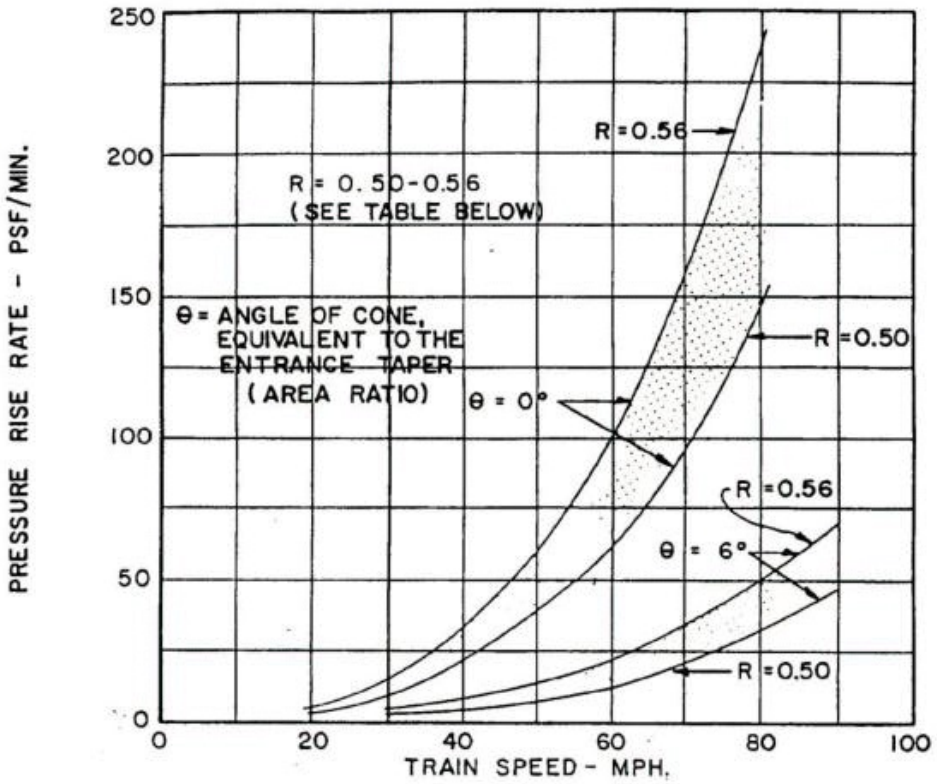


P_R = TABULATED AVERAGE VERTICAL ROCK PRESSURE

WASHINGTON METROPOLITAN AREA TRANSIT AUTHORITY	
DIVISION OF PLANNING, DEVELOPMENT, ENGINEERING AND CONSTRUCTION OFFICE OF CHIEF ENGINEER - FACILITIES	LOADING CONDITIONS FOR STATIONS

See Table 15.1

FIGURE 15.8



ESTIMATED PRESSURE RISE RATE VS. TRAIN SPEED FOR TUNNEL ENTRANCES WITH NO TAPER [θ = 0°] AND WITH 6° CONICAL TAPER [θ = 6°], OR EQUIVALENT.

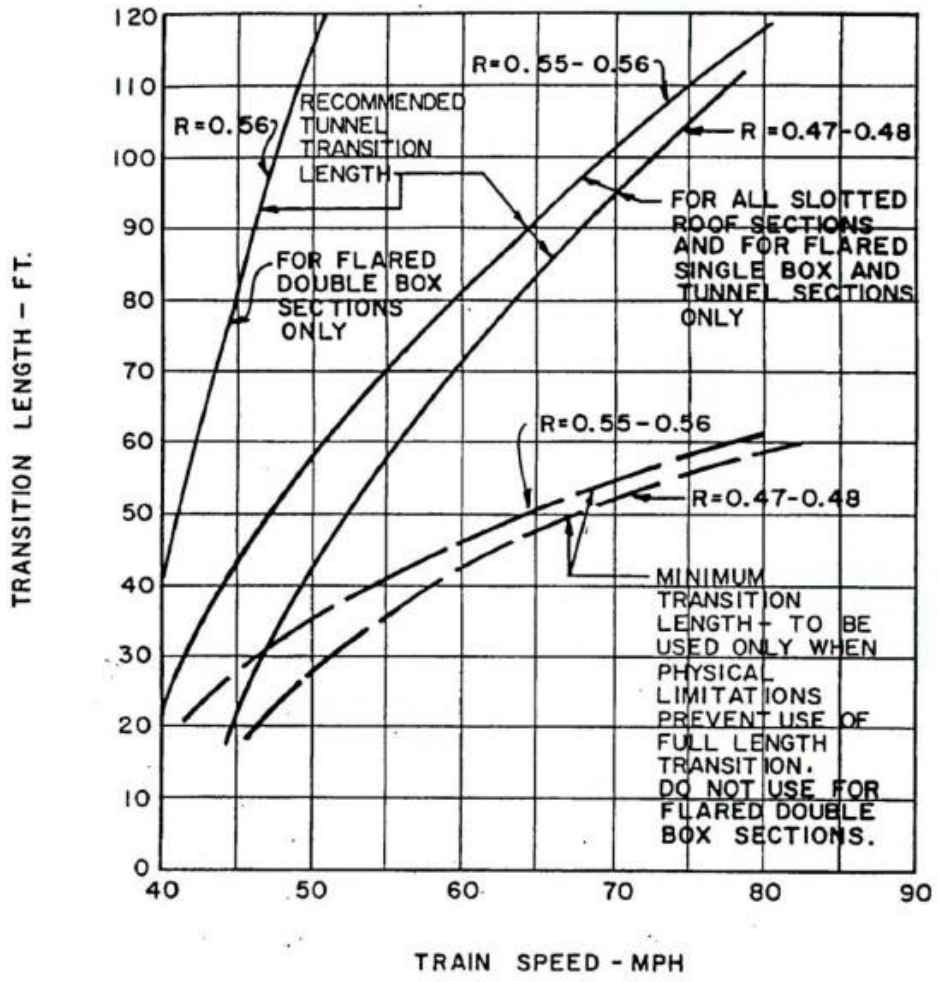
TYPE OF TUNNEL	CROSS-SECTIONAL AREA	R
SINGLE BOX, CUT AND COVER	174 sq. ft.	.55
DOUBLE BOX, CUT AND COVER	171	.56
CIRCULAR EARTH TUNNEL	203	.47
HORSESHOE EARTH TUNNEL	199	.48
HORSESHOE ROCK TUNNEL	180	.53

$$R = \frac{\text{CAR CROSS - SECTIONAL AREA}}{\text{TUNNEL CROSS - SECTIONAL AREA}}$$

WASHINGTON METROPOLITAN AREA TRANSIT AUTHORITY

DIVISION OF PLANNING, DEVELOPMENT, ENGINEERING AND CONSTRUCTION OFFICE OF CHIEF ENGINEER - FACILITIES	PRESSURE RISE RATE VS. TRAIN SPEED

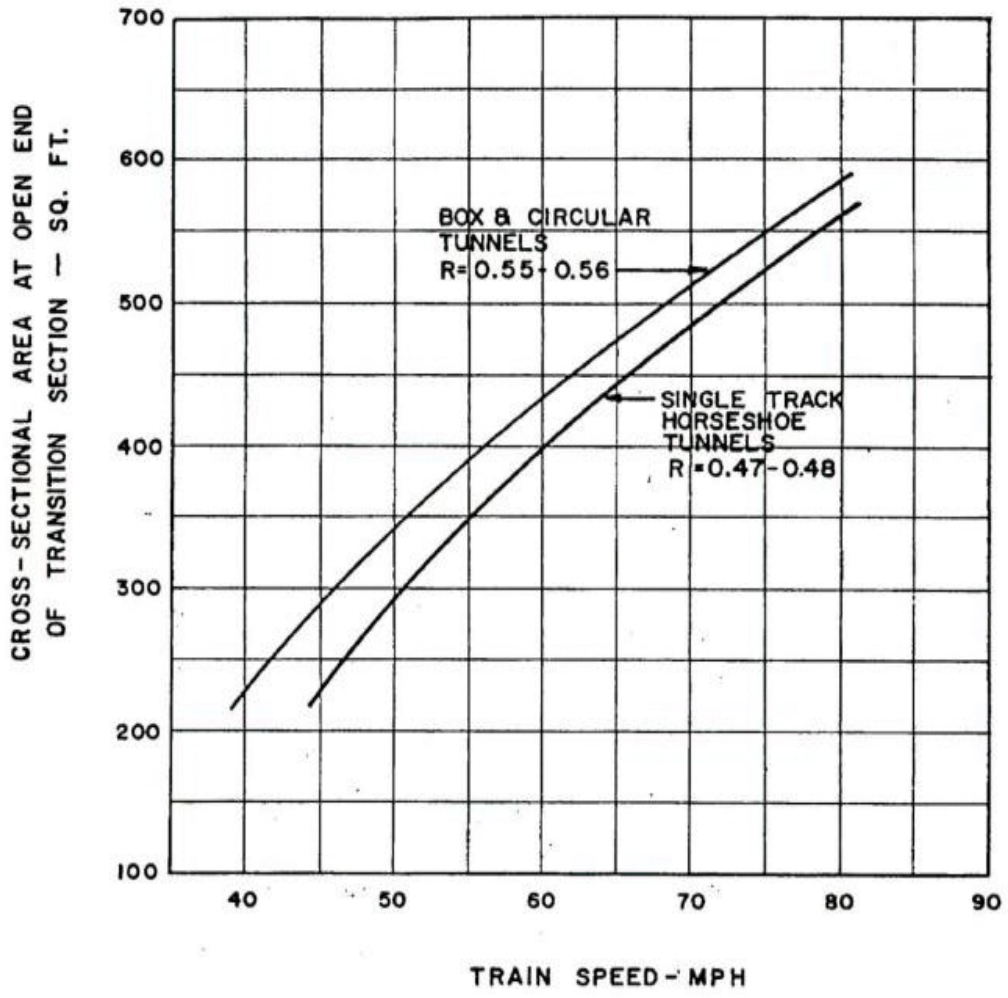
FIGURE 15.9



RECOMMENDED LENGTH OF TUNNEL PORTAL TRANSITION AS A FUNCTION OF TRAIN VELOCITY FOR METRO SYSTEM SINGLE TRACK TUNNELS.

WASHINGTON METROPOLITAN AREA TRANSIT AUTHORITY	
DIVISION OF PLANNING, DEVELOPMENT, ENGINEERING AND CONSTRUCTION OFFICE OF CHIEF ENGINEER - FACILITIES	TUNNEL TRANSITION LENGTH VS. TRAIN SPEED

FIGURE 15.10



WASHINGTON METROPOLITAN AREA TRANSIT AUTHORITY	
DIVISION OF PLANNING, DEVELOPMENT, ENGINEERING AND CONSTRUCTION OFFICE OF CHIEF ENGINEER - FACILITIES	RECOMMENDED AREA AT PORTAL OF TUNNEL OR BOX SECTION WITH FLARED TRANSITION

FIGURE 15.11

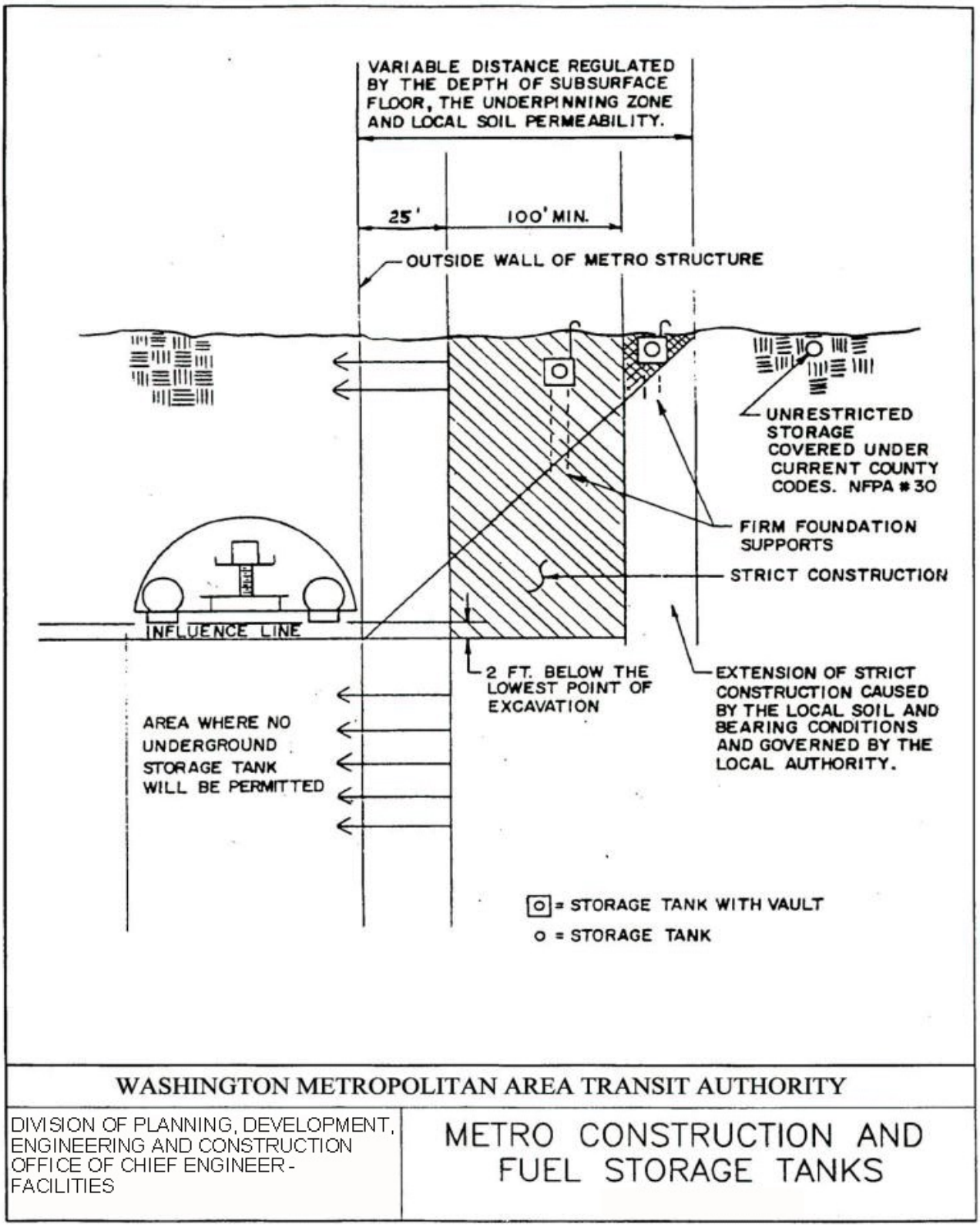
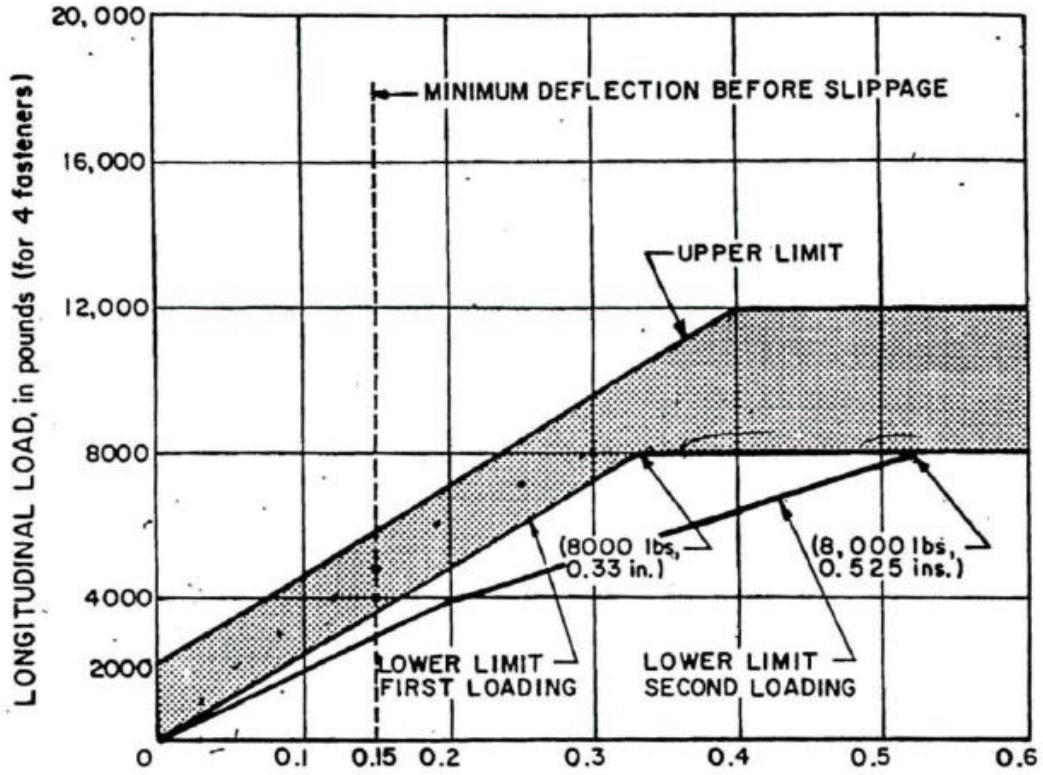

VARIABLE DISTANCE REGULATED BY THE DEPTH OF SUBSURFACE FLOOR, THE UNDERPINNING ZONE AND LOCAL SOIL PERMEABILITY.
25'
100' MIN.
OUTSIDE WALL OF METRO STRUCTURE
UNRESTRICTED STORAGE COVERED UNDER CURRENT COUNTY CODES. NFPA # 30
FIRM FOUNDATION SUPPORTS
STRICT CONSTRUCTION
INFLUENCE LINE
2 FT. BELOW THE LOWEST POINT OF EXCAVATION
EXTENSION OF STRICT CONSTRUCTION CAUSED BY THE LOCAL SOIL AND BEARING CONDITIONS AND GOVERNED BY THE LOCAL AUTHORITY.
AREA WHERE NO UNDERGROUND STORAGE TANK WILL BE PERMITTED
= STORAGE TANK WITH VAULT
= STORAGE TANK
WASHINGTON METROPOLITAN AREA TRANSIT AUTHORITY
DIVISION OF PLANNING, DEVELOPMENT, ENGINEERING AND CONSTRUCTION OFFICE OF CHIEF ENGINEER - FACILITIES
METRO CONSTRUCTION AND FUEL STORAGE TANKS

FIGURE 15.12



DEFLECTION OF SET OF FOUR FASTENERS

WASHINGTON METROPOLITAN AREA TRANSIT AUTHORITY	
DIVISION OF PLANNING, DEVELOPMENT, ENGINEERING AND CONSTRUCTION OFFICE OF CHIEF ENGINEER-FACILITIES	DIRECT FIXATION RAIL FASTENER LONGITUDINAL RESTRAINT TEST ACCEPTANCE CRITERIA

FIGURE 15.13

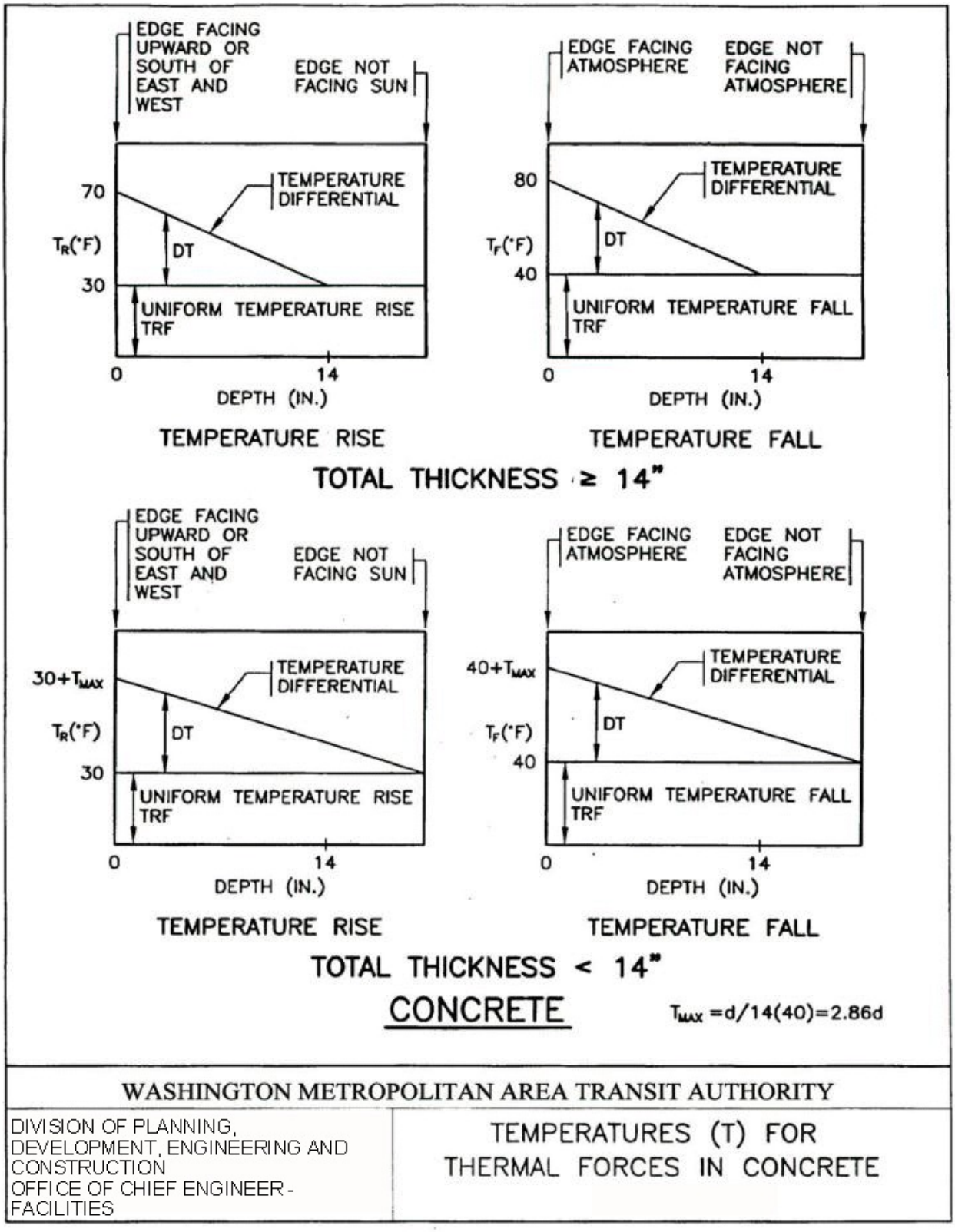


FIGURE 15.14a

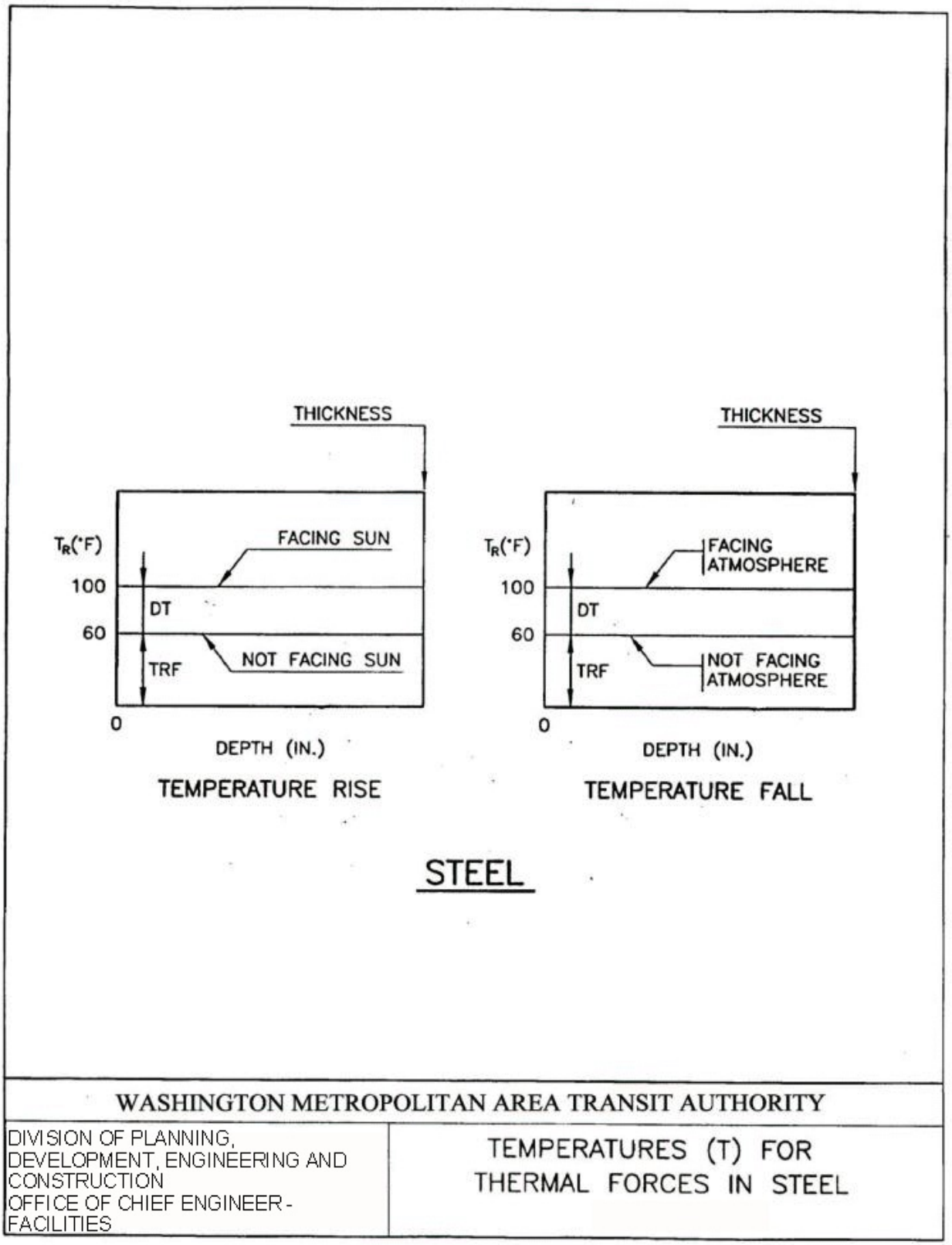
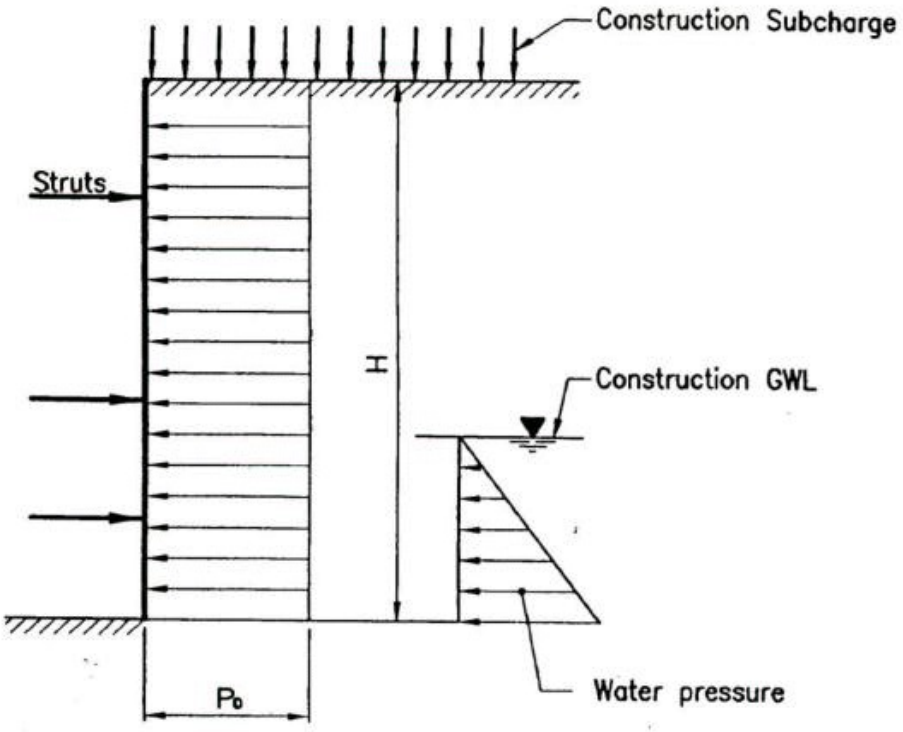


FIGURE 15.14b



APPARENT PRESSURE DIAGRAM FOR STRATIFIED SANDS WITH STIFF TO HARD CLAY AND SILT LAYERS

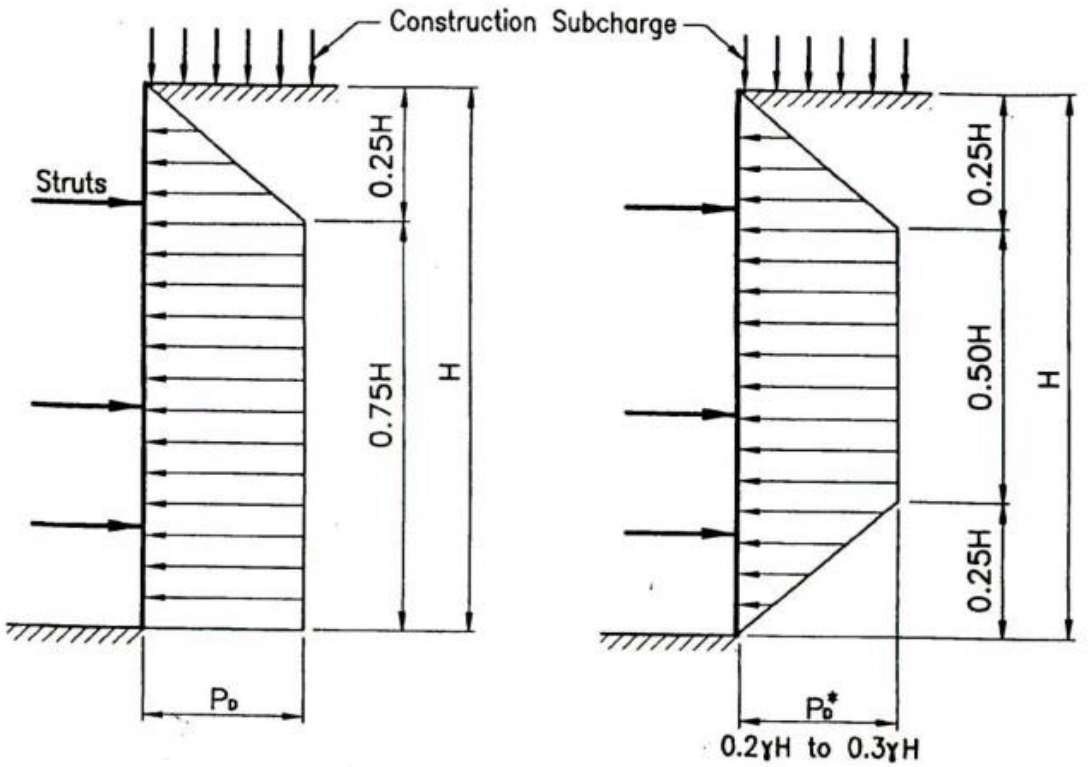
WATERTIGHT RIGID WALLS

NOTES:

1. Effective earth pressure is equal to the average of active and at-rest pressures distributed as a rectangle with P_o ordinate.
2. Total thickness of clay and silt layers as much as 50% of the depth of the cut.
3. Use effective soil friction shown on Table V.2 in estimating the active and at-rest earth pressures.

WASHINGTON METROPOLITAN AREA TRANSIT AUTHORITY	
DIVISION OF PLANNING, DEVELOPMENT, ENGINEERING AND CONSTRUCTION OFFICE OF CHIEF ENGINEER - FACILITIES	DESIGN LOADING–TEMPORARY COFFERDAM STRATIFIED SANDY SOILS

FIGURE 15.15a



(a) SOFT TO MEDIUM CLAYS N_b >5
WATERTIGHT RIGID WALLS

(b) STIFF TO HARD CLAYS N_b >5
WATERTIGHT RIGID WALLS

APPARENT PRESSURE DIAGRAMS FOR STRATIFIED CLAYS WITH SAND LAYERS AND LENSES

NOTES:

1. Diagrams (a) and (b) can be used in stratified clays, where the total thickness of sand layers or lenses does not exceed 25% of the depth of the cut.
2. Soil Pressure for soft to medium clays is equal to the average of active and at-rest pressures distributed as a trapezoid with P_D ordinate. P_D shall be not less than $0.3\gamma H$.
3. Use effective soil friction shown on Table V.2 in estimating the active and at-rest earth pressures.
4. Presence of groundwater level does not have any effect on magnetude of lateral pressure.

LEGEND

N = $\frac{\gamma H}{Su}$ = Base stability factor

Sub = Average undrained shear strength below base of cut.

γ = Total soil unit weight.

P^*_D = 0.2 γH for very stiff intact nonfissured clays.

P^*_D = 0.3 γH for fissured or slickensided clays.

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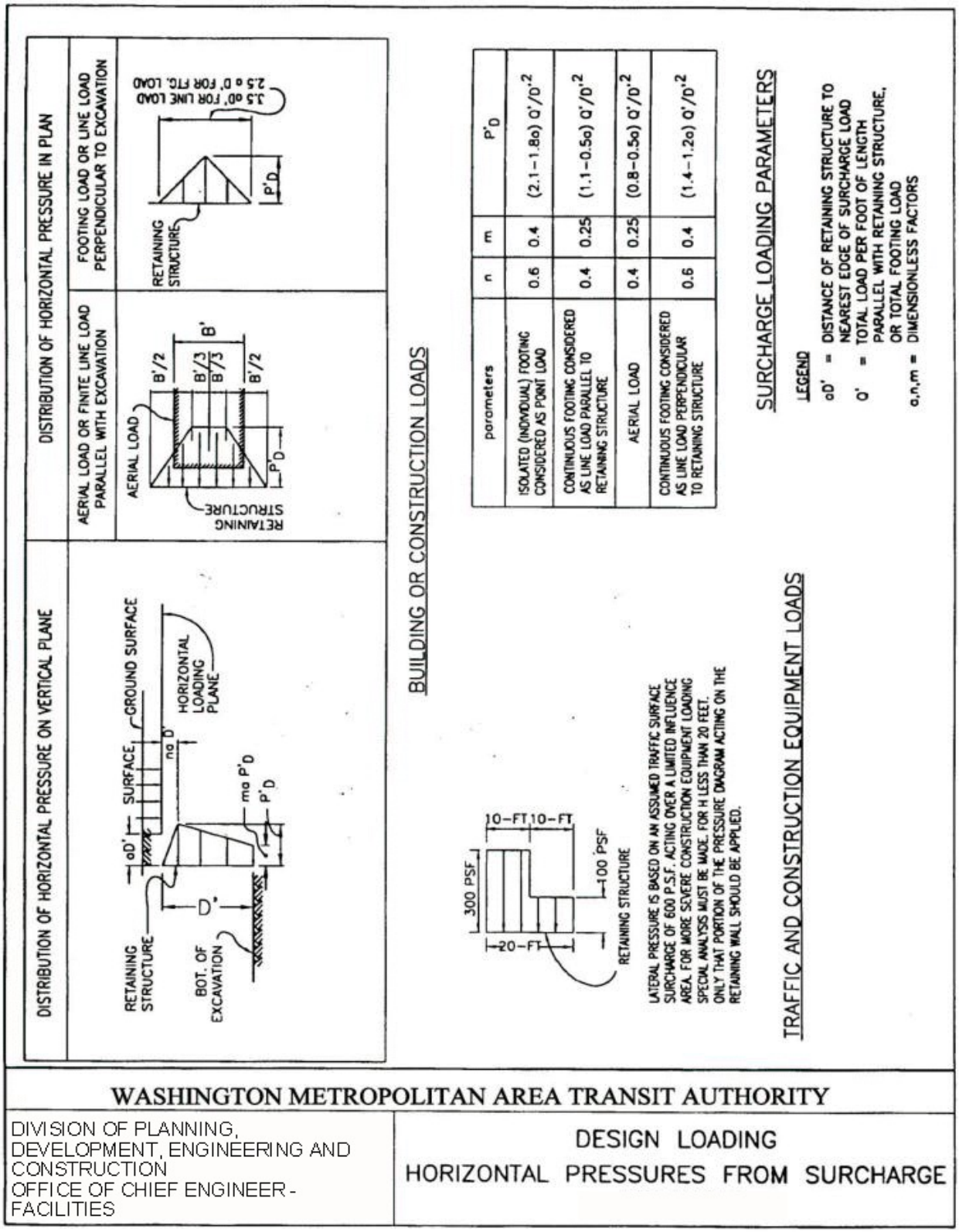
DIVISION OF PLANNING, DEVELOPMENT, ENGINEERING AND CONSTRUCTION OFFICE OF CHIEF ENGINEER - FACILITIES	DESIGN LOADING–TEMPORARY COFFERDAM STRATIFIED CLAY SOILS

FIGURE 15.15b


DISTRIBUTION OF HORIZONTAL PRESSURE ON VERTICAL PLANE
DISTRIBUTION OF HORIZONTAL PRESSURE IN PLAN
AERIAL LOAD OR FINITE LINE LOAD PARALLEL WITH EXCAVATION
FOOTING LOAD OR LINE LOAD PERPENDICULAR TO EXCAVATION
AERIAL LOAD
RETAINING STRUCTURE
B'/2
B'/3
B'/3
B'/2
B'
P'D
3.5 σ0', FOR LINE LOAD
2.5 σ 0', FOR FTG. LOAD
RETAINING STRUCTURE
σD'
SURFACE
GROUND SURFACE
HORIZONTAL LOADING PLANE
mσ P'D
P'D
D'
RETAINING STRUCTURE
BOT. OF EXCAVATION
BUILDING OR CONSTRUCTION LOADS
10-FT 10-FT
300 PSF
100 PSF
20-FT
RETAINING STRUCTURE
LATERAL PRESSURE IS BASED ON AN ASSUMED TRAFFIC SURFACE SURCHARGE OF 600 P.S.F. ACTING OVER A LIMITED INFLUENCE AREA. FOR MORE SEVERE CONSTRUCTION EQUIPMENT LOADING SPECIAL ANALYSIS MUST BE MADE. FOR H LESS THAN 20 FEET, ONLY THAT PORTION OF THE PRESSURE DIAGRAM ACTING ON THE RETAINING WALL SHOULD BE APPLIED.
TRAFFIC AND CONSTRUCTION EQUIPMENT LOADS
SURCHARGE LOADING PARAMETERS
LEGEND
σD' = DISTANCE OF RETAINING STRUCTURE TO NEAREST EDGE OF SURCHARGE LOAD
Q' = TOTAL LOAD PER FOOT OF LENGTH PARALLEL WITH RETAINING STRUCTURE, OR TOTAL FOOTING LOAD
σ,n,m = DIMENSIONLESS FACTORS
parameters | n | m | P'D
ISOLATED (INDIVIDUAL) FOOTING CONSIDERED AS POINT LOAD | 0.6 | 0.4 | (2.1−1.8σ) Q'/D'2
CONTINUOUS FOOTING CONSIDERED AS LINE LOAD PARALLEL TO RETAINING STRUCTURE | 0.4 | 0.25 | (1.1−0.5σ) Q'/D'2
AERIAL LOAD | 0.4 | 0.25 | (0.8−0.5σ) Q'/D'2
CONTINUOUS FOOTING CONSIDERED AS LINE LOAD PERPENDICULAR TO RETAINING STRUCTURE | 0.6 | 0.4 | (1.4−1.2σ) Q'/D'2
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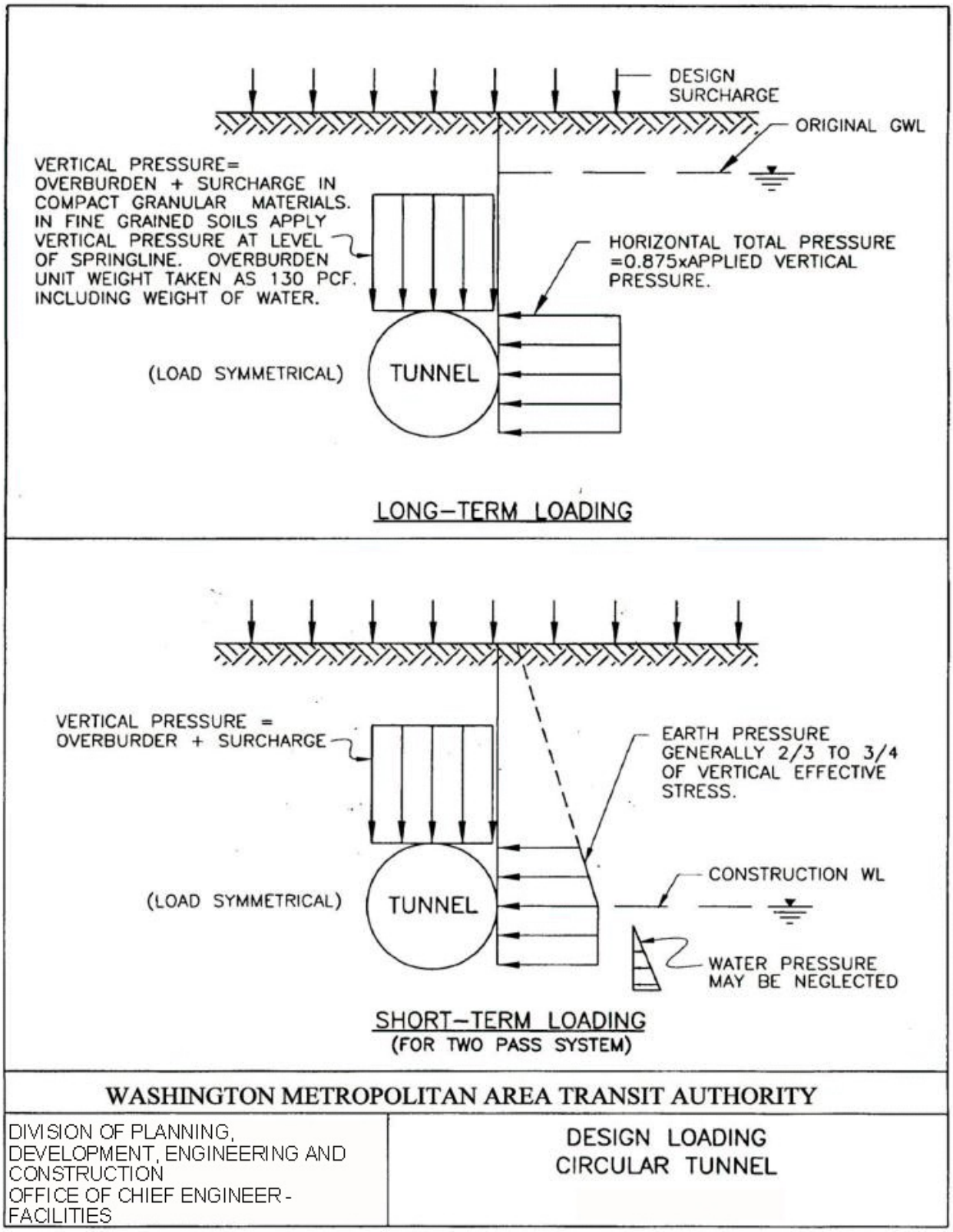
OFFICE OF CHIEF ENGINEER - FACILITIES
DESIGN LOADING
HORIZONTAL PRESSURES FROM SURCHARGE

FIGURE 15.16


DESIGN SURCHARGE
ORIGINAL GWL
VERTICAL PRESSURE= OVERBURDEN + SURCHARGE IN COMPACT GRANULAR MATERIALS. IN FINE GRAINED SOILS APPLY VERTICAL PRESSURE AT LEVEL OF SPRINGLINE. OVERBURDEN UNIT WEIGHT TAKEN AS 130 PCF. INCLUDING WEIGHT OF WATER.
HORIZONTAL TOTAL PRESSURE =0.875xAPPLIED VERTICAL PRESSURE.
(LOAD SYMMETRICAL)
TUNNEL
LONG-TERM LOADING
VERTICAL PRESSURE = OVERBURDER + SURCHARGE
EARTH PRESSURE GENERALLY 2/3 TO 3/4 OF VERTICAL EFFECTIVE STRESS.
CONSTRUCTION WL
(LOAD SYMMETRICAL)
TUNNEL
WATER PRESSURE MAY BE NEGLECTED
SHORT-TERM LOADING
(FOR TWO PASS SYSTEM)
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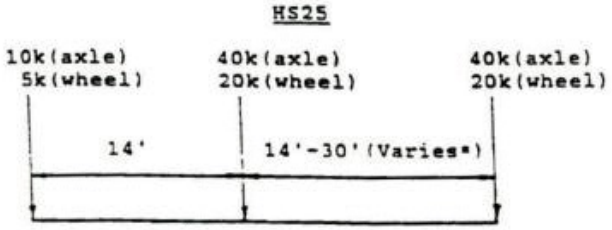
OFFICE OF CHIEF ENGINEER - FACILITIES
DESIGN LOADING
CIRCULAR TUNNEL

FIGURE 15.17

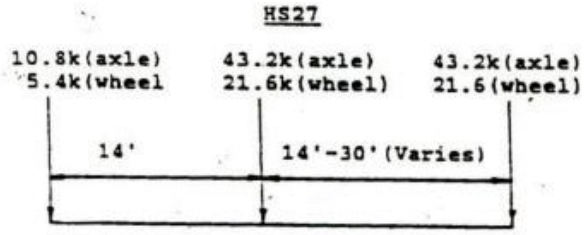
All components of new highway structures shall be designed to accommodate the following loadings:

A. For all bridge spans 35' and over in length, and all other structures an HS25 loading shall be used. The axle and lane loadings to be utilized shall be 125% of the AASHTO HS20-44 loading.



*Spacing to be used is that which produces maximum stresses.

B. For all bridge simple spans less than 35' in length an HS27 loading shall be used. The axle and lane loadings to be utilized shall be 135% of the AASHTO HS20-44 loading. This category only applies to simple span structures.



*Spacing to be used is that which produces maximum stresses.

Commentary: This special loading was developed to simulate the 65,000 pound three axle MD Dump Truck configuration loading.

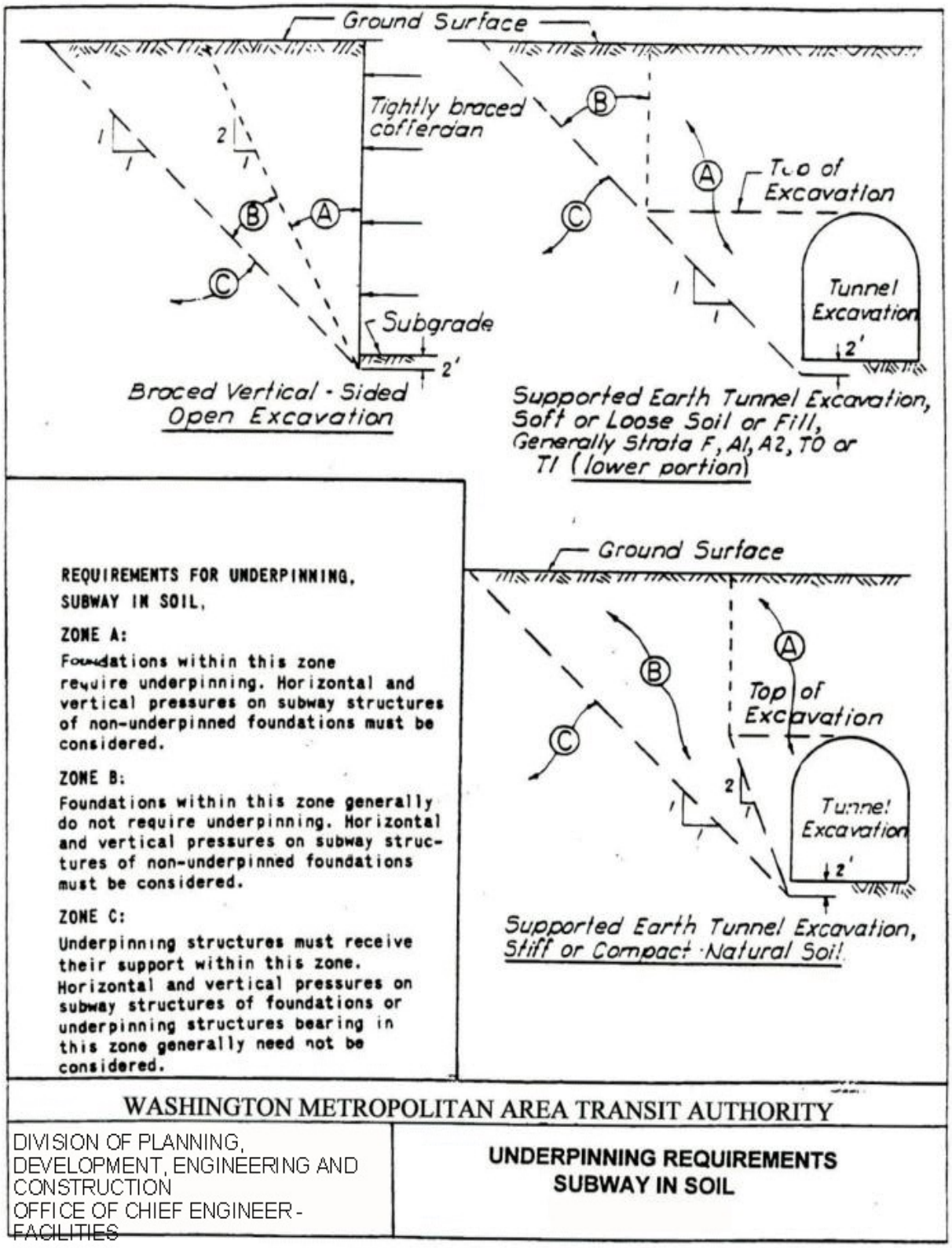
C. The concrete bridge deck portion of bridges with longitudinal stringers shall be designed with HS25 loading.

D. All structures shall be designed to accommodate additional loadings of 25 pounds per square foot for a future 2 inch wearing surface and 15 pounds per square foot when the use of steel stay in place bridge deck forms are required.

WASHINGTON METROPOLITAN AREA TRANSIT AUTHORITY

DIVISION OF PLANNING, DEVELOPMENT, ENGINEERING AND CONSTRUCTION OFFICE OF CHIEF ENGINEER - FACILITIES	ROADWAY LOADING

FIGURE 15.18


Ground Surface
Tightly braced cofferdam
Subgrade
2'
Broced Vertical - Sided Open Excavation
Top of Excavation
Tunnel Excavation
2'
Supported Earth Tunnel Excavation, Soft or Loose Soil or Fill, Generally Strata F, A1, A2, TO or T1 (lower portion)
REQUIREMENTS FOR UNDERPINNING, SUBWAY IN SOIL,
ZONE A:
Foundations within this zone require underpinning. Horizontal and vertical pressures on subway structures of non-underpinned foundations must be considered.
ZONE B:
Foundations within this zone generally do not require underpinning. Horizontal and vertical pressures on subway structures of non-underpinned foundations must be considered.
ZONE C:
Underpinning structures must receive their support within this zone. Horizontal and vertical pressures on subway structures of foundations or underpinning structures bearing in this zone generally need not be considered.
Ground Surface
Top of Excavation
Tunnel Excavation
2'
Supported Earth Tunnel Excavation, Stiff or Compact Natural Soil
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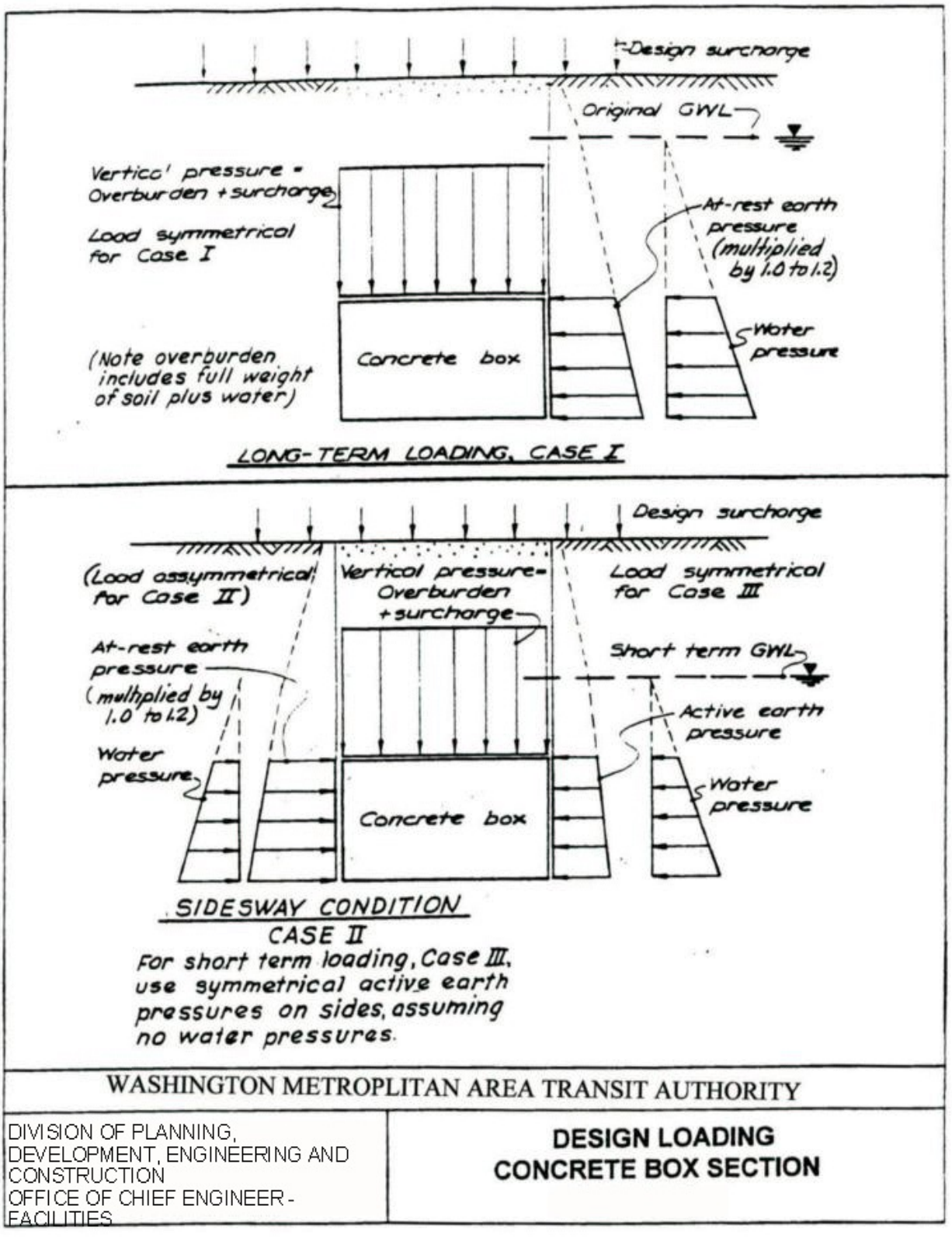
DIVISION OF PLANNING, DEVELOPMENT, ENGINEERING AND CONSTRUCTION
OFFICE OF CHIEF ENGINEER - FACILITIES
UNDERPINNING REQUIREMENTS
SUBWAY IN SOIL

FIGURE 15.19


Design surcharge
Original GWL
Vertical pressure = Overburden + surcharge
Load symmetrical for Case I
At-rest earth pressure (multiplied by 1.0 to 1.2)
Water pressure
(Note overburden includes full weight of soil plus water)
Concrete box
LONG-TERM LOADING, CASE I
Design surcharge
(Load assymmetrical for Case II)
Vertical pressure = Overburden + surcharge
Load symmetrical for Case III
At-rest earth pressure (multiplied by 1.0 to 1.2)
Short term GWL
Active earth pressure
Water pressure
Water pressure
Concrete box
SIDESWAY CONDITION
CASE II
For short term loading, Case III, use symmetrical active earth pressures on sides, assuming no water pressures.
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OFFICE OF CHIEF ENGINEER - FACILITIES
DESIGN LOADING
CONCRETE BOX SECTION

FIGURE 15.20

TABLE V-2 SOIL PROPERTIES FOR DESIGN

UNIFEID SOIL CLASSIFICATION		SHORT DESCRIPTION	MRWJ* SYMBOLS	FULL DESCRIPTION/SOURCE/AGE	SHEAR STRENGTH AND CONSOLIDATION CONDITION OF A COHESIVE STRATA	MIN. UNIT WEIGHT (PCF)	COEF OF SUBGRADE REACTION (KCF)	UNDRAIND SHEAR STRENGTH (KSF)	YOUNG MOD. OF SUBGRADE (KSI)	COEF. OF AT REST PRESS.	MAX. EFFECTIVE ANGLE OF FRICTION (DEGREES)	MAX. ALLOWABLE BEARING CAPACITY (TSF)
PRIMARY	SECONDARY											
				FILL								
ML & SM	SC & CL	FILL	F	FILL GENERALLY COMPOSED OF INORGANIC SOIL OBTAINED FROM NEAR BY NATURAL MATERIALS. MAY BE DERIVED FROM TERRACE, CRETACEOUS SOIL OR DECOMPOSED ROCK.	PLACED OVER MARSH, MIXED WITH CINDERS. NO COSOLIDATION	120					28	NONE, ORDINARILY
					FROM PLEISTOCENE SOILS	130					30	1.0 TO 1.50
					FROM DECOMPOSED ROCK (NW OF ROCK CREEK)	130					30	1.5 TO 2.0
					FROM CRETACEOUS CLAYS (NEAR UNION STATION) . MAX. SHEAR STRENGTH, COHESIVE STRATA: 0.8 KSF	130					25	0.75
					MIXED WITH ORGANIC SOILS (SOUTH OF ROSSLYN)	120					28	
					OTHER LOCATIONS	130					30	1.0 TO 1.50
				RIVER ALLUVIUM OF POST GLACIAL TIMES.								
CL, CH, OH	OL & PT	ORGANIC CLAY	A1	VERY SOFT TO MEDIUMSTIFF DARK GRAY ORGANIC CLAY WITH LENSES OF HIGHLY ORGANIC MATERIAL (WHERE LOVCATED UNDER WATER). SOFT TO STIFF MOTTLED GRAY-BROWN SLIGHTLY ORGANIC SILTY OR SANDY CLAY (WHERE LOCATED IN LAND).	BENEATH FILL OVERCONSOLIDATED 0.2 TO 0.3 TSF. STRENGTH 0.5 TO 0.7 KSF.	120					23	NONE, ORDINARILY
		ORGANIC CLAY			BENEATH WATER OVERCONSOLIDATED AS MUCH AS 0.2 TSF. STRENGTH 0.2 TO 0. 3 KSF.	110					23	NONE
		ORGANIC CLAY			MAX. SHEAR STRENGTH, COHESIVE STRATA: 0.9 KSF	120					23	0.75
SM	SP	SILTY SAND	A2	LOOSE TO MEDIUM COMPACT GRAY OR DARK BROWN SILTY FINE TO MEDIUM SAND WITH OCCASIONAL POPCKETS OR LENSES OF SMALL GRAVEL. MAY BE SLIGHTLY TO MODRATELY ORGANIC.		130					30	2 TO 2.5
		SILTY SAND				130					30	2

TABLE V-2 , page 1 of 5

TABLE 15.2 page 1 of 5

TABLE V-2 SOIL PROPERTIES FOR DESIGN

UNIFEID SOIL CLASSIFICATION		SHORT DESCRIPTION	MRWJ* SYMBOLS	FULL DESCRIPTION/SOURCE/AGE	SHEAR STRENGTH AND CONSOLIDATION CONDITION OF A COHESIVE STRATA	MIN. UNIT WEIGHT (PCF)	COEF OF SUBGRADE REACTION (KCF)	UNDRAIND SHEAR STRENGTH (KSF)	YOUNG MOD. OF SUBGRADE (KSI)	COEF. OF AT REST PRESS.	MAX. EFFECTIVE ANGLE OF FRICTION (DEGREES)	MAX. ALLOWABLE BEARING CAPACITY (TSF)
				PORTIONS OF THE "25-FOOT" "50-FOOT" AND "90-FOOT" TERRACES, DEPOSITED BY RIVERS IN PLEISTOCENE TIMES.								
CL & OL	CH & OH		T0	MEDIUM STIFF TO STIFF DARK GRAY ORGANIC CLAY WITH NUMEROUS WOOD FRAGMENTS. USUALLY FOUND INTERLENSED WITH STRATUM T4.	MAX. SHEAR STRENGTH, COHESIVE STRATA: 1.4 KSF	130					25	1.2 TO 1.5
CL, CL& CH	LENSES OF SM OR SC		T1	STIFF TO MEDIUM STIFF LIGHT BROWN OR GRAY OR MOTTLED BROWN-GRAY SILTY CLAY OR CLAYEY SILT WITH LENSES OF BROWN SILT FINE SAND. IN SOME AREAS, SEVERAL SEPARATE LAYERS OF PLEISTONCENE CLAYS HAVE BEEN ENCOUNTERED, WHICH ARE DISTINGUISHED BY A LETTER SUFFIX: T1A, T1C, ETC.								
		SILTY SAND			(DEPTH: 0 TO 40 FT) MAX. SHEAR STRENGTH, COHESIVE STRATA: 1.0 KSF TO 1.5 KSF	130					25	1.5 TO 2.0
		SILTY SAND			(DEPTH > 40 FT) MAX. SHEAR STRENGTH, COHESIVE STRATA: 1.0 TO 1.5 KSF	130					25	1.0 TO 1.5
		SILTY CLAY	T1 (A) & (G)		OVERCONSOLIDATEDD 3 TO 5 TSF. STRENGTH 1.5 TO 2.5 KSF, HIGHER NEAR SURFACE.	130					25 TO 28	1.50 TO 2.50
		ORGANIC CLAY	T1 (B)		OVERCONSOLIDATED 1.5 TO 2.5 TSF. STRENGTH 2 TO 3 KSF.	130					25	2
		SILTY CLAY	T1 (C) & (F)		OVERCONSOLIDATED 0.5 TO 1 TSF. STRENGTH 0.7 TO 0.9 KSF, HIGHER AT SURFACE.	130	150				25	1 OR LESS
		PLASTIC CLAY	T1(D)		OVERCONSOLIDATED 2.5 TO 3.0 TSF. STRENGTH 2.5 TO 3.5 KSF.	130					25	2.0 TO 3.0
		MEDIUM PLASTIC CLAY	T1(E)		OVERCONSOLIDATED 3.0 TSF. STRENGTH 2 TO 3 KSF.	130					25	2.0 TO 2.50
SM & SC	SP & SW	SILTY SAND	T2	MEDIUM COMPACT TO VERY COMPACT BROWN AND RED-BROWN SILTY OR CLAYEY FINE TO MEDIUM SAND WITH TRACE OF GRAVEL AND OCCASIONAL BOULDERS.		130					34	2.0 TO 3.0
SW & SM	SP & GM	GRGEVALLY SAND	T3	COMPACT TO VERY COMPACT BROWN AND RED BROWN FINE TO COARSE SAND WITH SOME SILT AND SMALL GRAVEL AND VARIABLE AMOUNTS OF COBBLES AND BOULDERS.		130	170				34-38	3.5 TO 4.0
SM & SP	SW	SILTY SAND	T4	MEDIUM COMPACT TO COMPACT GRAY AND GRAY-BROWN FINE TO MEDIUM SAND WITH SOME SILT AND SMALL GRAVEL, ONTAINING LENSES OF DARK GRAY CLAY, OCCASIONALLY SLIGHTLY ORGANIC.		130					30 T0 34	2.0 TO 3.0

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TABLE V-2 SOIL PROPERTIES FOR DESIGN

UNIFEID SOIL CLASSIFICATION		SHORT DESCRIPTION	MRWJ* SYMBOLS	FULL DESCRIPTION/SOURCE/AGE	SHEAR STRENGTH AND CONSOLIDATION CONDITION OF A COHESIVE STRATA	MIN. UNIT WEIGHT (PCF)	COEF OF SUBGRADE REACTION (KCF)	UNDRAIND SHEAR STRENGTH (KSF)	YOUNG MOD. OF SUBGRADE (KSI)	COEF. OF AT REST PRESS.	MAX. EFFECTIVE ANGLE OF FRICTION (DEGREES)	MAX. ALLOWABLE BEARING CAPACITY (TSF)
SW & SM	SP & GM	GRAVELLY SAND	T5	COMPACT TO VERY COMPACT GRAY AND GRAY-BROWN FINE TO COARSE SAND WITH SOME GRAVEL, SOME T0 TRACES OF SILT AND VARIABLE AMOUNTS OF COBBLES AND BOULDERS, OFTEN CONCENTRATED AT BASE OF LAYER.		130					32 - 38	2.5 TO 4.0
				BRANDYWINE FORMATION OF EARLY PLEISTOCENE OR PLIOCENE TIMES.								
SM & SC		SILTY SAND	Q1	LOOSE TO MEDIUM COMPACT LIGHT BROWN SILTY OR CLAYEY FINE TO MEDIUM SAND WITH TRACE OF SMALL GRAVEL.		130					30	2.5
SM & SC	SP	GRAVELLY SAND	Q2	LOSE TO MEDIUM COMPACT LIGHT BROWN OR TAN SILTY OR CLAYEY MEDIUM TO FINE SAND WITH SOME SMALL GRAVEL.		130	180	0.01-0.02	12-15	0.4	33	3.0
				MARINE DEPOSITS OF TERTIARY OR UPPER CRETACEOUS PERIODS								
SM & CH	SP & CL		C	MEDIUM COMPACT GRAY AND TANSILTY FINE SAND OR MEDIUM STIFF TO STIFF DARK GRAY TO OLIVE-GREEN CLAY. CALVERT FORMATION OF MIOCENE AGE.								
			Cc	PLASTIC CLAY, SILTY AND SANDY CLAY OR CLAYEY SILT		130	100	1.5-2.5	6-8	0.55	25	1.5-2.0
			Cs	FINE SAND, TRACE TO SOME SILT. CLAY AMD CLAEY FINE SAND		130	140		8-10	0.5	30-32	1.5 -2.0
				AQUIA FORMATION OF EOCENE AGE.								
MH & CH	ML & CL		E	MEDIUM STIFF DARK GREEN OR BROWN CLAY AND SILTY CLAY. AQUA FORMATION OF EOCENE AGE.								
			Es			130	140		8-10	0.5	30-32	1.5-2.0
			Ec			130	100	2.0-3.5	6-8	0.55	25	1.5 -2.0
				UPPER CRETACEOUS PERIOD								
MH & CL	MH & CH		M	MEDIUM STIFF TO STIFF GREEN OR BROWN SILT ANND CLAY. MONMOUTH FORMATION OF UPPER CRETACEOUS AGE.								
			Mc	SLIGHTLY ORGANIC FINE SANDY SILT AND CLAYEY SILT		130	120	3.0-3.5	8-10	0.6	25	2.0-4.0
			MS	SLIGHTLY ORGANIC MICACEOUS SILTY OR CLAYEY FINE SAND		130	160		10-12	0.45	32-34	2.0-4.0
				POTOMAC GROUP OF CRETACEOUS PERIOD,								

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TABLE V-2 SOIL PROPERTIES FOR DESIGN

UNIFEID SOIL CLASSIFICATION		SHORT DESCRIPTION	MRWJ* SYMBOLS	FULL DESCRIPTION/SOURCE/AGE	SHEAR STRENGTH AND CONSOLIDATION CONDITION OF A COHESIVE STRATA	MIN. UNIT WEIGHT (PCF)	COEF OF SUBGRADE REACTION (KCF)	UNDRAIND SHEAR STRENGTH (KSF)	YOUNG MOD. OF SUBGRADE (KSI)	COEF. OF AT REST PRESS.	MAX. EFFECTIVE ANGLE OF FRICTION (DEGREES)	MAX. ALLOWABLE BEARING CAPACITY (TSF)
CH	CL	PLASTIC CLAY	P1	HARD MOTTLES RED-BROWN AND GRAY LIGHT GRAY AND TAN PLASTIC CLAY WITH OCCASIONAL POCKETS OF FINE SAND. GENERALLY CONSISTS OF PATAPSCO FORMATION BUT MAY INCLUDE RARITAN FORMATION AT UPPER LEVELS.	NORTH & WEST OF NEW JERSEY AVE. OVERCONSOLIDATED 15 TO 20 TSF. STRENGTH 4 TO 5 KSF BUT ERRATIC.	130	200	3.0 TO 5.0	10-15	0.6	25	3.0 TO 5.0
CL		SANDY CLAY				130	200	4.0-4.5	10-14	0.5	30	3.0-5.0
		PLASTIC CLAY			PARTIALLY WEATHERED ALONG B&O RIGHT-OF-WAY IN PHASE VII PROVIDE STRENGTH AND BEARING CAPACITY IN LOWER PORTION OF THE RANGE NOTED.	130					25	2.0 TO 5.0
SM & SP	SP	SILTY SAND	P2	COMPACT TO VERY COMPACT LIGHT GRAY OR TAN SILTY OR CLAYEY FINE TO MEDIUM SAND WITH POCKETS OF SILTY CLAY AND TRACE OF SMALL GRAVEL, OCCASIONAL LIGNITE FRAGMENTS. ALSO INCLUDES MAGOTHY FORMATION OF UPPER CRETACEOUS AGE.		130	200			0.5	33 TO 34	3.5 TO 6.0
G		SAND, SOME GRAVEL				130	200			0.5	34	3.0 TO 6.0
		SILTY SAND				130	200				33 TO 36	3.0 TO 6.0
					OVERCONSOLIDATED 15 TO 20 TSF. STRENGTH 4 TO 6 KSF.	130					34	4.0 TO 7.0
SM & SW	SP & GM	GRAVELLY SAND	P4	VERY COMPACT MOTTLED LIGHT GRAY, TAN BUFF OR WHITE SILTY OR CLAYEY FINE TO MEDIUM SAND WITH SOME GRAVEL AND SCATTERED LIGNITE FRAGMENTS, FREQUENTLY WITH DENSE NESTS AND POCKETS OF ANGULAR ROCK FRAGMENTS, COBBLES AND BOULDERS.		135					34 TO 38	4.0 TO 7.0
				WEATHERED IN--SITU FROM CRYSTALLINE BEDROCK								
ML & SM	MH	DECOMPOSED ROCK	D	DECOMPOSED ROCK: HARD ORANGE-BROWN OR YELLOW-BROWN MICACEOUS FINE SANDY SILT OR VERY COMPACT LIGHT GRAY AND GREEN MICACEOUS SILTY FINE TO MEDIUM SAD WITH VARIABLE AMOUNTS OF HARD, INCOMPLETELY DECOMPOSED ROCK FRAGMENTS AND LANSES. PROPORTION OF HARD ROCK FRAGMENTS INCREASES WITH DEPTH TOWARD THE BEDROCK SURFACE.	HIGH-QUASI-OVERCONSOLIDATED STRENGTH INCREASE WITH DEPTH: 1.5 KSF TO 3.5 KSF AND MORE.	140					36	5

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TABLE V-2 SOIL PROPERTIES FOR DESIGN

UNIFEID SOIL CLASSIFICATION		SHORT DESCRIPTION	MRWJ* SYMBOLS	FULL DESCRIPTION/SOURCE/AGE	SHEAR STRENGTH AND CONSOLIDATION CONDITION OF A COHESIVE STRATA	MIN. UNIT WEIGHT (PCF)	COEF OF SUBGRADE REACTION (KCF)	UNDRAIND SHEAR STRENGTH (KSF)	YOUNG MOD. OF SUBGRADE (KSI)	COEF. OF AT REST PRESS.	MAX. EFFECTIVE ANGLE OF FRICTION (DEGREES)	MAX. ALLOWABLE BEARING CAPACITY (TSF)
	REQUIRE DIAMOND CORE DRILLING TO ADVANCE BOREHOLE			TRANSITION ZONE								
		WEATHERED& JOINTED BEDROCK	WR	WEATHERED AND JOINTED BEDROCK. WEATHERING ALONG JOINTS AND ALSO AFFECTING HE MINERAL FABRIC. RQD GENERALLY LESS THAN 50%.	BECOMING MORE ROCK LIKE WITH DEPTH, TOO HARD TO OBTAIN SOIL SAMPLE FOR TEST.	150 TO 160					32 TO 38	5.0 TO 15.0
		JOINTED BEDROCK	J	JOINTED TO MODERATELY JOINTED BEDROCK. WEATHERING ON JOINTS BUT RELATIVELY SMALL EFFECT ON MINERAL FABRIC. RQD GENERALLY BETWEEN 50% TO 75%.	MODERATELY JOINTED TO RELATIVELY SOUND. COMPRESSIVE STRENGTH 5 TO 25 KSI.	170					45	30.0 TO 60.0
		BEDROCK	R	RELATIVELY SOUND TO SOUND BEDROCK, OCCASIONALLY MODERATELY JOINTED. WEATHERING CONFINED PRINICPALLY TO JOINTS. RQD GENERALLY GREATER THAN 75%.	MODERATELY JOINTED TO RELATIVELY SOUND. COMPRESSIVE STRENGTH 5 TO 25 KSI.	170					45	30.0 TO 60.0

1. THIS TABLE IS INTENDED PRIMARILY FOR USE IN DESIGN OF PERMANENT STRUCTURES. IN ANY CASE, SPECIFIC BORING AND LABORATORY TEST INFORMATION AT THE LOCATION OF INTEREST SHOULD BE CONSULTED IN SELECTING THE PARAMETERS FOR DESIGN SINCE THE VALUES TABULATED ABOVE ARE GENERALIZED OVER A WIDE AREA.

2. "SHEAR STRENGTH" TABULATED FOR "COHESIVE STRATA" IS APPROXIMATE UNDRAINED COHESION AND IS NOT INTENDED TO BE COMBINED WITH OR SUPERPOSED ON THE "EFFECTIVE FRICTION ANGLE"FOR DRAINED SHEAR.

3. IN EVALUATING APPLIED PRESSURES OR STABILITY CONDITIONS IN THE TRANSITION ZONE AND VARIOUS BEDROCK ZONES, THE BORING INFORMATION ON ATTITUDE AND CHARACTER OF OF THE DISCONTINUITIES SHOULD BE TAKEN INTO CONSIDERATION. IF THERE IS EVIDENCE OF SLICKENSIDES, SHEARED ZONES OR SURFACES OR SMOOTH JOINTS DIPPING UNFAVORABLY INTO THE EXCAVATION, EFFECTIVE FRICTION ANGLES ON THESE DISCONTINUITIES CAN BE IN A RANGE OF 10 DEGREES TO 20 DEGREES.

NOTES: a) TABLE IS BASED ON MRW&J* GEOTECHNICAL INFORMATION FOR THE METRO PREVIOUS PROJECTS.

b) INFORMATION (ALLOWED LIMITS) NOT GIVEN IN THE TABLE SHALL BE PROVIDED BY DESIGNER/DESIGN-BUILDER FOR SPECIFIC PROJECT AS NECESSARY

* MEUSER RUTLEDGE WENTWORTH & JOHNSTON

Updated: September 6, 2000□

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SECTION 16 ENVIRONMENTAL

16 .1 General Environmental Requirements

It is the policy of WMATA to commit the necessary resources to establish, implement and maintain comprehensive environmental management programs and systems that ensure full compliance with environmental laws, regulations, policies, procedures and programs. To that end, all design projects for construction of new facilities or renovation of existing facilities shall incorporate elements that will ensure compliance with all local environmental laws and permits during construction and during subsequent operation. Further, designs shall consider environmental sustainability to improve the quality and health of the community and environment.

16 .1.1 Storm Water Management The primary goal of state and local storm water management programs is to maintain after development, as nearly as possible, the predevelopment runoff characteristics, and to reduce stream channel erosion, pollution, siltation and sedimentation, and local flooding.

16 .1.1.1 Meet all requirements of federal, state and local jurisdictions. Regulations and guidance governing storm water management programs are provided by the following, as amended and/or updated:

16 .1.1.1.1 Maryland: COMAR 26.17.02
Maryland Department of the Environment, Water Management Administration: 1) Maryland Storm Water Design Manual; and 2) Maryland Standards and Specifications for Soil Erosion and Sediment Control.

16 .1.1.1.2 Virginia: 9 9 VAC 25-150 and 9 VAC 25-820
Virginia Department of Environmental Quality, State Water Control Board, Water Quality Management Planning Regulation.

Virginia: 4 VAC 50-30
Erosion and Sediment Control Program: Virginia Erosion and Sediment Control Handbook.

16 .1.1.1.3 District of Columbia: 20 DCMR Chapter 31 & 21 DCMR Chapter 5:
District Department of the Environment, Watershed Protection Division: DC BMP Manual.

16 .1.1.2 All discharges to the storm sewer system, including those from discharge pumping stations, shall comply with the requirements of the state and local jurisdiction and General NPDES permits.

16 .1.1.2.1 Obtain permit for any planned discharge to the storm sewer system.

16 .1.1.3 Designer shall consider and implement low impact development (LID) integrated management practices (IMP) wherever possible.

16 .1.1.4 Implement storm water management requirements during construction. At a minimum, implement sediment and erosion control methods, dust control methods and temporary/relocated storage areas.

16 .1.1.5 Control storm water runoff by implementing appropriate best management practices (BMPs) accepted by the state and local jurisdiction. Select BMPs that will reduce the availability, detachment and transport of pollutants to both ground and surface waters.

16 .1.1.6 Storm water management system design shall be prepared by a Professional Engineer licensed by local jurisdiction. Provide storm water calculations and hydrographs prepared for design within the design package submittal.

16 .1.1.7 Storm water quality structures shall be installed to treat storm water prior to discharge to the storm sewer system. Storm water runoff for parking areas must be pretreated through an oil/water separator, or equivalent structure, prior to discharge to the storm sewer system. Prevent storm water runoff from flowing off site without treatment.

16 .1.1.8 Pretreatment structure design shall include installation of a sediment/grit chamber directly accessible for maintenance by vacuum truck.

16 .1.1.9 For parking garages where the top deck is not covered, only top deck drains may discharge to the storm sewer. Discharge must be treated through an oil/water separator, or equivalent structure.

16 .1.1.9.1 Maintain separate water quantity storage vaults for waters that will discharge to storm sewer and sanitary sewer systems.

16 .1.1.9.2 Cleaning in parking garages shall be accomplished using only vacuum truck recovery; uncontrolled washdown shall not be performed. Recovered wastewater shall be hauled off site for proper disposal and properly manifested.

16 .1.1.10 Re-infiltration of storm water under buildings, including parking garages, is not allowed unless approved by WMATA and the state or local jurisdiction.

16 .1.1.11 On design drawings, provide maintenance requirements for storm water management system. Provide access for inspection and maintenance of all structures using a vacuum truck. Access to each storm water pretreatment and grit structure shall be through a 36" diameter manhole with a composite H-20 rated cover.

16 .1.1.11.1 At each storm water pond, provide vehicle access to the outlet structure. Provide an anti-vortex trash rack, or similar device, to prevent discharge of large debris through the outlet structure. Plant native species to maintain a minimum 3-foot buffer around pond. In public areas, provide security fence around pond.

16 .1.1.11.2 At each parking garage, structures must be accessible for maintenance using a vacuum truck (min. clearance 14 feet above finished grade with a min. turning radius of 44 feet) or design must provide underground piping for vacuum truck connection at building exterior. Access to structure opening shall be located outside of main travel lane.

16 .1.1.12 Bulk Salt Storage

16 .1.1.12.1 Where bulk salt is stored on WMATA property, provide a building in which to stockpile the chemical and an adjacent impermeable pad that serves as a loading area for trucks.

16 .1.1.12.2 Provide curbing to prevent runoff to adjacent permeable areas.

16 .1.1.12.3 Do not locate bulk storage area within 25 feet of storm drain inlet.

16 .1.2 Wastewater Discharge: All discharges to the sanitary sewer system shall comply with requirements of the local public-owned treatment works (POTW) (i.e., wastewater treatment plant).

16 .1.2.1 Provide pretreatment systems for industrial operations prior to discharge to the sanitary sewer system to meet discharge requirements of the POTW.

16 .1.2.1.1 Provide dedicated space and/or separate room in which pretreatment system will be installed. Ensure adequate access around equipment for inspection and maintenance.

16 .1.2.1.2 At a minimum, install pretreatment system at rail car wash to adjust pH prior to discharge and provide grit chamber inside car wash for sedimentation. Install control equipment to prevent discharge when pH is outside of POTW and/or permit limits.

16 .1.2.1.3 At a minimum, install pretreatment system at steam clean areas, bus service lanes, and blow pits to collect oil and grease prior to discharge.

16 .1.2.1.4 Pretreatment systems shall include installation of a sediment/grit chamber directly accessible for maintenance by vacuum truck.

16 .1.2.1.5 Pretreatment systems shall include installation of a sediment/grit chamber directly accessible for maintenance by vacuum truck.

16 .1.2.1.6 Pretreatment systems shall have remote communication capabilities. At a minimum, sensors shall record data for permit parameters and for operational data. Data loggers shall be dataTaker 80, or equal.

16 .1.2.1.7 Where pretreatment systems are installed to meet permit requirements beyond oil/water separation, install auto-dialers to report data that is outside permit limits. Auto dialers shall be ANTX Dialog Elite, or equal.

16 .1.2.2 For parking garages, all drains on decks below the top deck shall discharge to the sanitary sewer. Discharge must be pretreated through an oil/water separator, or equivalent structure.

16 .1.2.2.1 Maintain separate water quantity storage vaults for waters that will discharge to storm sewer and sanitary sewer systems.

16 .1.2.2.2 Cleaning in parking garages shall be accomplished using only vacuum truck recovery; uncontrolled washdown shall not be performed. Recovered wastewater shall be hauled off site for proper disposal and properly manifested.

16 .1.2.3 No floor drains shall be present in paint booths or battery storage areas (including traction power substations and tie

breaker buildings). In general, floor drains are discouraged except in cleaning areas.

16 .1.2.4 Elevators and escalators shall have a sump that discharges to the sanitary sewer system through the use of an Oil Minder pump, or equal.

16 .1.2.5 For facilities where maintenance activities will be completed, provide aqueous-based, recycling parts washers with oil and grit removal. No solvent cleaning systems shall be installed. Where pretreatment systems are not installed, parts washers must be accessible for maintenance with a vacuum truck, or install piping connection to building exterior.

16 .1.2.6 At facilities that do not generate significant wastewater from industrial operations (e.g., less than 1,000 gallons/week), provide gray water systems rather than pretreatment systems. Gray water systems shall store wastewater generated by floor scrubbers, parts washers and mop water until the water is removed by vacuum truck. Within the facility, provide a building sump with floor grate into which parts washers drain and floor scrubber/mop water can be directly dumped. Water from the sump is pumped into a minimum 1,000-gallon fiberglass above ground storage tank, vented to the building exterior, that is accessible for clean out with a vacuum truck. Provide a 3" diameter connection at the base of the tank for cleanout.

16 .1.2.7 On design drawings, provide maintenance requirements for wastewater pretreatment systems. Provide access for inspection and maintenance of all structures using a vacuum truck. Access to each sanitary pretreatment and grit structure shall be through a 36" diameter manhole with a composite H-20 rated cover.

16 .1.2.7.1 For each wastewater system, storage tanks and pretreatment structures must be accessible or maintenance, including removal of sludge, using a vacuum truck. Where direct access is not possible, design shall provide piping and hose connection to allow maintenance.

16 .1.2.7.2 For each parking garage, pretreatment structures must be accessible for maintenance using a vacuum truck (min. clearance 14 feet above finished grade with a min. turning radius of 44 feet) or design must provide underground piping for vacuum truck connection at building exterior.

16 .1.3 Air Emissions: All discharges to the air shall comply with the requirements of the local jurisdiction.

16 .1.3.1 Evaluate fuel-burning equipment (such as generators and boilers) and other potential air emission sources (such as paint booths, printing operations, fire suppression systems, and CNG fueling systems) to determine permitting requirements in the state and local jurisdiction.

16 .1.3.2 Obtain permits to construct and operate prior to installing new equipment.

16 .1.3.3 Equipment that has been engineered to reduce air emissions to levels within the regulations must be certified.

16 .1.3.4 For each facility, design shall provide a dedicated area and certified equipment to crush fluorescent tubes and to evacuate aerosol cans.

16 .1.4 Noise: Noise shall be controlled such that it is within levels required by the local jurisdiction.

16 .1.4.1 Noise is regulated for mobile and stationary sources.

16 .1.4.2 Minimize the adverse impact of system operations and construction on the community by controlling transmission of noise and vibration to adjacent properties.

16 .1.4.3 Provide noise and vibration control consistent with economic constraints and appropriate technology.

16 .1.5 Hazardous Material/Waste Storage: For each facility, design shall provide for dedicated and proper storage of hazardous materials and/or wastes.

16 .1.5.1 For drum storage areas, including all material storerooms, provide spill containment pallets and signage for proper storage.

16 .1.5.1.1 Containment curbs may be installed in lieu of individual pallets where a designated room will be used for drum storage.

16 .1.5.2 For cylinder storage areas, including all material storerooms, provide equipment and signage for proper storage.

16 .1.5.3 For battery storage rooms, provide containment curbs and appropriate epoxy coating on floor that extends no less than 18 inches above the floor on all walls. Provide ventilation in accordance with NFPA and other applicable codes.

16 .1.5.4 Flammable cabinets that will be installed in exterior locations shall be weathertight, self-closing and shall include forklift pockets.

16 .1.5.5 Provide separate, dedicated and secured hazardous and non-hazardous waste storage shed. Sheds shall be large enough to hold a minimum of eight 55-gallon drums on one level, be accessible with forklift for loading material contained on pallets, and shall include integral spill containment. Sheds shall be located on an impervious surface at least 50 feet from the property line and no less than 25 feet from storm drain inlets. Provide signage to indicate “Hazardous Waste Storage Area” and “Non Hazardous Waste Storage Area” on applicable shed.

16 .1.5.6 At each facility, provide dedicated space for two dumpsters: one for solid waste and one for scrap metal. Dumpsters shall not be located within 25 feet of a storm drain inlet.

16 .1.5.7 Provide dedicated space and appropriate equipment for spill response (i.e., “spill kit”) adjacent to, and within easy access of, fueling areas, ddrum storage

areas and battery storage areas (including traction power substations and tie-breaker stations).

16 .1.6 Building Environmental Issues: For buildings to be renovated or demolished, designer shall identify environmental hazards that may impact construction activities and waste disposal. These issues include, but are not limited to, the presence of asbestos-containing materials (ACMs), lead-based paint (LBP), biohazards (e.g., toxic mold or animal waste), electrical equipment or fixtures that contain polychlorinated biphenyls (PCBs), and lamps that contain mercury. Where present, project design must identify the extent of these materials and must include specifications for proper abatement and waste disposal in accordance with all regulations.

16 .1.6.1 For new construction, to the extent possible, specify building materials that do not contain environmental hazards.

16 .1.7 Subsurface Environmental Issues: Designer shall identify and characterize subsurface environmental conditions that will impact construction and operation. Designer shall review any available data, including but not limited to Environmental Impact Statements (EIS), Phase I and Phase II Environmental Site Assessments, and geotechnical data and shall collect additional data as required to adequately characterize subsurface contaminants. Implement EIS mitigation requirements and contaminant pretreatment, including storm water discharge. For example, building dewatering systems or the tunnel discharge pumping stations may require pH adjustment or treatment to remove oil and grease prior to discharge to the sewer system. Temporary treatment requirements due to construction activities and materials (e.g., grout and concrete user) must also be implemented.

16 .1.7.1 Obtain permits from federal, state and local agencies for planned discharges prior to construction.

16 .1.7.2 Design discharge from areas with subsurface contaminants to meet requirements of discharge permits.

16 .1.7.3 When a steel tank is encountered during renovation or construction operations, the tank shall be removed or abandoned in accordance with codes and regulations. Provide notification to WMATA's Environmental Services branch.

16 .1.8 Environmentally Sustainable Design and Construction: Environmental sustainability refers to the implementation of building design and construction that satisfies the needs of the present without diminishing the ability of future generations to meet their needs. Design and construction must implement environmental building principles that include, but are not limited to, energy efficiency, water efficiency, and waste minimization.

16 .1.9 Storage Tank Systems: Tank systems (underground storage tanks, aboveground storage tanks, associated piping systems, and dispensing systems) shall be designed in accordance with applicable codes and regulations, including but not limited to the following: API, ASTM, NFPA, PEI, UL, USEPA, DCMR, COMAR and VAC.

16 .1.9.1 Aboveground Storage Tanks (ASTs)

16 .1.9.1.1 Whenever possible, install ASTs for product storage as a preference over underground product storage.

16 .1.9.1.2 ASTs for petroleum products shall be double-walled steel, installed in accordance with manufacturer's installation instructions, and warranted for 10 years. The material used for tank construction, or lining, shall be compatible with the substance to be stored.

16 .1.9.1.3 ASTs shall meet the requirements of UL 142 and shall be protected by bollards on all sides. Bollard shall be min. 8" diameter and spaced sufficiently to protect tank from damage. When required by the local jurisdiction, ASTs shall meet the requirements of UL 2085.

16 .1.9.1.4 Fill ports shall be located directly over the tank, where possible. Provide ladder access with platform, where necessary. If remote fill port is required, provide stainless steel enclosure with locking fill cap and fusible link.

16 .1.9.1.5 Tank shall be provided with overfill prevention valve, spill containment box, and manual tank gauge. Tank shall be primed and painted by the tank manufacturer.

16 .1.9.1.6 Tanks shall be vented, both primary and interstitial vents, to the building exterior when required by code.

16 .1.9.1.7 Used oil ASTs shall be Safe Waste, or equivalent, supplied with roll-kaddy units.

16 .1.9.1.8 Third rail de-icer shall be stored at each rail yard in two 5,000-gallon ASTs. Tanks may be single-walled steel only if constructed by the manufacturer with a dike and provided with rain shields.

16 .1.9.1.9 In parking garages, if emergency generator is fueled by diesel, diesel shall be stored in an AST and AST shall be vented to the building exterior.

16 .1.9.1.10 All ASTs shall be labeled to identify tank capacity and product stored in minimum 2" high text. Labeling shall include a completed NFPA fire diamond.

16 .1.9.2 Underground Storage Tanks (USTs)

16 .1.9.2.1 Only tanks exceeding 2,500 gallons may be considered for UST installation.

16 .1.9.2.2 USTs shall be double-walled fiberglass with brine in interstice, installed in accordance with manufacturer's installation instructions, and warranted for 30 years. The material used for tank construction, or lining, shall be compatible with the substance to be stored.

16 .1.9.2.3 USTs shall be installed by certified tank installers.

16 .1.9.2.4 Design UST systems to minimize length of piping runs. Place tank systems outside of main travel areas (roadways) and within required property setbacks.

16 .1.9.2.5 UST anchoring shall be accomplished using a reinforced concrete anchor pad; dead men are not acceptable. Anchor pad shall be reinforced using two layers of No. 4 rebar spaced 12 inches OCEW. Straps, not ropes, shall be used to anchor tank to pad.