

ATTACHMENT A

One-Dimensional Landfill Settlement Calculations

**One-Dimensional Landfill Settlement Calculations
Proposed West Landfill Expansion (Section A-A')**

Project No. 18111331
March 2020

1. Calculation of Total Consolidation Settlement at Pt. A (Section A-A' of Proposed West Landfill Expansion)

Inputs	masl
Approximate Midpoint of Clay Deposit	172.3
Approximate Original Ground Surface	198.5
Final Cover Elevation at Bottom of 3:1 Excavation Slope - West Side of Central Ridge (Point A)	209.4
Final Cover Elevation at 4(H):1(V) "Mid-Slope" Point - West Side of Central Ridge (Point B)	221.2
Final Cover Elevation at Slope Change Contour - West Side of Central Ridge (Point C)	233.0
Final Cover Elevation at 5% "Mid-Slope" Point - West Side of Central Ridge (Point D)	237.6
Final Cover Elevation at Peak of Landfill - At Peak of Central Ridge (Point E)	241.0
Final Cover Elevation at 5% "Mid-Slope" Point - East Side of Central Ridge (Point F)	237.3
Final Cover Elevation at Slope Change Contour - East Side of Central Ridge (Point G)	233.0
Final Cover Elevation at 4(H):1(V) "Mid-Slope" Point - East Side of Central Ridge (Point H)	220.4
Final Cover Elevation at Bottom of 3:1 Excavation Slope - East Side of Central Ridge (Point I)	207.9
Elevation of Base of LCS (Point A)	188.6
Elevation of Base of LCS (Point B)	189.2
Elevation of Base of LCS (Point C)	189.8
Elevation of Base of LCS (Point D)	190.5
Elevation of Base of LCS (Point E)	191.3
Elevation of Base of LCS (Point F)	190.5
Elevation of Base of LCS (Point G)	189.7
Elevation of Base of LCS (Point H)	189.0
Elevation of Base of LCS (Point I)	188.4
Bottom of Clay Deposit	156
Groundwater Elevation in Overburden	198
Groundwater Elevation in Bedrock	178

1a. Final total Stress at Pt. A (Refer to Figure B1 for the location of Point A)

Layer	Thickness (m)	Unit Weight (kN/m ³)	Applied Pressure at Pt. A (kPa)
Final Cover	1.5	21	31.5
Waste	18.8	13	244.9
Sand Filter	0.2	19	3.8
Stone Drainage Layer	0.3	18	5.4
Natural Clay	16.3	21.0	341.8

Total Applied Pressure 627

1b. Initial Total Stress at Pt. A

$$\sigma \text{ (initial)} = 26.2 \times 21.0 = 551 \text{ kPa}$$

1c. Initial Effective Stress at Pt. A

$$\sigma' \text{ (initial)} = \sigma - u \quad \text{where } u \text{ is the pore pressure at the midpoint of the clay deposit}$$

$$= 551 - 13.5 \times 9.81 \text{ kN/m}^3 = 418 \text{ kPa}$$

$$\text{Pressure Head} = 13.5 \text{ m}$$

1d. Final Total Stress at Pt. A

$$\sigma \text{ (final)} = 627 \text{ kPa}$$

1e. Final Effective Stress at Pt. A

$$\sigma' \text{ (final)} = \sigma - u \quad \text{Pressure Head} = 11.0 \text{ m}$$

$$= 627 - 11.0 \times 9.81 \text{ kN/m}^3 = 519 \text{ kPa}$$

1f. Change in Effective Stress at Pt. A

$$\Delta\sigma' = \sigma' \text{ (final)} - \sigma' \text{ (initial)}$$

$$\Delta\sigma' = 519 - 418$$

$$\Delta\sigma' = 102 \text{ kPa}$$

1d. Settlement at Pt. A

$$S = m_v \times \Delta\sigma'_{A'} \times H_{clay}$$

$$S = (5 \times 10^{-5} \text{ m}^2/\text{kN}) \times 102 \times (188.55 - 156.00)$$

$$S = 0.17 \text{ m}$$

Summary

$$H = 20.8 \text{ m} \quad \text{where } H = \text{total thickness of cover + waste + liner above Point A}$$

$$\text{Settlement} = 165 \text{ mm}$$

Assumptions & Limitations

- The coefficient of volume compressibility was derived from consolidation testing reported in Gartner Lee's Report dated December, 1991; $M_v = (5 \times 10^{-5} \text{ m}^2/\text{kN})$ (low compressibility clays).
- Point A' defined as point on top of the clay foundation (i.e., directly below the leachate collection system)
- Depth to groundwater assumed to be at ground surface pre-construction and at the base of the leachate collection system after Cell construction

**One-Dimensional Landfill Settlement Calculations
Proposed West Landfill Expansion (Section A-A')**

Project No. 18111331
March 2020

1. Calculation of Total Consolidation Settlement at Pt. B (Section A-A' of Proposed West Landfill Expansion)

Inputs	masl
Approximate Midpoint of Clay Deposit	172.6
Approximate Original Ground Surface	198.5
Final Cover Elevation at Bottom of 3:1 Excavation Slope - West Side of Central Ridge (Point A)	209.4
Final Cover Elevation at 4(H):1(V) "Mid-Slope" Point - West Side of Central Ridge (Point B)	221.2
Final Cover Elevation at Slope Change Contour - West Side of Central Ridge (Point C)	233.0
Final Cover Elevation at 5% "Mid-Slope" Point - West Side of Central Ridge (Point D)	237.6
Final Cover Elevation at Peak of Landfill - At Peak of Central Ridge (Point E)	241.0
Final Cover Elevation at 5% "Mid-Slope" Point - East Side of Central Ridge (Point F)	237.3
Final Cover Elevation at Slope Change Contour - East Side of Central Ridge (Point G)	233.0
Final Cover Elevation at 4(H):1(V) "Mid-Slope" Point - East Side of Central Ridge (Point H)	220.4
Final Cover Elevation at Bottom of 3:1 Excavation Slope - East Side of Central Ridge (Point I)	207.9
Elevation of Base of LCS (Point A)	188.6
Elevation of Base of LCS (Point B)	189.2
Elevation of Base of LCS (Point C)	189.8
Elevation of Base of LCS (Point D)	190.5
Elevation of Base of LCS (Point E)	191.3
Elevation of Base of LCS (Point F)	190.5
Elevation of Base of LCS (Point G)	189.7
Elevation of Base of LCS (Point H)	189.0
Elevation of Base of LCS (Point I)	188.4
Bottom of Clay Deposit	156
Groundwater Elevation in Overburden	198
Groundwater Elevation in Bedrock	178

1a. Final total Stress at Pt. B (Refer to Figure B1 for the location of Point B)

Layer	Thickness (m)	Unit Weight (kN/m ³)	Applied Pressure at Pt. B (kPa)
Final Cover	1.5	21	31.5
Waste	30.0	13	390.4
Sand Filter	0.2	19	3.8
Stone Drainage Layer	0.3	18	5.4
Natural Clay	16.6	21.0	348.2

Total Applied Pressure

779

1b. Initial Total Stress at Pt. B

$$\sigma \text{ (initial)} = 25.9 \times 21.0 = 544 \text{ kPa}$$

1c. Initial Effective Stress at Pt. B

$$\sigma' \text{ (initial)} = \sigma - u \quad \text{where } u \text{ is the pore pressure at the midpoint of the clay deposit}$$

$$= 544 - 13.4 \times 9.81 \text{ kN/m}^3 = 413 \text{ kPa}$$

$$\text{Pressure Head} = 13.4 \text{ m}$$

1d. Final Total Stress at Pt. B

$$\sigma \text{ (final)} = 779 \text{ kPa}$$

1e. Final Effective Stress at Pt. B

$$\sigma' \text{ (final)} = \sigma - u \quad \text{Pressure Head} = 11.0 \text{ m}$$

$$= 779 - 11.0 \times 9.81 \text{ kN/m}^3 = 671 \text{ kPa}$$

1f. Change in Effective Stress at Pt. B

$$\Delta\sigma' = \sigma' \text{ (final)} - \sigma' \text{ (initial)}$$

$$\Delta\sigma' = 671 - 413 = 258 \text{ kPa}$$

1d. Settlement at Pt. B

$$S = m_v \times \Delta\sigma'_{A'} \times H_{clay}$$

$$S = (5 \times 10^{-5} \text{ m}^2/\text{kN}) \times 258 \times (189.16 - 156.00)$$

$$S = 0.42 \text{ m}$$

Summary

$$H = 32.0 \text{ m} \quad \text{where } H = \text{total thickness of cover + waste + liner above Point B'}$$

$$\text{Settlement} = 420 \text{ mm}$$

Assumptions & Limitations

- The coefficient of volume compressibility was derived from consolidation testing reported in Gartner Lee's Report dated December, 1991; $M_v = (5 \times 10^{-5} \text{ m}^2/\text{kN})$ (low compressibility clays).
- Point B defined as point on top of the clay foundation (i.e., directly below the leachate collection system)
- Depth to groundwater assumed to be at ground surface pre-construction and at the base of the leachate collection system after Cell construction

**One-Dimensional Landfill Settlement Calculations
Proposed West Landfill Expansion (Section A-A')**

Project No. 18111331
March 2020

1. Calculation of Total Consolidation Settlement at Pt. C (Section A-A' of Proposed West Landfill Expansion)

Inputs	masl
Approximate Midpoint of Clay Deposit	172.9
Approximate Original Ground Surface	198.5
Final Cover Elevation at Bottom of 3:1 Excavation Slope - West Side of Central Ridge (Point A)	209.4
Final Cover Elevation at 4(H):1(V) "Mid-Slope" Point - West Side of Central Ridge (Point B)	221.2
Final Cover Elevation at Slope Change Contour - West Side of Central Ridge (Point C)	233.0
Final Cover Elevation at 5% "Mid-Slope" Point - West Side of Central Ridge (Point D)	237.6
Final Cover Elevation at Peak of Landfill - At Peak of Central Ridge (Point E)	241.0
Final Cover Elevation at 5% "Mid-Slope" Point - East Side of Central Ridge (Point F)	237.3
Final Cover Elevation at Slope Change Contour - East Side of Central Ridge (Point G)	233.0
Final Cover Elevation at 4(H):1(V) "Mid-Slope" Point - East Side of Central Ridge (Point H)	220.4
Final Cover Elevation at Bottom of 3:1 Excavation Slope - East Side of Central Ridge (Point I)	207.9
Elevation of Base of LCS (Point A)	188.6
Elevation of Base of LCS (Point B)	189.2
Elevation of Base of LCS (Point C)	189.8
Elevation of Base of LCS (Point D)	190.5
Elevation of Base of LCS (Point E)	191.3
Elevation of Base of LCS (Point F)	190.5
Elevation of Base of LCS (Point G)	189.7
Elevation of Base of LCS (Point H)	189.0
Elevation of Base of LCS (Point I)	188.4
Bottom of Clay Deposit	156
Groundwater Elevation in Overburden	198
Groundwater Elevation in Bedrock	178

1a. Final total Stress at Pt. C (Refer to Figure B1 for the location of Point C)

Layer	Thickness (m)	Unit Weight (kN/m ³)	Applied Pressure at Pt. C (kPa)
Final Cover	1.5	21	31.5
Waste	41.2	13	536.1
Sand Filter	0.2	19	3.8
Stone Drainage Layer	0.3	18	5.4
Natural Clay	16.9	21.0	354.5

Total Applied Pressure 931

1b. Initial Total Stress at Pt. C

$$\sigma \text{ (initial)} = 25.6 \times 21.0 = 538 \text{ kPa}$$

1c. Initial Effective Stress at Pt. C

$$\begin{aligned} \sigma' \text{ (initial)} &= \sigma - u \quad \text{where } u \text{ is the pore pressure at the midpoint of the clay deposit} \\ &= 538 - 13.2 \times 9.81 \text{ kN/m}^3 \\ &= 408 \text{ kPa} \end{aligned}$$

Pressure Head = 13.2 m

1d. Final Total Stress at Pt. C

$$\sigma \text{ (final)} = 931 \text{ kPa}$$

1e. Final Effective Stress at Pt. C

$$\begin{aligned} \sigma' \text{ (final)} &= \sigma - u \quad \text{Pressure Head} = 11.0 \text{ m} \\ &= 931 - 11.0 \times 9.81 \text{ kN/m}^3 \\ &= 823 \text{ kPa} \end{aligned}$$

1f. Change in Effective Stress at Pt. C

$$\begin{aligned} \Delta\sigma' &= \sigma' \text{ (final)} - \sigma' \text{ (initial)} \\ &= 823 - 408 \\ \Delta\sigma' &= 415 \text{ kPa} \end{aligned}$$

1d. Settlement at Pt. C

$$\begin{aligned} S &= m_v \times \Delta\sigma'_{A'} \times H_{clay} \\ S &= (5 \times 10^{-5} \text{ m}^2/\text{kN}) \times 415 \times (189.76 - 156.00) \\ S &= 0.68 \text{ m} \end{aligned}$$

Summary

H = 43.2 m where H = total thickness of cover + waste + liner above Point C
Settlement = 676 mm

Assumptions & Limitations

- The coefficient of volume compressibility was derived from consolidation testing reported in Gartner Lee's Report dated December, 1991; $M_v = (5 \times 10^{-5} \text{ m}^2/\text{kN})$ (low compressibility clays).
- Point C defined as point on top of the clay foundation (i.e., directly below the leachate collection system)
- Depth to groundwater assumed to be at ground surface pre-construction and at the base of the leachate collection system after Cell construction

**One-Dimensional Landfill Settlement Calculations
Proposed West Landfill Expansion (Section A-A')**

Project No. 18111331
March 2020

1. Calculation of Total Consolidation Settlement at Pt. D (Section A-A' of Proposed West Landfill Expansion)

Inputs	masl
Approximate Midpoint of Clay Deposit	173.3
Approximate Original Ground Surface	198.5
Final Cover Elevation at Bottom of 3:1 Excavation Slope - West Side of Central Ridge (Point A)	209.4
Final Cover Elevation at 4(H):1(V) "Mid-Slope" Point - West Side of Central Ridge (Point B)	221.2
Final Cover Elevation at Slope Change Contour - West Side of Central Ridge (Point C)	233.0
Final Cover Elevation at 5% "Mid-Slope" Point - West Side of Central Ridge (Point D)	237.6
Final Cover Elevation at Peak of Landfill - At Peak of Central Ridge (Point E)	241.0
Final Cover Elevation at 5% "Mid-Slope" Point - East Side of Central Ridge (Point F)	237.3
Final Cover Elevation at Slope Change Contour - East Side of Central Ridge (Point G)	233.0
Final Cover Elevation at 4(H):1(V) "Mid-Slope" Point - East Side of Central Ridge (Point H)	220.4
Final Cover Elevation at Bottom of 3:1 Excavation Slope - East Side of Central Ridge (Point I)	207.9
Elevation of Base of LCS (Point A)	188.6
Elevation of Base of LCS (Point B)	189.2
Elevation of Base of LCS (Point C)	189.8
Elevation of Base of LCS (Point D)	190.5
Elevation of Base of LCS (Point E)	191.3
Elevation of Base of LCS (Point F)	190.5
Elevation of Base of LCS (Point G)	189.7
Elevation of Base of LCS (Point H)	189.0
Elevation of Base of LCS (Point I)	188.4
Bottom of Clay Deposit	156
Groundwater Elevation in Overburden	198
Groundwater Elevation in Bedrock	178

1a. Final total Stress at Pt. D (Refer to Figure B1 for the location of Point D)

Layer	Thickness (m)	Unit Weight (kN/m ³)	Applied Pressure at Pt. D (kPa)
Final Cover	1.5	21	31.5
Waste	45.1	13	586.6
Sand Filter	0.2	19	3.8
Stone Drainage Layer	0.3	18	5.4
Natural Clay	17.3	21.0	362.3

Total Applied Pressure 990

1b. Initial Total Stress at Pt. D

$$\begin{aligned}\sigma \text{ (initial)} &= 25.3 \times 21.0 \\ &= 530 \text{ kPa}\end{aligned}$$

1c. Initial Effective Stress at Pt. D

$$\begin{aligned}\sigma' \text{ (initial)} &= \sigma - u \quad \text{where } u \text{ is the pore pressure at the midpoint of the clay deposit} \\ &= 530 - 13.0 \times 9.81 \text{ kN/m}^3 \\ &= 402 \text{ kPa}\end{aligned}$$

$$\text{Pressure Head} = 13.0 \text{ m}$$

1d. Final Total Stress at Pt. D

$$\sigma \text{ (final)} = 990 \text{ kPa}$$

1e. Final Effective Stress at Pt. D

$$\begin{aligned}\sigma' \text{ (final)} &= \sigma - u \quad \text{Pressure Head} = 11.0 \text{ m} \\ &= 990 - 11.0 \times 9.81 \text{ kN/m}^3 \\ &= 882 \text{ kPa}\end{aligned}$$

1f. Change in Effective Stress at Pt. D

$$\begin{aligned}\Delta\sigma' &= \sigma' \text{ (final)} - \sigma' \text{ (initial)} \\ \Delta\sigma' &= 882 - 402 \\ \Delta\sigma' &= 479 \text{ kPa}\end{aligned}$$

1d. Settlement at Pt. D

$$\begin{aligned}S &= m_v \times \Delta\sigma'_{A'} \times H_{clay} \\ S &= (5 \times 10^{-5} \text{ m}^2/\text{kN}) \times 479 \times (190.50 - 156.00) \\ S &= 0.78 \text{ m}\end{aligned}$$

Summary

$$\begin{aligned}H &= 47.1 \text{ m} \quad \text{where } H = \text{total thickness of cover + waste + liner above Point D} \\ \text{Settlement} &= 780 \text{ mm}\end{aligned}$$

Assumptions & Limitations

- The coefficient of volume compressibility was derived from consolidation testing reported in Gartner Lee's Report dated December, 1991; $M_v = (5 \times 10^{-5} \text{ m}^2/\text{kN})$ (low compressibility clays).
- Point D defined as point on top of the clay foundation (i.e., directly below the leachate collection system)
- Depth to groundwater assumed to be at ground surface pre-construction and at the base of the leachate collection system after Cell construction

**One-Dimensional Landfill Settlement Calculations
Proposed West Landfill Expansion (Section A-A')**

Project No. 18111331
March 2020

1. Calculation of Total Consolidation Settlement at Pt. E (Section A-A' of Proposed West Landfill Expansion)

Inputs	masl
Approximate Midpoint of Clay Deposit	173.6
Approximate Original Ground Surface	198.5
Final Cover Elevation at Bottom of 3:1 Excavation Slope - West Side of Central Ridge (Point A)	209.4
Final Cover Elevation at 4(H):1(V) "Mid-Slope" Point - West Side of Central Ridge (Point B)	221.2
Final Cover Elevation at Slope Change Contour - West Side of Central Ridge (Point C)	233.0
Final Cover Elevation at 5% "Mid-Slope" Point - West Side of Central Ridge (Point D)	237.6
Final Cover Elevation at Peak of Landfill - At Peak of Central Ridge (Point E)	241.0
Final Cover Elevation at 5% "Mid-Slope" Point - East Side of Central Ridge (Point F)	237.3
Final Cover Elevation at Slope Change Contour - East Side of Central Ridge (Point G)	233.0
Final Cover Elevation at 4(H):1(V) "Mid-Slope" Point - East Side of Central Ridge (Point H)	220.4
Final Cover Elevation at Bottom of 3:1 Excavation Slope - East Side of Central Ridge (Point I)	207.9
Elevation of Base of LCS (Point A)	188.6
Elevation of Base of LCS (Point B)	189.2
Elevation of Base of LCS (Point C)	189.8
Elevation of Base of LCS (Point D)	190.5
Elevation of Base of LCS (Point E)	191.3
Elevation of Base of LCS (Point F)	190.5
Elevation of Base of LCS (Point G)	189.7
Elevation of Base of LCS (Point H)	189.0
Elevation of Base of LCS (Point I)	188.4
Bottom of Clay Deposit	156
Groundwater Elevation in Overburden	198
Groundwater Elevation in Bedrock	178

1a. Final total Stress at Pt. E (Refer to Figure B1 for the location of Point E)

Layer	Thickness (m)	Unit Weight (kN/m ³)	Applied Pressure at Pt. E (kPa)
Final Cover	1.5	21	31.5
Waste	47.8	13	620.8
Sand Filter	0.2	19	3.8
Stone Drainage Layer	0.3	18	5.4
Natural Clay	17.6	21.0	370.1

Total Applied Pressure 1032

1b. Initial Total Stress at Pt. E

$$\sigma \text{ (initial)} = 24.9 \times 21.0 = 522 \text{ kPa}$$

1c. Initial Effective Stress at Pt. E

$$\begin{aligned} \sigma' \text{ (initial)} &= \sigma - u \quad \text{where } u \text{ is the pore pressure at the midpoint of the clay deposit} \\ &= 522 - 12.8 \times 9.81 \text{ kN/m}^3 \\ &= 396 \text{ kPa} \end{aligned}$$

Pressure Head = 12.8 m

1d. Final Total Stress at Pt. E

$$\sigma \text{ (final)} = 1032 \text{ kPa}$$

1e. Final Effective Stress at Pt. E

$$\begin{aligned} \sigma' \text{ (final)} &= \sigma - u \quad \text{Pressure Head} = 11.0 \text{ m} \\ &= 1032 - 11.0 \times 9.81 \text{ kN/m}^3 \\ &= 924 \text{ kPa} \end{aligned}$$

1f. Change in Effective Stress at Pt. E

$$\begin{aligned} \Delta\sigma' &= \sigma' \text{ (final)} - \sigma' \text{ (initial)} \\ \Delta\sigma' &= 924 - 396 \\ \Delta\sigma' &= 527 \text{ kPa} \end{aligned}$$

1d. Settlement at Pt. E

$$\begin{aligned} S &= m_v \times \Delta\sigma'_{A'} \times H_{clay} \\ S &= (5 \times 10^{-5} \text{ m}^2/\text{kN}) \times 527 \times (191.25 - 156.00) \\ S &= 0.86 \text{ m} \end{aligned}$$

Summary

H = 49.8 m where H = total thickness of cover + waste + liner above Point E
Settlement = 858 mm

Assumptions & Limitations

- The coefficient of volume compressibility was derived from consolidation testing reported in Gartner Lee's Report dated December, 1991; $M_v = (5 \times 10^{-5} \text{ m}^2/\text{kN})$ (low compressibility clays).
- Point E defined as point on top of the clay foundation (i.e., directly below the leachate collection system)
- Depth to groundwater assumed to be at ground surface pre-construction and at the base of the leachate collection system after Cell construction

**One-Dimensional Landfill Settlement Calculations
Proposed West Landfill Expansion (Section A-A')**

Project No. 18111331
March 2020

1. Calculation of Total Consolidation Settlement at Pt. F (Section A-A' of Proposed West Landfill Expansion)

Inputs	masl
Approximate Midpoint of Clay Deposit	173.2
Approximate Original Ground Surface	198.5
Final Cover Elevation at Bottom of 3:1 Excavation Slope - West Side of Central Ridge (Point A)	209.4
Final Cover Elevation at 4(H):1(V) "Mid-Slope" Point - West Side of Central Ridge (Point B)	221.2
Final Cover Elevation at Slope Change Contour - West Side of Central Ridge (Point C)	233.0
Final Cover Elevation at 5% "Mid-Slope" Point - West Side of Central Ridge (Point D)	237.6
Final Cover Elevation at Peak of Landfill - At Peak of Central Ridge (Point E)	241.0
Final Cover Elevation at 5% "Mid-Slope" Point - East Side of Central Ridge (Point F)	237.3
Final Cover Elevation at Slope Change Contour - East Side of Central Ridge (Point G)	233.0
Final Cover Elevation at 4(H):1(V) "Mid-Slope" Point - East Side of Central Ridge (Point H)	220.4
Final Cover Elevation at Bottom of 3:1 Excavation Slope - East Side of Central Ridge (Point I)	207.9
Elevation of Base of LCS (Point A)	188.6
Elevation of Base of LCS (Point B)	189.2
Elevation of Base of LCS (Point C)	189.8
Elevation of Base of LCS (Point D)	190.5
Elevation of Base of LCS (Point E)	191.3
Elevation of Base of LCS (Point F)	190.5
Elevation of Base of LCS (Point G)	189.7
Elevation of Base of LCS (Point H)	189.0
Elevation of Base of LCS (Point I)	188.4
Bottom of Clay Deposit	156
Groundwater Elevation in Overburden	198
Groundwater Elevation in Bedrock	178

1a. Final total Stress at Pt. F (Refer to Figure B1 for the location of Point F)

Layer	Thickness (m)	Unit Weight (kN/m ³)	Applied Pressure at Pt. F (kPa)
Final Cover	1.5	21	31.5
Waste	44.9	13	583.4
Sand Filter	0.2	19	3.8
Stone Drainage Layer	0.3	18	5.4
Natural Clay	17.2	21.0	361.8

Total Applied Pressure 986

1b. Initial Total Stress at Pt. F

$$\sigma \text{ (initial)} = 25.3 \times 21.0 = 531 \text{ kPa}$$

1c. Initial Effective Stress at Pt. F

$$\begin{aligned} \sigma' \text{ (initial)} &= \sigma - u \quad \text{where } u \text{ is the pore pressure at the midpoint of the clay deposit} \\ &= 531 - 13.0 \times 9.81 \text{ kN/m}^3 \\ &= 403 \text{ kPa} \end{aligned}$$

Pressure Head = 13.0 m

1d. Final Total Stress at Pt. F

$$\sigma \text{ (final)} = 986 \text{ kPa}$$

1e. Final Effective Stress at Pt. F

$$\begin{aligned} \sigma' \text{ (final)} &= \sigma - u \quad \text{Pressure Head} = 11.0 \text{ m} \\ &= 986 - 11.0 \times 9.81 \text{ kN/m}^3 \\ &= 878 \text{ kPa} \end{aligned}$$

1f. Change in Effective Stress at Pt. F

$$\begin{aligned} \Delta\sigma' &= \sigma' \text{ (final)} - \sigma' \text{ (initial)} \\ &= 878 - 403 \\ &= 475 \text{ kPa} \end{aligned}$$

1d. Settlement at Pt. F

$$\begin{aligned} S &= m_v \times \Delta\sigma'_{A'} \times H_{clay} \\ S &= (5 \times 10^{-5} \text{ m}^2/\text{kN}) \times 475 \times (190.46 - 156.00) \\ S &= 0.77 \text{ m} \end{aligned}$$

Summary

H = 46.9 m where H = total thickness of cover + waste + liner above Point F
Settlement = 774 mm

Assumptions & Limitations

- The coefficient of volume compressibility was derived from consolidation testing reported in Gartner Lee's Report dated December, 1991; $M_v = (5 \times 10^{-5} \text{ m}^2/\text{kN})$ (low compressibility clays).
- Point F defined as point on top of the clay foundation (i.e., directly below the leachate collection system)
- Depth to groundwater assumed to be at ground surface pre-construction and at the base of the leachate collection system after Cell construction

**One-Dimensional Landfill Settlement Calculations
Proposed West Landfill Expansion (Section A-A')**

Project No. 18111331
March 2020

1. Calculation of Total Consolidation Settlement at Pt. G (Section A-A' of Proposed West Landfill Expansion)

Inputs	masl
Approximate Midpoint of Clay Deposit	172.8
Approximate Original Ground Surface	198.5
Final Cover Elevation at Bottom of 3:1 Excavation Slope - West Side of Central Ridge (Point A)	209.4
Final Cover Elevation at 4(H):1(V) "Mid-Slope" Point - West Side of Central Ridge (Point B)	221.2
Final Cover Elevation at Slope Change Contour - West Side of Central Ridge (Point C)	233.0
Final Cover Elevation at 5% "Mid-Slope" Point - West Side of Central Ridge (Point D)	237.6
Final Cover Elevation at Peak of Landfill - At Peak of Central Ridge (Point E)	241.0
Final Cover Elevation at 5% "Mid-Slope" Point - East Side of Central Ridge (Point F)	237.3
Final Cover Elevation at Slope Change Contour - East Side of Central Ridge (Point G)	233.0
Final Cover Elevation at 4(H):1(V) "Mid-Slope" Point - East Side of Central Ridge (Point H)	220.4
Final Cover Elevation at Bottom of 3:1 Excavation Slope - East Side of Central Ridge (Point I)	207.9
Elevation of Base of LCS (Point A)	188.6
Elevation of Base of LCS (Point B)	189.2
Elevation of Base of LCS (Point C)	189.8
Elevation of Base of LCS (Point D)	190.5
Elevation of Base of LCS (Point E)	191.3
Elevation of Base of LCS (Point F)	190.5
Elevation of Base of LCS (Point G)	189.7
Elevation of Base of LCS (Point H)	189.0
Elevation of Base of LCS (Point I)	188.4
Bottom of Clay Deposit	156
Groundwater Elevation in Overburden	198
Groundwater Elevation in Bedrock	178

1a. Final total Stress at Pt. G (Refer to Figure B1 for the location of Point G)

Layer	Thickness (m)	Unit Weight (m)	Applied Pressure at Pt. G (kN/m ³)
Final Cover	1.5	21	31.5
Waste	41.3	13	537.4
Sand Filter	0.2	19	3.8
Stone Drainage Layer	0.3	18	5.4
Natural Clay	18.4	21.0	386.8

Total Applied Pressure 965

1b. Initial Total Stress at Pt. G

$$\sigma \text{ (initial)} = 25.7 \times 21.0 = 539 \text{ kPa}$$

1c. Initial Effective Stress at Pt. G

$$\sigma' \text{ (initial)} = \sigma - u \quad \text{where } u \text{ is the pore pressure at the midpoint of the clay deposit}$$

$$= 539 - 13.2 \times 9.81 \text{ kN/m}^3 = 409 \text{ kPa}$$

Pressure Head = 13.2 m

1d. Final Total Stress at Pt. G

$$\sigma \text{ (final)} = 965 \text{ kPa}$$

1e. Final Effective Stress at Pt. G

$$\sigma' \text{ (final)} = \sigma - u \quad \text{Pressure Head} = 11.0 \text{ m}$$

$$= 965 - 11.0 \times 9.81 \text{ kN/m}^3 = 857 \text{ kPa}$$

1f. Change in Effective Stress at Pt. G

$$\Delta\sigma' = \sigma' \text{ (final)} - \sigma' \text{ (initial)}$$

$$\Delta\sigma' = 857 - 409 = 448 \text{ kPa}$$

1d. Settlement at Pt. G

$$S = m_v \times \Delta\sigma'_{A'} \times H_{clay}$$

$$S = (5 \times 10^{-5} \text{ m}^2/\text{kN}) \times 448 \times (189.66 - 156.00)$$

$$S = 0.73 \text{ m}$$

Summary

H = 43.3 m where H = total thickness of cover + waste + liner above Point G

Settlement = 729 mm

Assumptions & Limitations

- The coefficient of volume compressibility was derived from consolidation testing reported in Gartner Lee's Report dated December, 1991; $M_v = (5 \times 10^{-5} \text{ m}^2/\text{kN})$ (low compressibility clays).
- Point G defined as point on top of the clay foundation (i.e., directly below the leachate collection system)
- Depth to groundwater assumed to be at ground surface pre-construction and at the base of the leachate collection system after Cell construction

**One-Dimensional Landfill Settlement Calculations
Proposed West Landfill Expansion (Section A-A')**

Project No. 18111331
March 2020

1. Calculation of Total Consolidation Settlement at Pt. H (Section A-A' of Proposed West Landfill Expansion)

Inputs	masl
Approximate Midpoint of Clay Deposit	172.5
Approximate Original Ground Surface	198.5
Final Cover Elevation at Bottom of 3:1 Excavation Slope - West Side of Central Ridge (Point A)	209.4
Final Cover Elevation at 4(H):1(V) "Mid-Slope" Point - West Side of Central Ridge (Point B)	221.2
Final Cover Elevation at Slope Change Contour - West Side of Central Ridge (Point C)	233.0
Final Cover Elevation at 5% "Mid-Slope" Point - West Side of Central Ridge (Point D)	237.6
Final Cover Elevation at Peak of Landfill - At Peak of Central Ridge (Point E)	241.0
Final Cover Elevation at 5% "Mid-Slope" Point - East Side of Central Ridge (Point F)	237.3
Final Cover Elevation at Slope Change Contour - East Side of Central Ridge (Point G)	233.0
Final Cover Elevation at 4(H):1(V) "Mid-Slope" Point - East Side of Central Ridge (Point H)	220.4
Final Cover Elevation at Bottom of 3:1 Excavation Slope - East Side of Central Ridge (Point I)	207.9
Elevation of Base of LCS (Point A)	188.6
Elevation of Base of LCS (Point B)	189.2
Elevation of Base of LCS (Point C)	189.8
Elevation of Base of LCS (Point D)	190.5
Elevation of Base of LCS (Point E)	191.3
Elevation of Base of LCS (Point F)	190.5
Elevation of Base of LCS (Point G)	189.7
Elevation of Base of LCS (Point H)	189.0
Elevation of Base of LCS (Point I)	188.4
Bottom of Clay Deposit	156
Groundwater Elevation in Overburden	198
Groundwater Elevation in Bedrock	178

1a. Final total Stress at Pt. H (Refer to Figure B1 for the location of Point H)

Layer	Thickness (m)	Unit Weight (m)	Applied Pressure at Pt. H (kN/m ³)
Final Cover	1.5	21	31.5
Waste	29.4	13	382.2
Sand Filter	0.2	19	3.8
Stone Drainage Layer	0.3	18	5.4
Natural Clay	18.7	21.0	393.4

Total Applied Pressure

816

1b. Initial Total Stress at Pt. H

$$\sigma \text{ (initial)} = 26.0 \times 21.0 = 546 \text{ kPa}$$

1c. Initial Effective Stress at Pt. H

$$\sigma' \text{ (initial)} = \sigma - u \quad \text{where } u \text{ is the pore pressure at the midpoint of the clay deposit}$$

$$= 546 - 13.4 \times 9.81 \text{ kN/m}^3 = 414 \text{ kPa}$$

$$\text{Pressure Head} = 13.4 \text{ m}$$

1d. Final Total Stress at Pt. H

$$\sigma \text{ (final)} = 816 \text{ kPa}$$

1e. Final Effective Stress at Pt. H

$$\sigma' \text{ (final)} = \sigma - u \quad \text{Pressure Head} = 11.0 \text{ m}$$

$$= 816 - 11.0 \times 9.81 \text{ kN/m}^3 = 708 \text{ kPa}$$

1f. Change in Effective Stress at Pt. H

$$\Delta\sigma' = \sigma' \text{ (final)} - \sigma' \text{ (initial)}$$

$$\Delta\sigma' = 708 - 414 = 294 \text{ kPa}$$

1d. Settlement at Pt. H

$$S = m_v \times \Delta\sigma'_{A'} \times H_{clay}$$

$$S = (5 \times 10^{-5} \text{ m}^2/\text{kN}) \times 294 \times (189.03 - 156.00)$$

$$S = 0.48 \text{ m}$$

Summary

$$H = 31.4 \text{ m} \quad \text{where } H = \text{total thickness of cover + waste + liner above Point H}$$

$$\text{Settlement} = 479 \text{ mm}$$

Assumptions & Limitations

1. The coefficient of volume compressibility was derived from consolidation testing reported in Gartner Lee's Report dated December, 1991; $M_v = (5 \times 10^{-5} \text{ m}^2/\text{kN})$ (low compressibility clays).
2. Point H defined as point on top of the clay foundation (i.e., directly below the leachate collection system)
3. Depth to groundwater assumed to be at ground surface pre-construction and at the base of the leachate collection system after Cell construction

**One-Dimensional Landfill Settlement Calculations
Proposed West Landfill Expansion (Section A-A')**

Project No. 18111331
March 2020

1. Calculation of Total Consolidation Settlement at Pt. I (Section A-A' of Proposed West Landfill Expansion)

Inputs	masl
Approximate Midpoint of Clay Deposit	172.2
Approximate Original Ground Surface	198.5
Final Cover Elevation at Bottom of 3:1 Excavation Slope - West Side of Central Ridge (Point A)	209.4
Final Cover Elevation at 4(H):1(V) "Mid-Slope" Point - West Side of Central Ridge (Point B)	221.2
Final Cover Elevation at Slope Change Contour - West Side of Central Ridge (Point C)	233.0
Final Cover Elevation at 5% "Mid-Slope" Point - West Side of Central Ridge (Point D)	237.6
Final Cover Elevation at Peak of Landfill - At Peak of Central Ridge (Point E)	241.0
Final Cover Elevation at 5% "Mid-Slope" Point - East Side of Central Ridge (Point F)	237.3
Final Cover Elevation at Slope Change Contour - East Side of Central Ridge (Point G)	233.0
Final Cover Elevation at 4(H):1(V) "Mid-Slope" Point - East Side of Central Ridge (Point H)	220.4
Final Cover Elevation at Bottom of 3:1 Excavation Slope - East Side of Central Ridge (Point I)	207.9
Elevation of Base of LCS (Point A)	188.6
Elevation of Base of LCS (Point B)	189.2
Elevation of Base of LCS (Point C)	189.8
Elevation of Base of LCS (Point D)	190.5
Elevation of Base of LCS (Point E)	191.3
Elevation of Base of LCS (Point F)	190.5
Elevation of Base of LCS (Point G)	189.7
Elevation of Base of LCS (Point H)	189.0
Elevation of Base of LCS (Point I)	188.4
Bottom of Clay Deposit	156
Groundwater Elevation in Overburden	198
Groundwater Elevation in Bedrock	178

1a. Final total Stress at Pt. I (Refer to Figure B1 for the location of Point I)

Layer	Thickness (m)	Unit Weight (m)	Applied Pressure at Pt. I (kN/m ³)
Final Cover	1.5	21	31.5
Waste	17.5	13	227.1
Sand Filter	0.2	19	3.8
Stone Drainage Layer	0.3	18	5.4
Natural Clay	19.1	21.0	400.3

Total Applied Pressure 668

1b. Initial Total Stress at Pt. I

$$\sigma \text{ (initial)} = 26.3 \times 21.0 = 553 \text{ kPa}$$

1c. Initial Effective Stress at Pt. I

$$\sigma' \text{ (initial)} = \sigma - u \quad \text{where } u \text{ is the pore pressure at the midpoint of the clay deposit}$$

$$= 553 - 13.6 \times 9.81 \text{ kN/m}^3 = 419 \text{ kPa}$$

$$\text{Pressure Head} = 13.6 \text{ m}$$

1d. Final Total Stress at Pt. I

$$\sigma \text{ (final)} = 668 \text{ kPa}$$

1e. Final Effective Stress at Pt. I

$$\sigma' \text{ (final)} = \sigma - u \quad \text{Pressure Head} = 11.0 \text{ m}$$

$$= 668 - 11.0 \times 9.81 \text{ kN/m}^3 = 560 \text{ kPa}$$

1f. Change in Effective Stress at Pt. I

$$\Delta\sigma' = \sigma' \text{ (final)} - \sigma' \text{ (initial)}$$

$$\Delta\sigma' = 560 - 419$$

$$\Delta\sigma' = 141 \text{ kPa}$$

1d. Settlement at Pt. I

$$S = m_v \times \Delta\sigma'_{A'} \times H_{clay}$$

$$S = (5 \times 10^{-5} \text{ m}^2/\text{kN}) \times 141 \times (188.38 - 156.00)$$

$$S = 0.23 \text{ m}$$

Summary

$$H = 19.5 \text{ m} \quad \text{where } H = \text{total thickness of cover + waste + liner above Point I}$$

$$\text{Settlement} = 229 \text{ mm}$$

Assumptions & Limitations

- The coefficient of volume compressibility was derived from consolidation testing reported in Gartner Lee's Report dated December, 1991; $M_v = (5 \times 10^{-5} \text{ m}^2/\text{kN})$ (low compressibility clays).
- Point I defined as point on top of the clay foundation (i.e., directly below the leachate collection system)
- Depth to groundwater assumed to be at ground surface pre-construction and at the base of the leachate collection system after Cell construction

**One-Dimensional Landfill Settlement Calculations
Proposed West Landfill Expansion (Section A-A')**

Project No. 18111331
March 2020

Proposed West Landfill Expansion (Section A-A')
Summary of One-Dimensional Total Settlement and Differential Settlement

Point	Total Settlement (mm)
A	165
B	420
C	676
D	780
E	858
F	774
G	729
H	479
I	229

Line ¹	Length (m)	Initial Base Grade (%)	Differential Settlement (mm)	Grade Change ² (%)	Final Base Grade ³ (%)	Design Requirement ⁴ (%)
A-B	47	1.2	255	-0.54	0.66	0.5
B-C	47	1.2	255	-0.54	0.66	0.5
C-D	68	1.0	104	-0.15	0.85	0.5
D-E	68	1.0	78	-0.12	0.88	0.5
E-F	73	1.0	84	-0.12	0.88	0.5
F-G	73	1.0	45	-0.06	0.94	0.5
G-H	50	1.2	250	-0.50	0.70	0.5
H-I	50	1.2	250	-0.50	0.70	0.5

Notes:

- 1 Refer to Attachment B for locations
- 2 Grade change = differential settlement ÷ length
- 3 Final base grade = initial base grade - [differential settlement ÷ length]
- 4 Recommended minimum base grade [MOE Landfill Standards]

**One-Dimensional Landfill Settlement Calculations
Proposed South Landfill Expansion (Section C-C')**

Project No. 18111331
March 2020

1. Calculation of Total Consolidation Settlement at Pt. A (Section C-C' of Proposed South Landfill Expansion)

Inputs	masl
Approximate Midpoint of Clay Deposit	172.4
Approximate Original Ground Surface	199.0
Final Cover Elevation at Bottom of 3:1 Excavation Slope - West Side of Central Ridge (Point A)	207.2
Final Cover Elevation at 4(H):1(V) "Mid-Slope" Point - West Side of Central Ridge (Point B)	220.1
Final Cover Elevation at Slope Change Contour - West Side of Central Ridge (Point C)	233.0
Final Cover Elevation at Location along 5% slope - West Side of Central Ridge (Point D)	236.3
Final Cover Elevation at Peak of Landfill - West Side of Central Ridge (Point E)	238.6
Final Cover Elevation at Location along 5% slope - East Side of Central Ridge (Point F)	238.0
Final Cover Elevation at Location along 5% slope - East Side of Central Ridge (Point G)	237.9
Final Cover Elevation at Location along 5% slope - East Side of Central Ridge (Point H)	235.8
Final Cover Elevation at Location along 5% slope - East Side of Central Ridge (Point I)	233.0
Final Cover Elevation at 4(H):1(V) "Mid-Slope" Point - East Side of Central Ridge (Point J)	223.4
Final Cover Elevation at Bottom of 3:1 Excavation Slope - East Side of Central Ridge (Point K)	213.9
Elevation of Base of LCS (Point A)	188.8
Elevation of Base of LCS (Point B)	189.4
Elevation of Base of LCS (Point C)	190.1
Elevation of Base of LCS (Point D)	190.7
Elevation of Base of LCS (Point E)	191.3
Elevation of Base of LCS (Point F)	191.4
Elevation of Base of LCS (Point G)	190.9
Elevation of Base of LCS (Point H)	190.4
Elevation of Base of LCS (Point I)	189.9
Elevation of Base of LCS (Point J)	189.4
Elevation of Base of LCS (Point K)	189.0
Bottom of Clay Deposit	156
Groundwater Elevation in Overburden	199
Groundwater Elevation in Bedrock	178

1a. Final total Stress at Pt. A (Refer to Figure B2 for location of Point A)

Layer	Thickness (m)	Unit V N/m ³	Applied Pressure at pt A' (kPa)
Final Cover	1.5	21	31.5
Waste	16.4	13	213.1
Sand Filter	0.2	19	3.8
Stone Drainage Layer	0.3	18	5.4
Natural Clay	16.4	21.0	344.6

Total Applied Pressure 598

1b. Initial Total Stress at Pt. A

$$\begin{aligned}\sigma \text{ (initial)} &= 26.6 \times 21.0 \\ &= 558 \text{ kPa}\end{aligned}$$

1c. Initial Effective Stress at Pt. A

$$\begin{aligned}\sigma' \text{ (initial)} &= \sigma - u \quad \text{where } u \text{ is the pore pressure at the midpoint of the clay deposit} \\ &= 558 - 13.6 \times 9.81 \text{ kN/m}^3 \\ &= 425 \text{ kPa}\end{aligned}$$

Pressure Head = 13.6 m

1d. Final Total Stress at Pt. A

$$\sigma \text{ (final)} = 598 \text{ kPa}$$

1e. Final Effective Stress at Pt. A

$$\begin{aligned}\sigma' \text{ (final)} &= \sigma - u \quad \text{Pressure Head} = 11.0 \text{ m} \\ &= 598 - 11.0 \times 9.81 \text{ kN/m}^3 \\ &= 490 \text{ kPa}\end{aligned}$$

1f. Change in Effective Stress at Pt. A

$$\begin{aligned}\Delta\sigma' &= \sigma' \text{ (final)} - \sigma' \text{ (initial)} \\ \Delta\sigma' &= 490 - 425 \\ \Delta\sigma' &= 66 \text{ kPa}\end{aligned}$$

1d. Settlement at Pt. A

$$\begin{aligned}S &= m_v \times \Delta\sigma'_{A'} \times H_{clay} \\ S &= (5 \times 10^{-5} \text{ m}^2/\text{kN}) \times 66 \times (188.8 - 156.00) \\ S &= 0.11 \text{ m}\end{aligned}$$

Summary

$$\begin{aligned}H &= 18.4 \text{ m} \quad \text{where } H = \text{total thickness of cover + waste + liner above Point A} \\ \text{Settlement} &= 108 \text{ mm}\end{aligned}$$

Assumptions & Limitations

- The coefficient of volume compressibility was derived from consolidation testing reported in Gartner Lee's Report dated December, 1991; $M_v = (5 \times 10^{-5} \text{ m}^2/\text{kN})$ (low compressibility clays)
- Point A' defined as point on top of the clay foundation (i.e., directly below the leachate collection system)
- Depth to groundwater assumed to be at ground surface pre-construction and at the base of the leachate collection system after Cell construction

**One-Dimensional Landfill Settlement Calculations
Proposed South Landfill Expansion (Section C-C')**

Project No. 18111331
March 2020

1. Calculation of Total Consolidation Settlement at Pt. B (Section C-C' of Proposed South Landfill Expansion)

Inputs	masl
Approximate Midpoint of Clay Deposit	172.7
Approximate Original Ground Surface	199.0
Final Cover Elevation at Bottom of 3:1 Excavation Slope - West Side of Central Ridge (Point A)	207.2
Final Cover Elevation at 4(H):1(V) "Mid-Slope" Point - West Side of Central Ridge (Point B)	220.1
Final Cover Elevation at Slope Change Contour - West Side of Central Ridge (Point C)	233.0
Final Cover Elevation at Location along 5% slope - West Side of Central Ridge (Point D)	236.3
Final Cover Elevation at Peak of Landfill - West Side of Central Ridge (Point E)	238.6
Final Cover Elevation at Location along 5% slope - East Side of Central Ridge (Point F)	238.0
Final Cover Elevation at Location along 5% slope - East Side of Central Ridge (Point G)	237.9
Final Cover Elevation at Location along 5% slope - East Side of Central Ridge (Point H)	235.8
Final Cover Elevation at Location along 5% slope - East Side of Central Ridge (Point I)	233.0
Final Cover Elevation at 4(H):1(V) "Mid-Slope" Point - East Side of Central Ridge (Point J)	223.4
Final Cover Elevation at Bottom of 3:1 Excavation Slope - East Side of Central Ridge (Point K)	213.9
Elevation of Base of LCS (Point A)	188.8
Elevation of Base of LCS (Point B)	189.4
Elevation of Base of LCS (Point C)	190.1
Elevation of Base of LCS (Point D)	190.7
Elevation of Base of LCS (Point E)	191.3
Elevation of Base of LCS (Point F)	191.4
Elevation of Base of LCS (Point G)	190.9
Elevation of Base of LCS (Point H)	190.4
Elevation of Base of LCS (Point I)	189.9
Elevation of Base of LCS (Point J)	189.4
Elevation of Base of LCS (Point K)	189.0
Bottom of Clay Deposit	156
Groundwater Elevation in Overburden	199
Groundwater Elevation in Bedrock	178

1a. Final total Stress at Pt. B (Refer to Figure B2 for location of Point B)

Layer	Thickness (m)	Unit V N/m ³	Applied Pressure at Pt. B (kPa)
Final Cover	1.5	21	31.5
Waste	28.7	13	372.6
Sand Filter	0.2	19	3.8
Stone Drainage Layer	0.3	18	5.4
Natural Clay	16.7	21.0	351.1

Total Applied Pressure 764

1b. Initial Total Stress at Pt. B

$$\begin{aligned}\sigma(\text{initial}) &= 26.3 \times 21.0 \\ &= 552 \text{ kPa}\end{aligned}$$

1c. Initial Effective Stress at Pt. B

$$\begin{aligned}\sigma'(\text{initial}) &= \sigma - u \quad \text{where } u \text{ is the pore pressure at the midpoint of the clay deposit} \\ &= 552 - 13.4 \times 9.81 \text{ kN/m}^3 \\ &= 420 \text{ kPa}\end{aligned}$$

Pressure Head = 13.4 m

1d. Final Total Stress at Pt. B

$$\sigma(\text{final}) = 764 \text{ kPa}$$

1e. Final Effective Stress at Pt. B

$$\begin{aligned}\sigma'(\text{final}) &= \sigma - u \quad \text{Pressure Head} = 11.0 \text{ m} \\ &= 764 - 11.0 \times 9.81 \text{ kN/m}^3 \\ &= 656 \text{ kPa}\end{aligned}$$

1f. Change in Effective Stress at Pt. B

$$\begin{aligned}\Delta\sigma' &= \sigma'(\text{final}) - \sigma'(\text{initial}) \\ \Delta\sigma' &= 656 - 420 \\ \Delta\sigma' &= 237 \text{ kPa}\end{aligned}$$

1d. Settlement at Pt. B

$$S = m_v \times \Delta\sigma'_{A'} \times H_{\text{clay}}$$

$$\begin{aligned}S &= (5 \times 10^{-5} \text{ m}^2/\text{kN}) \times 237 \times (189.4 - 156.00) \\ S &= 0.39 \text{ m}\end{aligned}$$

Summary

$$\begin{aligned}H &= 30.7 \text{ m} \quad \text{where } H = \text{total thickness of cover} + \text{waste} + \text{liner above Point B} \\ \text{Settlement} &= 388 \text{ mm}\end{aligned}$$

Assumptions & Limitations

- The coefficient of volume compressibility was derived from consolidation testing reported in Gartner Lee's Report dated December, 1991; $M_v = (5 \times 10^{-5} \text{ m}^2/\text{kN})$ (low compressibility clays)
- Point B defined as point on top of the clay foundation (i.e., directly below the leachate collection system)
- Depth to groundwater assumed to be at ground surface pre-construction and at the base of the leachate collection system after Cell construction



Prepared By: RW
Reviewed By: FB

**One-Dimensional Landfill Settlement Calculations
Proposed South Landfill Expansion (Section C-C')**

Project No. 18111331
March 2020

1. Calculation of Total Consolidation Settlement at Pt. C (Section C-C' of Proposed South Landfill Expansion)

Inputs	masl
Approximate Midpoint of Clay Deposit	173.0
Approximate Original Ground Surface	199.0
Final Cover Elevation at Bottom of 3:1 Excavation Slope - West Side of Central Ridge (Point A)	207.2
Final Cover Elevation at 4(H):1(V) "Mid-Slope" Point - West Side of Central Ridge (Point B)	220.1
Final Cover Elevation at Slope Change Contour - West Side of Central Ridge (Point C)	233.0
Final Cover Elevation at Location along 5% slope - West Side of Central Ridge (Point D)	236.3
Final Cover Elevation at Peak of Landfill - West Side of Central Ridge (Point E)	238.6
Final Cover Elevation at Location along 5% slope - East Side of Central Ridge (Point F)	238.0
Final Cover Elevation at Location along 5% slope - East Side of Central Ridge (Point G)	237.9
Final Cover Elevation at Location along 5% slope - East Side of Central Ridge (Point H)	235.8
Final Cover Elevation at Location along 5% slope - East Side of Central Ridge (Point I)	233.0
Final Cover Elevation at 4(H):1(V) "Mid-Slope" Point - East Side of Central Ridge (Point J)	223.4
Final Cover Elevation at Bottom of 3:1 Excavation Slope - East Side of Central Ridge (Point K)	213.9
Elevation of Base of LCS (Point A)	188.8
Elevation of Base of LCS (Point B)	189.4
Elevation of Base of LCS (Point C)	190.1
Elevation of Base of LCS (Point D)	190.7
Elevation of Base of LCS (Point E)	191.3
Elevation of Base of LCS (Point F)	191.4
Elevation of Base of LCS (Point G)	190.9
Elevation of Base of LCS (Point H)	190.4
Elevation of Base of LCS (Point I)	189.9
Elevation of Base of LCS (Point J)	189.4
Elevation of Base of LCS (Point K)	189.0
Bottom of Clay Deposit	156
Groundwater Elevation in Overburden	199
Groundwater Elevation in Bedrock	178

1a. Final total Stress at Pt. C (Refer to Figure B2 for location of Point C)

Layer	Thickness (m)	Unit V N/m ³	Applied Pressure at Pt. C (kPa)
Final Cover	1.5	21	31.5
Waste	41.0	13	532.4
Sand Filter	0.2	19	3.8
Stone Drainage Layer	0.3	18	5.4
Natural Clay	17.0	21.0	357.5

Total Applied Pressure 931

1b. Initial Total Stress at Pt. C

$$\begin{aligned}\sigma(\text{initial}) &= 26.0 \times 21.0 \\ &= 545 \text{ kPa}\end{aligned}$$

1c. Initial Effective Stress at Pt. C

$$\begin{aligned}\sigma'(\text{initial}) &= \sigma - u \quad \text{where } u \text{ is the pore pressure at the midpoint of the clay deposit} \\ &= 545 - 13.3 \times 9.81 \text{ kN/m}^3 \\ &= 415 \text{ kPa}\end{aligned}$$

Pressure Head = 13.3 m

1d. Final Total Stress at Pt. C

$$\sigma(\text{final}) = 931 \text{ kPa}$$

1e. Final Effective Stress at Pt. C

$$\begin{aligned}\sigma'(\text{final}) &= \sigma - u \quad \text{Pressure Head} = 11.0 \text{ m} \\ &= 931 - 11.0 \times 9.81 \text{ kN/m}^3 \\ &= 823 \text{ kPa}\end{aligned}$$

1f. Change in Effective Stress at Pt. C

$$\begin{aligned}\Delta\sigma' &= \sigma'(\text{final}) - \sigma'(\text{initial}) \\ \Delta\sigma' &= 823 - 415 \\ \Delta\sigma' &= 408 \text{ kPa}\end{aligned}$$

1d. Settlement at Pt. C

$$\begin{aligned}S &= m_v \times \Delta\sigma'_{A'} \times H_{clay} \\ S &= (5 \times 10^{-5} \text{ m}^2/\text{kN}) \times 408 \times (190.1 - 156.00) \\ S &= 0.67 \text{ m}\end{aligned}$$

Summary

$$\begin{aligned}H &= 43.0 \text{ m} \quad \text{where } H = \text{total thickness of cover} + \text{waste} + \text{liner above Point C} \\ \text{Settlement} &= 669 \text{ mm}\end{aligned}$$

Assumptions & Limitations

- The coefficient of volume compressibility was derived from consolidation testing reported in Gartner Lee's Report dated December, 1991; $M_v = (5 \times 10^{-5} \text{ m}^2/\text{kN})$ (low compressibility clays)
- Point C defined as point on top of the clay foundation (i.e., directly below the leachate collection system)
- Depth to groundwater assumed to be at ground surface pre-construction and at the base of the leachate collection system after Cell construction

**One-Dimensional Landfill Settlement Calculations
Proposed South Landfill Expansion (Section C-C')**

Project No. 18111331
March 2020

1. Calculation of Total Consolidation Settlement at Pt. D (Section C-C' of Proposed South Landfill Expansion)

Inputs	masl
Approximate Midpoint of Clay Deposit	173.3
Approximate Original Ground Surface	199.0
Final Cover Elevation at Bottom of 3:1 Excavation Slope - West Side of Central Ridge (Point A)	207.2
Final Cover Elevation at 4(H):1(V) "Mid-Slope" Point - West Side of Central Ridge (Point B)	220.1
Final Cover Elevation at Slope Change Contour - West Side of Central Ridge (Point C)	233.0
Final Cover Elevation at Location along 5% slope - West Side of Central Ridge (Point D)	236.3
Final Cover Elevation at Peak of Landfill - West Side of Central Ridge (Point E)	238.6
Final Cover Elevation at Location along 5% slope - East Side of Central Ridge (Point F)	238.0
Final Cover Elevation at Location along 5% slope - East Side of Central Ridge (Point G)	237.9
Final Cover Elevation at Location along 5% slope - East Side of Central Ridge (Point H)	235.8
Final Cover Elevation at Location along 5% slope - East Side of Central Ridge (Point I)	233.0
Final Cover Elevation at 4(H):1(V) "Mid-Slope" Point - East Side of Central Ridge (Point J)	223.4
Final Cover Elevation at Bottom of 3:1 Excavation Slope - East Side of Central Ridge (Point K)	213.9
Elevation of Base of LCS (Point A)	188.8
Elevation of Base of LCS (Point B)	189.4
Elevation of Base of LCS (Point C)	190.1
Elevation of Base of LCS (Point D)	190.7
Elevation of Base of LCS (Point E)	191.3
Elevation of Base of LCS (Point F)	191.4
Elevation of Base of LCS (Point G)	190.9
Elevation of Base of LCS (Point H)	190.4
Elevation of Base of LCS (Point I)	189.9
Elevation of Base of LCS (Point J)	189.4
Elevation of Base of LCS (Point K)	189.0
Bottom of Clay Deposit	156
Groundwater Elevation in Overburden	199
Groundwater Elevation in Bedrock	178

1a. Final total Stress at Pt. D (Refer to Figure B2 for location of Point D)

Layer	Thickness (m)	Unit V N/m ³	Applied Pressure at Pt. D (kPa)
Final Cover	1.5	21	31.5
Waste	43.7	13	567.8
Sand Filter	0.2	19	3.8
Stone Drainage Layer	0.3	18	5.4
Natural Clay	17.3	21.0	363.9

Total Applied Pressure 972

1b. Initial Total Stress at Pt. D

$$\begin{aligned}\sigma(\text{initial}) &= 25.7 \times 21.0 \\ &= 539 \text{ kPa}\end{aligned}$$

1c. Initial Effective Stress at Pt. D

$$\begin{aligned}\sigma'(\text{initial}) &= \sigma - u \quad \text{where } u \text{ is the pore pressure at the midpoint of the clay deposit} \\ &= 539 - 13.1 \times 9.81 \text{ kN/m}^3 \\ &= 410 \text{ kPa}\end{aligned}$$

Pressure Head = 13.1 m

1d. Final Total Stress at Pt. D

$$\sigma(\text{final}) = 972 \text{ kPa}$$

1e. Final Effective Stress at Pt. D

$$\begin{aligned}\sigma'(\text{final}) &= \sigma - u \quad \text{Pressure Head} = 11.0 \text{ m} \\ &= 972 - 11.0 \times 9.81 \text{ kN/m}^3 \\ &= 865 \text{ kPa}\end{aligned}$$

1f. Change in Effective Stress at Pt. D

$$\begin{aligned}\Delta\sigma' &= \sigma'(\text{final}) - \sigma'(\text{initial}) \\ \Delta\sigma' &= 865 - 410 \\ \Delta\sigma' &= 454 \text{ kPa}\end{aligned}$$

1d. Settlement at Pt. D

$$S = m_v \times \Delta\sigma'_{Av} \times H_{clay}$$

$$\begin{aligned}S &= (5 \times 10^{-5} \text{ m}^2/\text{kN}) \times 454 \times (190.7 - 156.00) \\ S &= 0.75 \text{ m}\end{aligned}$$

Summary

$$\begin{aligned}H &= 45.7 \text{ m} \quad \text{where } H = \text{total thickness of cover} + \text{waste} + \text{liner above Point D} \\ \text{Settlement} &= 746 \text{ mm}\end{aligned}$$

Assumptions & Limitations

- The coefficient of volume compressibility was derived from consolidation testing reported in Gartner Lee's Report dated December, 1991; $M_v = (5 \times 10^{-5} \text{ m}^2/\text{kN})$ (low compressibility clays)
- Point D defined as point on top of the clay foundation (i.e., directly below the leachate collection system)
- Depth to groundwater assumed to be at ground surface pre-construction and at the base of the leachate collection system after Cell construction



Prepared By: RW
Reviewed By: FB

**One-Dimensional Landfill Settlement Calculations
Proposed South Landfill Expansion (Section C-C')**

Project No. 18111331
March 2020

1. Calculation of Total Consolidation Settlement at Pt. E (Section C-C' of Proposed South Landfill Expansion)

Inputs	masl
Approximate Midpoint of Clay Deposit	173.6
Approximate Original Ground Surface	199.0
Final Cover Elevation at Bottom of 3:1 Excavation Slope - West Side of Central Ridge (Point A)	207.2
Final Cover Elevation at 4(H):1(V) "Mid-Slope" Point - West Side of Central Ridge (Point B)	220.1
Final Cover Elevation at Slope Change Contour - West Side of Central Ridge (Point C)	233.0
Final Cover Elevation at Location along 5% slope - West Side of Central Ridge (Point D)	236.3
Final Cover Elevation at Peak of Landfill - West Side of Central Ridge (Point E)	238.6
Final Cover Elevation at Location along 5% slope - East Side of Central Ridge (Point F)	238.0
Final Cover Elevation at Location along 5% slope - East Side of Central Ridge (Point G)	237.9
Final Cover Elevation at Location along 5% slope - East Side of Central Ridge (Point H)	235.8
Final Cover Elevation at Location along 5% slope - East Side of Central Ridge (Point I)	233.0
Final Cover Elevation at 4(H):1(V) "Mid-Slope" Point - East Side of Central Ridge (Point J)	223.4
Final Cover Elevation at Bottom of 3:1 Excavation Slope - East Side of Central Ridge (Point K)	213.9
Elevation of Base of LCS (Point A)	188.8
Elevation of Base of LCS (Point B)	189.4
Elevation of Base of LCS (Point C)	190.1
Elevation of Base of LCS (Point D)	190.7
Elevation of Base of LCS (Point E)	191.3
Elevation of Base of LCS (Point F)	191.4
Elevation of Base of LCS (Point G)	190.9
Elevation of Base of LCS (Point H)	190.4
Elevation of Base of LCS (Point I)	189.9
Elevation of Base of LCS (Point J)	189.4
Elevation of Base of LCS (Point K)	189.0
Bottom of Clay Deposit	156
Groundwater Elevation in Overburden	199
Groundwater Elevation in Bedrock	178

1a. Final total Stress at Pt. E (Refer to Figure B2 for location of Point E)

Layer	Thickness (m)	Unit V N/m ³	Applied Pressure at Pt. E (kPa)
Final Cover	1.5	21	31.5
Waste	45.3	13	588.9
Sand Filter	0.2	19	3.8
Stone Drainage Layer	0.3	18	5.4
Natural Clay	17.6	21.0	370.4

Total Applied Pressure 1000

1b. Initial Total Stress at Pt. E

$$\begin{aligned}\sigma(\text{initial}) &= 25.4 \times 21.0 \\ &= 533 \text{ kPa}\end{aligned}$$

1c. Initial Effective Stress at Pt. E

$$\begin{aligned}\sigma'(\text{initial}) &= \sigma - u \quad \text{where } u \text{ is the pore pressure at the midpoint of the clay deposit} \\ &= 533 - 13.0 \times 9.81 \text{ kN/m}^3 \\ &= 405 \text{ kPa}\end{aligned}$$

Pressure Head = 13.0 m

1d. Final Total Stress at Pt. E

$$\sigma(\text{final}) = 1000 \text{ kPa}$$

1e. Final Effective Stress at Pt. E

$$\begin{aligned}\sigma'(\text{final}) &= \sigma - u \quad \text{Pressure Head} = 11.0 \text{ m} \\ &= 1000 - 11.0 \times 9.81 \text{ kN/m}^3 \\ &= 892 \text{ kPa}\end{aligned}$$

1f. Change in Effective Stress at Pt. E

$$\begin{aligned}\Delta\sigma' &= \sigma'(\text{final}) - \sigma'(\text{initial}) \\ \Delta\sigma' &= 892 - 405 \\ \Delta\sigma' &= 487 \text{ kPa}\end{aligned}$$

1d. Settlement at Pt. E

$$\begin{aligned}S &= m_v \times \Delta\sigma'_{A'} \times H_{\text{clay}} \\ S &= (5 \times 10^{-5} \text{ m}^2/\text{kN}) \times 487 \times (191.3 - 156.00) \\ S &= 0.80 \text{ m}\end{aligned}$$

Summary

$$\begin{aligned}H &= 47.3 \text{ m} \quad \text{where } H = \text{total thickness of cover} + \text{waste} + \text{liner above Point E} \\ \text{Settlement} &= 799 \text{ mm}\end{aligned}$$

Assumptions & Limitations

- The coefficient of volume compressibility was derived from consolidation testing reported in Gartner Lee's Report dated December, 1991; $M_v = (5 \times 10^{-5} \text{ m}^2/\text{kN})$ (low compressibility clays)
- Point E defined as point on top of the clay foundation (i.e., directly below the leachate collection system)
- Depth to groundwater assumed to be at ground surface pre-construction and at the base of the leachate collection system after Cell construction



Prepared By: RW
Reviewed By: FB

**One-Dimensional Landfill Settlement Calculations
Proposed South Landfill Expansion (Section C-C')**

Project No. 18111331
March 2020

1. Calculation of Total Consolidation Settlement at Pt. F (Section C-C' of Proposed South Landfill Expansion)

Inputs	masl
Approximate Midpoint of Clay Deposit	173.7
Approximate Original Ground Surface	199.0
Final Cover Elevation at Bottom of 3:1 Excavation Slope - West Side of Central Ridge (Point A)	207.2
Final Cover Elevation at 4(H):1(V) "Mid-Slope" Point - West Side of Central Ridge (Point B)	220.1
Final Cover Elevation at Slope Change Contour - West Side of Central Ridge (Point C)	233.0
Final Cover Elevation at Location along 5% slope - West Side of Central Ridge (Point D)	236.3
Final Cover Elevation at Peak of Landfill - West Side of Central Ridge (Point E)	238.6
Final Cover Elevation at Location along 5% slope - East Side of Central Ridge (Point F)	238.0
Final Cover Elevation at Location along 5% slope - East Side of Central Ridge (Point G)	237.9
Final Cover Elevation at Location along 5% slope - East Side of Central Ridge (Point H)	235.8
Final Cover Elevation at Location along 5% slope - East Side of Central Ridge (Point I)	233.0
Final Cover Elevation at 4(H):1(V) "Mid-Slope" Point - East Side of Central Ridge (Point J)	223.4
Final Cover Elevation at Bottom of 3:1 Excavation Slope - East Side of Central Ridge (Point K)	213.9
Elevation of Base of LCS (Point A)	188.8
Elevation of Base of LCS (Point B)	189.4
Elevation of Base of LCS (Point C)	190.1
Elevation of Base of LCS (Point D)	190.7
Elevation of Base of LCS (Point E)	191.3
Elevation of Base of LCS (Point F)	191.4
Elevation of Base of LCS (Point G)	190.9
Elevation of Base of LCS (Point H)	190.4
Elevation of Base of LCS (Point I)	189.9
Elevation of Base of LCS (Point J)	189.4
Elevation of Base of LCS (Point K)	189.0
Bottom of Clay Deposit	156
Groundwater Elevation in Overburden	199
Groundwater Elevation in Bedrock	178

1a. Final total Stress at Pt. F (Refer to Figure B2 for location of Point F)

Layer	Thickness (m)	Unit V N/m ³	Applied Pressure at Pt. F (kPa)
Final Cover	1.5	21	31.5
Waste	44.6	13	579.7
Sand Filter	0.2	19	3.8
Stone Drainage Layer	0.3	18	5.4
Natural Clay	17.7	21.0	371.7

Total Applied Pressure 992

1b. Initial Total Stress at Pt. F

$$\begin{aligned}\sigma(\text{initial}) &= 25.3 \times 21.0 \\ &= 531 \text{ kPa}\end{aligned}$$

1c. Initial Effective Stress at Pt. F

$$\begin{aligned}\sigma'(\text{initial}) &= \sigma - u \quad \text{where } u \text{ is the pore pressure at the midpoint of the clay deposit} \\ &= 531 - 12.9 \times 9.81 \text{ kN/m}^3 \\ &= 404 \text{ kPa}\end{aligned}$$

Pressure Head = 12.9 m

1d. Final Total Stress at Pt. F

$$\sigma(\text{final}) = 992 \text{ kPa}$$

1e. Final Effective Stress at Pt. F

$$\begin{aligned}\sigma'(\text{final}) &= \sigma - u \quad \text{Pressure Head} = 11.0 \text{ m} \\ &= 992 - 11.0 \times 9.81 \text{ kN/m}^3 \\ &= 884 \text{ kPa}\end{aligned}$$

1f. Change in Effective Stress at Pt. F

$$\begin{aligned}\Delta\sigma' &= \sigma'(\text{final}) - \sigma'(\text{initial}) \\ \Delta\sigma' &= 884 - 404 \\ \Delta\sigma' &= 480 \text{ kPa}\end{aligned}$$

1d. Settlement at Pt. F

$$S = m_v \times \Delta\sigma'_{A'} \times H_{clay}$$

$$\begin{aligned}S &= (5 \times 10^{-5} \text{ m}^2/\text{kN}) \times 480 \times (191.4 - 156.00) \\ S &= 0.79 \text{ m}\end{aligned}$$

Summary

$$\begin{aligned}H &= 46.6 \text{ m} \quad \text{where } H = \text{total thickness of cover} + \text{waste} + \text{liner above Point F} \\ \text{Settlement} &= 787 \text{ mm}\end{aligned}$$

Assumptions & Limitations

- The coefficient of volume compressibility was derived from consolidation testing reported in Gartner Lee's Report dated December, 1991; $M_v = (5 \times 10^{-5} \text{ m}^2/\text{kN})$ (low compressibility clays)
- Point F defined as point on top of the clay foundation (i.e., directly below the leachate collection system)
- Depth to groundwater assumed to be at ground surface pre-construction and at the base of the leachate collection system after Cell construction



Prepared By: RW
Reviewed By: FB

**One-Dimensional Landfill Settlement Calculations
Proposed South Landfill Expansion (Section C-C')**

Project No. 18111331
March 2020

1. Calculation of Total Consolidation Settlement at Pt. G (Section C-C' of Proposed South Landfill Expansion)

Inputs	masl
Approximate Midpoint of Clay Deposit	173.5
Approximate Original Ground Surface	199.0
Final Cover Elevation at Bottom of 3:1 Excavation Slope - West Side of Central Ridge (Point A)	207.2
Final Cover Elevation at 4(H):1(V) "Mid-Slope" Point - West Side of Central Ridge (Point B)	220.1
Final Cover Elevation at Slope Change Contour - West Side of Central Ridge (Point C)	233.0
Final Cover Elevation at Location along 5% slope - West Side of Central Ridge (Point D)	236.3
Final Cover Elevation at Peak of Landfill - West Side of Central Ridge (Point E)	238.6
Final Cover Elevation at Location along 5% slope - East Side of Central Ridge (Point F)	238.0
Final Cover Elevation at Location along 5% slope - East Side of Central Ridge (Point G)	237.9
Final Cover Elevation at Location along 5% slope - East Side of Central Ridge (Point H)	235.8
Final Cover Elevation at Location along 5% slope - East Side of Central Ridge (Point I)	233.0
Final Cover Elevation at 4(H):1(V) "Mid-Slope" Point - East Side of Central Ridge (Point J)	223.4
Final Cover Elevation at Bottom of 3:1 Excavation Slope - East Side of Central Ridge (Point K)	213.9
Elevation of Base of LCS (Point A)	188.8
Elevation of Base of LCS (Point B)	189.4
Elevation of Base of LCS (Point C)	190.1
Elevation of Base of LCS (Point D)	190.7
Elevation of Base of LCS (Point E)	191.3
Elevation of Base of LCS (Point F)	191.4
Elevation of Base of LCS (Point G)	190.9
Elevation of Base of LCS (Point H)	190.4
Elevation of Base of LCS (Point I)	189.9
Elevation of Base of LCS (Point J)	189.4
Elevation of Base of LCS (Point K)	189.0
Bottom of Clay Deposit	156
Groundwater Elevation in Overburden	199
Groundwater Elevation in Bedrock	178

1a. Final total Stress at Pt. G (Refer to Figure B2 for location of Point G)

Layer	Thickness (m)	Unit V N/m ³	Applied Pressure at Pt. G (kPa)
Final Cover	1.5	21	31.5
Waste	45.0	13	584.7
Sand Filter	0.2	19	3.8
Stone Drainage Layer	0.3	18	5.4
Natural Clay	17.5	21.0	366.8

Total Applied Pressure 992

1b. Initial Total Stress at Pt. G

$$\begin{aligned}\sigma(\text{initial}) &= 25.5 \times 21.0 \\ &= 536 \text{ kPa}\end{aligned}$$

1c. Initial Effective Stress at Pt. G

$$\begin{aligned}\sigma'(\text{initial}) &= \sigma - u \quad \text{where } u \text{ is the pore pressure at the midpoint of the clay deposit} \\ &= 536 - 13.1 \times 9.81 \text{ kN/m}^3 \\ &= 408 \text{ kPa}\end{aligned}$$

Pressure Head = 13.1 m

1d. Final Total Stress at Pt. G

$$\sigma(\text{final}) = 992 \text{ kPa}$$

1e. Final Effective Stress at Pt. G

$$\begin{aligned}\sigma'(\text{final}) &= \sigma - u \quad \text{Pressure Head} = 11.0 \text{ m} \\ &= 992 - 11.0 \times 9.81 \text{ kN/m}^3 \\ &= 884 \text{ kPa}\end{aligned}$$

1f. Change in Effective Stress at Pt. G

$$\begin{aligned}\Delta\sigma' &= \sigma'(\text{final}) - \sigma'(\text{initial}) \\ \Delta\sigma' &= 884 - 408 \\ \Delta\sigma' &= 476 \text{ kPa}\end{aligned}$$

1d. Settlement at Pt. G

$$\begin{aligned}S &= m_v \times \Delta\sigma'_{A'} \times H_{\text{clay}} \\ S &= (5 \times 10^{-5} \text{ m}^2/\text{kN}) \times 476 \times (190.9 - 156.00) \\ S &= 0.78 \text{ m}\end{aligned}$$

Summary

$$\begin{aligned}H &= 47.0 \text{ m} \quad \text{where } H = \text{total thickness of cover} + \text{waste} + \text{liner above Point G} \\ \text{Settlement} &= 781 \text{ mm}\end{aligned}$$

Assumptions & Limitations

- The coefficient of volume compressibility was derived from consolidation testing reported in Gartner Lee's Report dated December, 1991; $M_v = (5 \times 10^{-5} \text{ m}^2/\text{kN})$ (low compressibility clays)
- Point G defined as point on top of the clay foundation (i.e., directly below the leachate collection system)
- Depth to groundwater assumed to be at ground surface pre-construction and at the base of the leachate collection system after Cell construction



Prepared By: RW
Reviewed By: FB

**One-Dimensional Landfill Settlement Calculations
Proposed South Landfill Expansion (Section C-C')**

Project No. 18111331
March 2020

1. Calculation of Total Consolidation Settlement at Pt. H (Section C-C' of Proposed South Landfill Expansion)

Inputs	masl
Approximate Midpoint of Clay Deposit	173.2
Approximate Original Ground Surface	199.0
Final Cover Elevation at Bottom of 3:1 Excavation Slope - West Side of Central Ridge (Point A)	207.2
Final Cover Elevation at 4(H):1(V) "Mid-Slope" Point - West Side of Central Ridge (Point B)	220.1
Final Cover Elevation at Slope Change Contour - West Side of Central Ridge (Point C)	233.0
Final Cover Elevation at Location along 5% slope - West Side of Central Ridge (Point D)	236.3
Final Cover Elevation at Peak of Landfill - West Side of Central Ridge (Point E)	238.6
Final Cover Elevation at Location along 5% slope - East Side of Central Ridge (Point F)	238.0
Final Cover Elevation at Location along 5% slope - East Side of Central Ridge (Point G)	237.9
Final Cover Elevation at Location along 5% slope - East Side of Central Ridge (Point H)	235.8
Final Cover Elevation at Location along 5% slope - East Side of Central Ridge (Point I)	233.0
Final Cover Elevation at 4(H):1(V) "Mid-Slope" Point - East Side of Central Ridge (Point J)	223.4
Final Cover Elevation at Bottom of 3:1 Excavation Slope - East Side of Central Ridge (Point K)	213.9
Elevation of Base of LCS (Point A)	188.8
Elevation of Base of LCS (Point B)	189.4
Elevation of Base of LCS (Point C)	190.1
Elevation of Base of LCS (Point D)	190.7
Elevation of Base of LCS (Point E)	191.3
Elevation of Base of LCS (Point F)	191.4
Elevation of Base of LCS (Point G)	190.9
Elevation of Base of LCS (Point H)	190.4
Elevation of Base of LCS (Point I)	189.9
Elevation of Base of LCS (Point J)	189.4
Elevation of Base of LCS (Point K)	189.0
Bottom of Clay Deposit	156
Groundwater Elevation in Overburden	199
Groundwater Elevation in Bedrock	178

1a. Final total Stress at Pt. H (Refer to Figure B2 for location of Point H)

Layer	Thickness (m)	Unit V N/m ³	Applied Pressure at pt H (kPa)
Final Cover	1.5	21	31.5
Waste	43.4	13	564.1
Sand Filter	0.2	19	3.8
Stone Drainage Layer	0.3	18	5.4
Natural Clay	17.2	21.0	361.3

Total Applied Pressure 966

1b. Initial Total Stress at Pt. H

$$\begin{aligned}\sigma(\text{initial}) &= 25.8 \times 21.0 \\ &= 542 \text{ kPa}\end{aligned}$$

1c. Initial Effective Stress at Pt. H

$$\begin{aligned}\sigma'(\text{initial}) &= \sigma - u \quad \text{where } u \text{ is the pore pressure at the midpoint of the clay deposit} \\ &= 542 - 13.2 \times 9.81 \text{ kN/m}^3 \\ &= 412 \text{ kPa}\end{aligned}$$

Pressure Head = 13.2 m

1d. Final Total Stress at Pt. H

$$\sigma(\text{final}) = 966 \text{ kPa}$$

1e. Final Effective Stress at Pt. H

$$\begin{aligned}\sigma'(\text{final}) &= \sigma - u \quad \text{Pressure Head} = 11.0 \text{ m} \\ &= 966 - 11.0 \times 9.81 \text{ kN/m}^3 \\ &= 858 \text{ kPa}\end{aligned}$$

1f. Change in Effective Stress at Pt. H

$$\begin{aligned}\Delta\sigma' &= \sigma'(\text{final}) - \sigma'(\text{initial}) \\ \Delta\sigma' &= 858 - 412 \\ \Delta\sigma' &= 446 \text{ kPa}\end{aligned}$$

1d. Settlement at Pt. H

$$S = m_v \times \Delta\sigma'_{A'} \times H_{\text{clay}}$$

$$\begin{aligned}S &= (5 \times 10^{-5} \text{ m}^2/\text{kN}) \times 446 \times (190.4 - 156.00) \\ S &= 0.73 \text{ m}\end{aligned}$$

Summary

$$\begin{aligned}H &= 45.4 \text{ m} \quad \text{where } H = \text{total thickness of cover} + \text{waste} + \text{liner above Point H} \\ \text{Settlement} &= 732 \text{ mm}\end{aligned}$$

Assumptions & Limitations

- The coefficient of volume compressibility was derived from consolidation testing reported in Gartner Lee's Report dated December, 1991; $M_v = (5 \times 10^{-5} \text{ m}^2/\text{kN})$ (low compressibility clays)
- Point H defined as point on top of the clay foundation (i.e., directly below the leachate collection system)
- Depth to groundwater assumed to be at ground surface pre-construction and at the base of the leachate collection system after Cell construction



Prepared By: RW
Reviewed By: FB

**One-Dimensional Landfill Settlement Calculations
Proposed South Landfill Expansion (Section C-C')**

Project No. 18111331
March 2020

1. Calculation of Total Consolidation Settlement at Pt. I (Section C-C' of Proposed South Landfill Expansion)

Inputs	masl
Approximate Midpoint of Clay Deposit	172.9
Approximate Original Ground Surface	199.0
Final Cover Elevation at Bottom of 3:1 Excavation Slope - West Side of Central Ridge (Point A)	207.2
Final Cover Elevation at 4(H):1(V) "Mid-Slope" Point - West Side of Central Ridge (Point B)	220.1
Final Cover Elevation at Slope Change Contour - West Side of Central Ridge (Point C)	233.0
Final Cover Elevation at Location along 5% slope - West Side of Central Ridge (Point D)	236.3
Final Cover Elevation at Peak of Landfill - West Side of Central Ridge (Point E)	238.6
Final Cover Elevation at Location along 5% slope - East Side of Central Ridge (Point F)	238.0
Final Cover Elevation at Location along 5% slope - East Side of Central Ridge (Point G)	237.9
Final Cover Elevation at Location along 5% slope - East Side of Central Ridge (Point H)	235.8
Final Cover Elevation at Location along 5% slope - East Side of Central Ridge (Point I)	233.0
Final Cover Elevation at 4(H):1(V) "Mid-Slope" Point - East Side of Central Ridge (Point J)	223.4
Final Cover Elevation at Bottom of 3:1 Excavation Slope - East Side of Central Ridge (Point K)	213.9
Elevation of Base of LCS (Point A)	188.8
Elevation of Base of LCS (Point B)	189.4
Elevation of Base of LCS (Point C)	190.1
Elevation of Base of LCS (Point D)	190.7
Elevation of Base of LCS (Point E)	191.3
Elevation of Base of LCS (Point F)	191.4
Elevation of Base of LCS (Point G)	190.9
Elevation of Base of LCS (Point H)	190.4
Elevation of Base of LCS (Point I)	189.9
Elevation of Base of LCS (Point J)	189.4
Elevation of Base of LCS (Point K)	189.0
Bottom of Clay Deposit	156
Groundwater Elevation in Overburden	199
Groundwater Elevation in Bedrock	178

1a. Final total Stress at Pt. I (Refer to Figure B2 for location of Point I)

Layer	Thickness (m)	Unit V N/m ³	Applied Pressure at Pt. I (kPa)
Final Cover	1.5	21	31.5
Waste	41.1	13	534.8
Sand Filter	0.2	19	3.8
Stone Drainage Layer	0.3	18	5.4
Natural Clay	16.9	21.0	355.5

Total Applied Pressure 931

1b. Initial Total Stress at Pt. I

$$\begin{aligned}\sigma(\text{initial}) &= 26.1 \times 21.0 \\ &= 547 \text{ kPa}\end{aligned}$$

1c. Initial Effective Stress at Pt. I

$$\begin{aligned}\sigma'(\text{initial}) &= \sigma - u \quad \text{where } u \text{ is the pore pressure at the midpoint of the clay deposit} \\ &= 547 - 13.3 \times 9.81 \text{ kN/m}^3 \\ &= 417 \text{ kPa}\end{aligned}$$

Pressure Head = 13.3 m

1d. Final Total Stress at Pt. I

$$\sigma(\text{final}) = 931 \text{ kPa}$$

1e. Final Effective Stress at Pt. I

$$\begin{aligned}\sigma'(\text{final}) &= \sigma - u \quad \text{Pressure Head} = 11.0 \text{ m} \\ &= 931 - 11.0 \times 9.81 \text{ kN/m}^3 \\ &= 823 \text{ kPa}\end{aligned}$$

1f. Change in Effective Stress at Pt. I

$$\begin{aligned}\Delta\sigma' &= \sigma'(\text{final}) - \sigma'(\text{initial}) \\ \Delta\sigma' &= 823 - 417 \\ \Delta\sigma' &= 407 \text{ kPa}\end{aligned}$$

1d. Settlement at Pt. I

$$S = m_v \times \Delta\sigma'_{A'} \times H_{\text{clay}}$$

$$S = (5 \times 10^{-5} \text{ m}^2/\text{kN}) \times 407 \times (189.9 - 156.00)$$

$$S = 0.67 \text{ m}$$

Summary

$$\begin{aligned}H &= 43.1 \text{ m} \quad \text{where } H = \text{total thickness of cover} + \text{waste} + \text{liner above Point I} \\ \text{Settlement} &= 667 \text{ mm}\end{aligned}$$

Assumptions & Limitations

- The coefficient of volume compressibility was derived from consolidation testing reported in Gartner Lee's Report dated December, 1991; $M_v = (5 \times 10^{-5} \text{ m}^2/\text{kN})$ (low compressibility clays)
- Point I defined as point on top of the clay foundation (i.e., directly below the leachate collection system)
- Depth to groundwater assumed to be at ground surface pre-construction and at the base of the leachate collection system after Cell construction

**One-Dimensional Landfill Settlement Calculations
Proposed South Landfill Expansion (Section C-C')**

Project No. 18111331
March 2020

1. Calculation of Total Consolidation Settlement at Pt. J (Section C-C' of Proposed South Landfill Expansion)

Inputs	masl
Approximate Midpoint of Clay Deposit	172.7
Approximate Original Ground Surface	199.0
Final Cover Elevation at Bottom of 3:1 Excavation Slope - West Side of Central Ridge (Point A)	207.2
Final Cover Elevation at 4(H):1(V) "Mid-Slope" Point - West Side of Central Ridge (Point B)	220.1
Final Cover Elevation at Slope Change Contour - West Side of Central Ridge (Point C)	233.0
Final Cover Elevation at Location along 5% slope - West Side of Central Ridge (Point D)	236.3
Final Cover Elevation at Peak of Landfill - West Side of Central Ridge (Point E)	238.6
Final Cover Elevation at Location along 5% slope - East Side of Central Ridge (Point F)	238.0
Final Cover Elevation at Location along 5% slope - East Side of Central Ridge (Point G)	237.9
Final Cover Elevation at Location along 5% slope - East Side of Central Ridge (Point H)	235.8
Final Cover Elevation at Location along 5% slope - East Side of Central Ridge (Point I)	233.0
Final Cover Elevation at 4(H):1(V) "Mid-Slope" Point - East Side of Central Ridge (Point J)	223.4
Final Cover Elevation at Bottom of 3:1 Excavation Slope - East Side of Central Ridge (Point K)	213.9
Elevation of Base of LCS (Point A)	188.8
Elevation of Base of LCS (Point B)	189.4
Elevation of Base of LCS (Point C)	190.1
Elevation of Base of LCS (Point D)	190.7
Elevation of Base of LCS (Point E)	191.3
Elevation of Base of LCS (Point F)	191.4
Elevation of Base of LCS (Point G)	190.9
Elevation of Base of LCS (Point H)	190.4
Elevation of Base of LCS (Point I)	189.9
Elevation of Base of LCS (Point J)	189.4
Elevation of Base of LCS (Point K)	189.0
Bottom of Clay Deposit	156
Groundwater Elevation in Overburden	199
Groundwater Elevation in Bedrock	178

1a. Final total Stress at Pt. J (Refer to Figure B2 for location of Point J)

Layer	Thickness (m)	Unit V N/m ³	Applied Pressure at Pt. J (kPa)
Final Cover	1.5	21	31.5
Waste	32.0	13	416.1
Sand Filter	0.2	19	3.8
Stone Drainage Layer	0.3	18	5.4
Natural Clay	16.7	21.0	350.8

Total Applied Pressure 808

1b. Initial Total Stress at Pt. J

$$\begin{aligned}\sigma(\text{initial}) &= 26.3 \times 21.0 \\ &= 552 \text{ kPa}\end{aligned}$$

1c. Initial Effective Stress at Pt. J

$$\begin{aligned}\sigma'(\text{initial}) &= \sigma - u \quad \text{where } u \text{ is the pore pressure at the midpoint of the clay deposit} \\ &= 552 - 13.5 \times 9.81 \text{ kN/m}^3 \\ &= 420 \text{ kPa}\end{aligned}$$

Pressure Head = 13.5 m

1d. Final Total Stress at Pt. J

$$\sigma(\text{final}) = 808 \text{ kPa}$$

1e. Final Effective Stress at Pt. J

$$\begin{aligned}\sigma'(\text{final}) &= \sigma - u \quad \text{Pressure Head} = 11.0 \text{ m} \\ &= 808 - 11.0 \times 9.81 \text{ kN/m}^3 \\ &= 700 \text{ kPa}\end{aligned}$$

1f. Change in Effective Stress at Pt. J

$$\begin{aligned}\Delta\sigma' &= \sigma'(\text{final}) - \sigma'(\text{initial}) \\ \Delta\sigma' &= 700 - 420 \\ \Delta\sigma' &= 280 \text{ kPa}\end{aligned}$$

1d. Settlement at Pt. J

$$S = m_v \times \Delta\sigma'_{A'} \times H_{\text{clay}}$$

$$\begin{aligned}S &= (5 \times 10^{-5} \text{ m}^2/\text{kN}) \times 280 \times (189.4 - 156.00) \\ S &= 0.46 \text{ m}\end{aligned}$$

Summary

$$\begin{aligned}H &= 34.0 \text{ m} \quad \text{where } H = \text{total thickness of cover} + \text{waste} + \text{liner above Point J} \\ \text{Settlement} &= 459 \text{ mm}\end{aligned}$$

Assumptions & Limitations

- The coefficient of volume compressibility was derived from consolidation testing reported in Gartner Lee's Report dated December, 1991; $M_v = (5 \times 10^{-5} \text{ m}^2/\text{kN})$ (low compressibility clays)
- Point J defined as point on top of the clay foundation (i.e., directly below the leachate collection system)
- Depth to groundwater assumed to be at ground surface pre-construction and at the base of the leachate collection system after Cell construction



Prepared By: RW
Reviewed By: FB

**One-Dimensional Landfill Settlement Calculations
Proposed South Landfill Expansion (Section C-C')**

Project No. 18111331
March 2020

1. Calculation of Total Consolidation Settlement at Pt. K (Section C-C' of Proposed South Landfill Expansion)

Inputs	masl
Approximate Midpoint of Clay Deposit	172.5
Approximate Original Ground Surface	199.0
Final Cover Elevation at Bottom of 3:1 Excavation Slope - West Side of Central Ridge (Point A)	207.2
Final Cover Elevation at 4(H):1(V) "Mid-Slope" Point - West Side of Central Ridge (Point B)	220.1
Final Cover Elevation at Slope Change Contour - West Side of Central Ridge (Point C)	233.0
Final Cover Elevation at Location along 5% slope - West Side of Central Ridge (Point D)	236.3
Final Cover Elevation at Peak of Landfill - West Side of Central Ridge (Point E)	238.6
Final Cover Elevation at Location along 5% slope - East Side of Central Ridge (Point F)	238.0
Final Cover Elevation at Location along 5% slope - East Side of Central Ridge (Point G)	237.9
Final Cover Elevation at Location along 5% slope - East Side of Central Ridge (Point H)	235.8
Final Cover Elevation at Location along 5% slope - East Side of Central Ridge (Point I)	233.0
Final Cover Elevation at 4(H):1(V) "Mid-Slope" Point - East Side of Central Ridge (Point J)	223.4
Final Cover Elevation at Bottom of 3:1 Excavation Slope - East Side of Central Ridge (Point K)	213.9
Elevation of Base of LCS (Point A)	188.8
Elevation of Base of LCS (Point B)	189.4
Elevation of Base of LCS (Point C)	190.1
Elevation of Base of LCS (Point D)	190.7
Elevation of Base of LCS (Point E)	191.3
Elevation of Base of LCS (Point F)	191.4
Elevation of Base of LCS (Point G)	190.9
Elevation of Base of LCS (Point H)	190.4
Elevation of Base of LCS (Point I)	189.9
Elevation of Base of LCS (Point J)	189.4
Elevation of Base of LCS (Point K)	189.0
Bottom of Clay Deposit	156
Groundwater Elevation in Overburden	199
Groundwater Elevation in Bedrock	178

1a. Final total Stress at Pt. K (Refer to Figure B2 for location of Point K)

Layer	Thickness (m)	Unit V N/m ³	Applied Pressure at Pt. K (kPa)
Final Cover	1.5	21	31.5
Waste	22.9	13	297.6
Sand Filter	0.2	19	3.8
Stone Drainage Layer	0.3	18	5.4
Natural Clay	16.5	21.0	346.1

Total Applied Pressure 684

1b. Initial Total Stress at Pt. K

$$\begin{aligned}\sigma(\text{initial}) &= 26.5 \times 21.0 \\ &= 557 \text{ kPa}\end{aligned}$$

1c. Initial Effective Stress at Pt. K

$$\begin{aligned}\sigma'(\text{initial}) &= \sigma - u \quad \text{where } u \text{ is the pore pressure at the midpoint of the clay deposit} \\ &= 557 - 13.6 \times 9.81 \text{ kN/m}^3 \\ &= 424 \text{ kPa}\end{aligned}$$

Pressure Head = 13.6 m

1d. Final Total Stress at Pt. K

$$\sigma(\text{final}) = 684 \text{ kPa}$$

1e. Final Effective Stress at Pt. K

$$\begin{aligned}\sigma'(\text{final}) &= \sigma - u \quad \text{Pressure Head} = 11.0 \text{ m} \\ &= 684 - 11.0 \times 9.81 \text{ kN/m}^3 \\ &= 576 \text{ kPa}\end{aligned}$$

1f. Change in Effective Stress at Pt. K

$$\begin{aligned}\Delta\sigma' &= \sigma'(\text{final}) - \sigma'(\text{initial}) \\ \Delta\sigma' &= 576 - 424 \\ \Delta\sigma' &= 153 \text{ kPa}\end{aligned}$$

1d. Settlement at Pt. K

$$\begin{aligned}S &= m_v \times \Delta\sigma'_{A'} \times H_{\text{clay}} \\ S &= (5 \times 10^{-5} \text{ m}^2/\text{kN}) \times 153 \times (189.0 - 156.00) \\ S &= 0.25 \text{ m}\end{aligned}$$

Summary

$$\begin{aligned}H &= 24.9 \text{ m} \quad \text{where } H = \text{total thickness of cover} + \text{waste} + \text{liner above Point K} \\ \text{Settlement} &= 250 \text{ mm}\end{aligned}$$

Assumptions & Limitations

- The coefficient of volume compressibility was derived from consolidation testing reported in Gartner Lee's Report dated December, 1991; $M_v = (5 \times 10^{-5} \text{ m}^2/\text{kN})$ (low compressibility clays)
- Point K defined as point on top of the clay foundation (i.e., directly below the leachate collection system)
- Depth to groundwater assumed to be at ground surface pre-construction and at the base of the leachate collection system after Cell construction

**One-Dimensional Landfill Settlement Calculations
Proposed South Landfill Expansion (Section C-C')**

Project No. 18111331
March 2020

Proposed South Landfill Expansion (Section C-C')
Summary of One-Dimensional Total Settlement and Differential Settlement

Point	Total Settlement (mm)
A	108
B	388
C	669
D	746
E	799
F	787
G	781
H	732
I	667
J	459
K	250

Line ¹	Length (m)	Initial Base Grade (%)	Differential Settlement (mm)	Grade Change ² (%)	Final Base Grade ³ (%)	Design Requirement ⁴ (%)
A-B	51	1.2	281	-0.55	0.65	0.5
B-C	52	1.2	281	-0.54	0.66	0.5
C-D	62	1.0	77	-0.12	0.88	0.5
D-E	62	1.0	53	-0.09	0.91	0.5
E-F	48	1.0	12	-0.02	0.98	0.5
F-G	49	1.0	6	-0.01	0.99	0.5
G-H	55	1.0	50	-0.09	0.91	0.5
H-I	55	1.0	65	-0.12	0.88	0.5
I-J	38	1.2	208	-0.54	0.66	0.5
J-K	38	1.2	208	-0.54	0.66	0.5

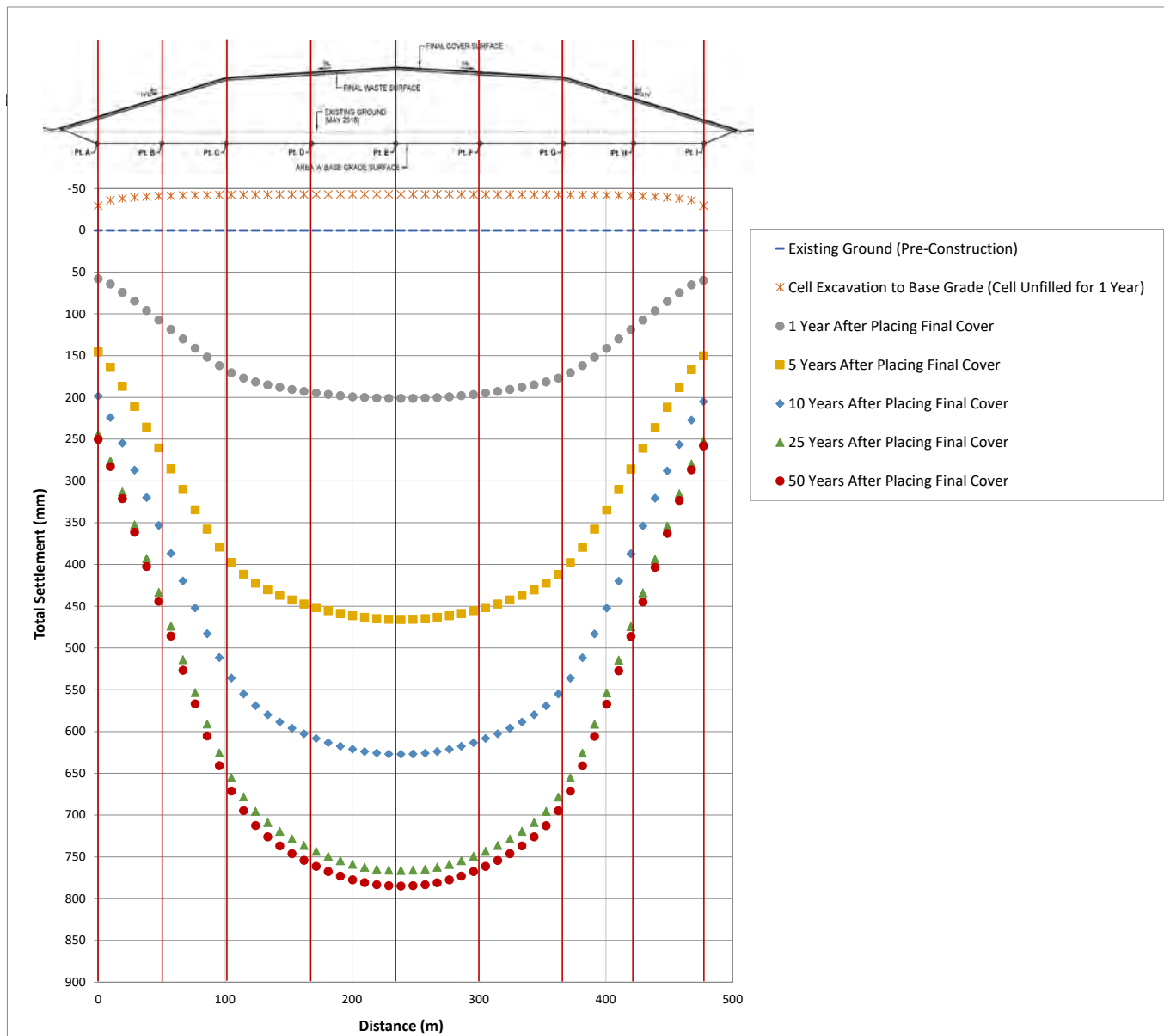
Notes:

- 1 Refer to Attachment B for locations
- 2 Grade change = differential settlement ÷ length
- 3 Final base grade = initial base grade - [differential settlement ÷ length]
- 4 Recommended minimum base grade [MOE Landfill Standards]

ATTACHMENT B

Three-Dimensional Landfill Settlement Analysis

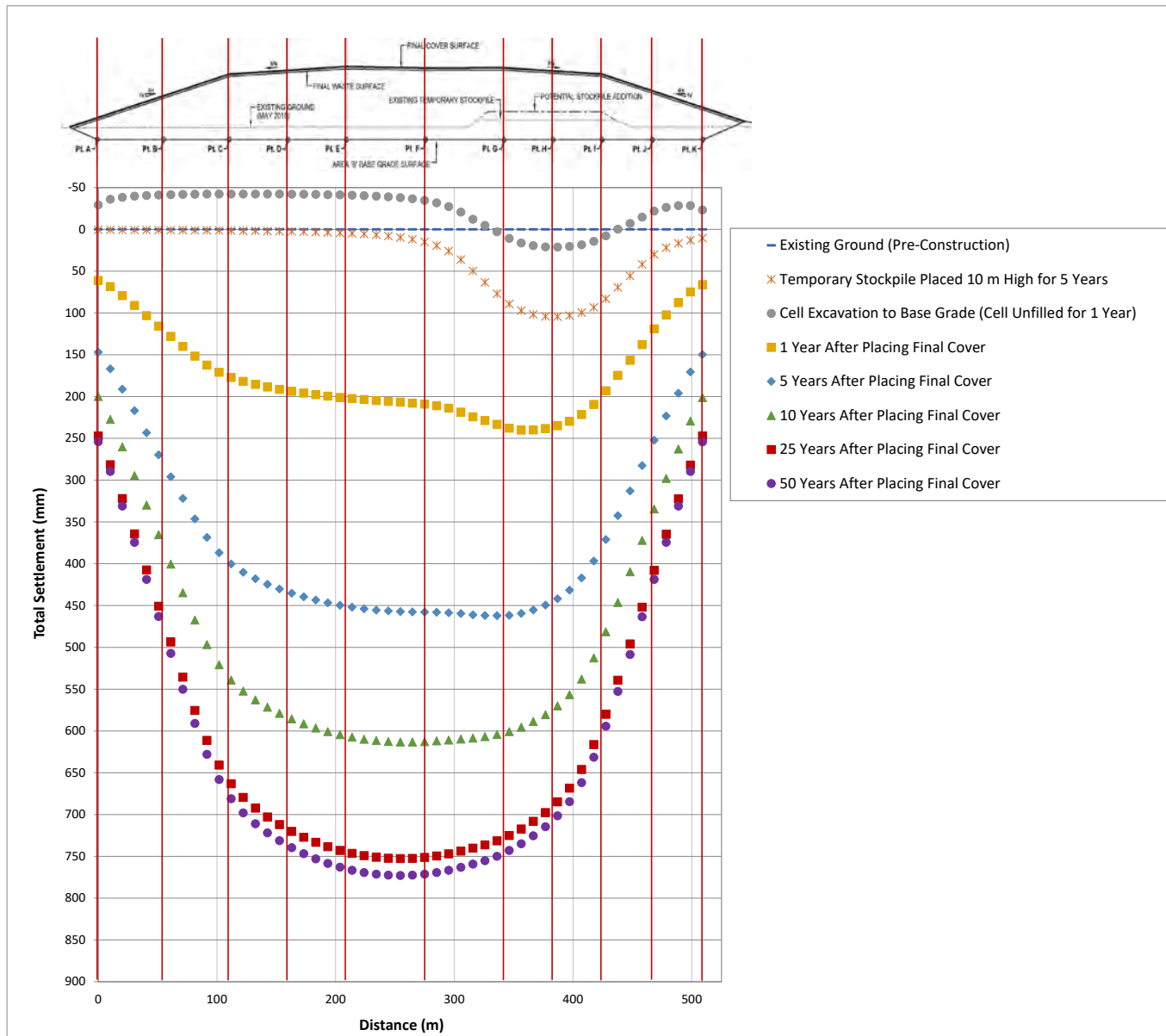
FIGURE B1
Three-Dimensional Landfill Settlement Analysis
Proposed West Landfill Expansion (Section A-A')



Point	Distance (m)	Settlement @ 50 years (mm)
A	0	250
B	47	441
C	94	636
D	162	754
E	230	785
F	303	763
G	376	660
H	426	459
I	476	260

Line	Length (m)	Differential Settlement (mm)	Change in Gradient (%)
A-B	47	191	0.41
B-C	47	195	0.41
C-D	68	118	0.17
D-E	68	30	0.04
E-F	73	22	0.03
F-G	73	103	0.14
G-H	50	200	0.40
H-I	50	199	0.40

FIGURE B2
Three-Dimensional Landfill Settlement Analysis
Proposed South Landfill Expansion (Section C-C')



Note: Negative settlement indicates rebound

Point	Distance (m)	Settlement @ 50 years (mm)
A	0	254
B	51	464
C	103	661
D	165	741
E	227	770
F	275	771
G	324	756
H	379	712
I	434	569
J	472	403
K	510	254

Line	Length (m)	Differential Settlement (mm)	Change in Gradient (%)
A-B	51	209	0.41
B-C	52	198	0.38
C-D	62	80	0.13
D-E	62	29	0.05
E-F	48	1	0.00
F-G	49	16	0.03
G-H	55	44	0.08
H-I	55	143	0.26
I-J	38	166	0.44
J-K	38	148	0.39

ATTACHMENT C

Calculation of Landfill Foundation Bearing Capacity

Calculation of Landfill Foundation Bearing Capacity

Undrained Shear Strength of Clayey Silt Till Foundation Soil

$C_u = 235 \text{ kPa (min.)}$. (Gartner Lee. Lt. 1991).

$$\begin{aligned} \text{Bearing Capacity} &= 5 \times C_u + H_{\text{excavation}} \times \gamma_{\text{clay}} \\ &= 5 \times 235 \text{ kPa} + 8 \text{ m} \times 21 \text{ kN/m}^3 \\ &= 1,343 \text{ kPa} \end{aligned}$$

Maximum Applied Waste Fill Pressure on Foundation

Layer	Thickness (m)	Unit Wt. (kN/m ³)	Applied Pressure (kPa)
Final Cover	1.5	21	32
Waste	47 (max.)	13	611
Sand Filter	0.2	19	4
Stone Drainage Layer	0.3	18	<u>5</u>

Total = 652 kPa

Factor of Safety Against Bearing Capacity Failure

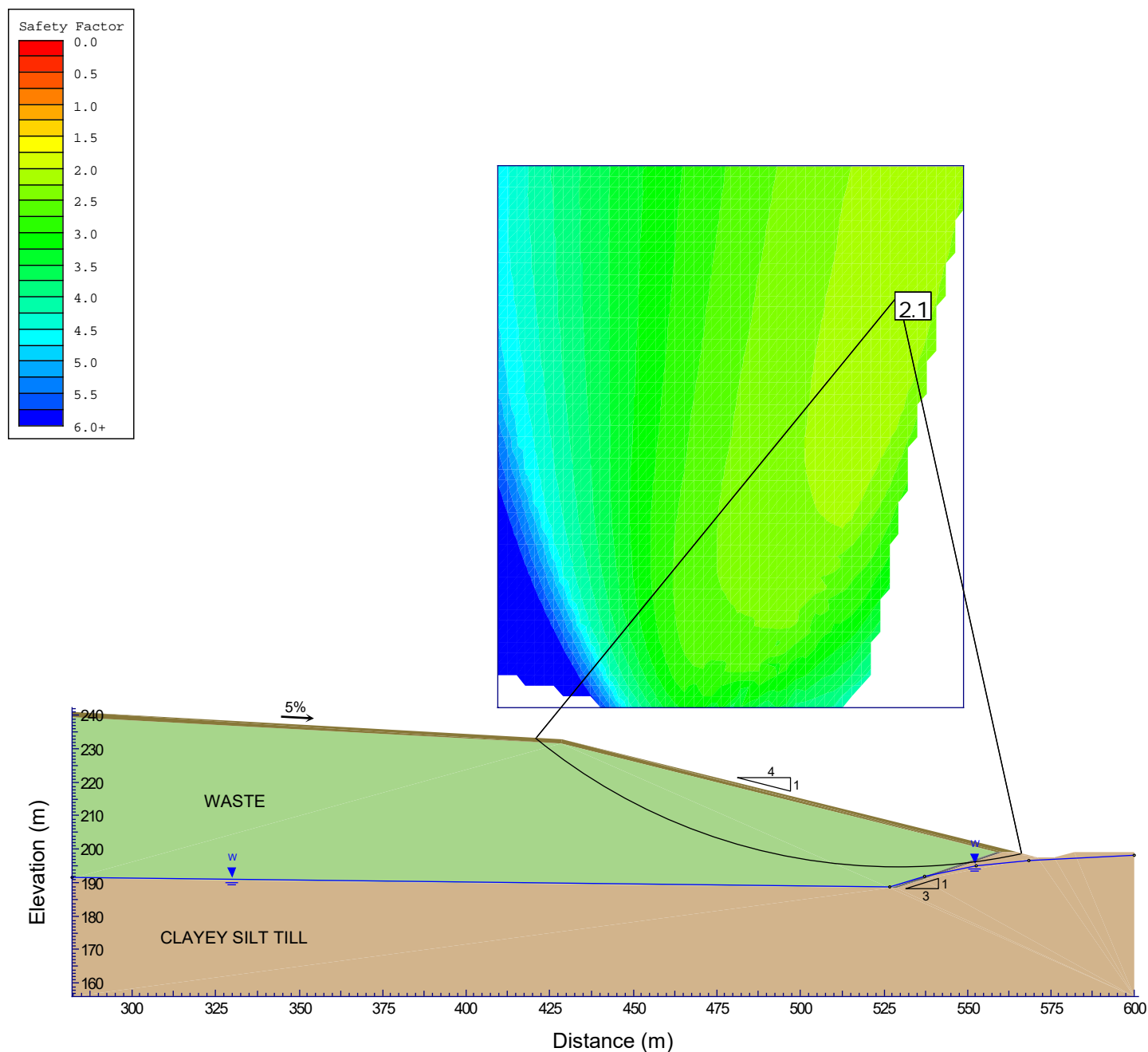
$$\begin{aligned} \text{F.S.} &= 1,343 \text{ kPa} \div 652 \text{ kPa} \\ &= 2.1 \text{ (min)} \end{aligned}$$

ATTACHMENT D

Ridge Landfill Slope Stability Analysis



Ridge Landfill Slope Stability Analysis Exterior Waste Slope (South and West Landfill Expansions) Figure D1 Normal Operating Condition - Static



Material Name	Color	Unit Weight (kN/m3)	Cohesion (kPa)	Phi (deg)
Clayey Silt Till		21	0	26
Final Clay Cover Material		21	0	26
Municipal Solid Waste		13	20	20
Recompacted Clay Side Slope		21	0	26

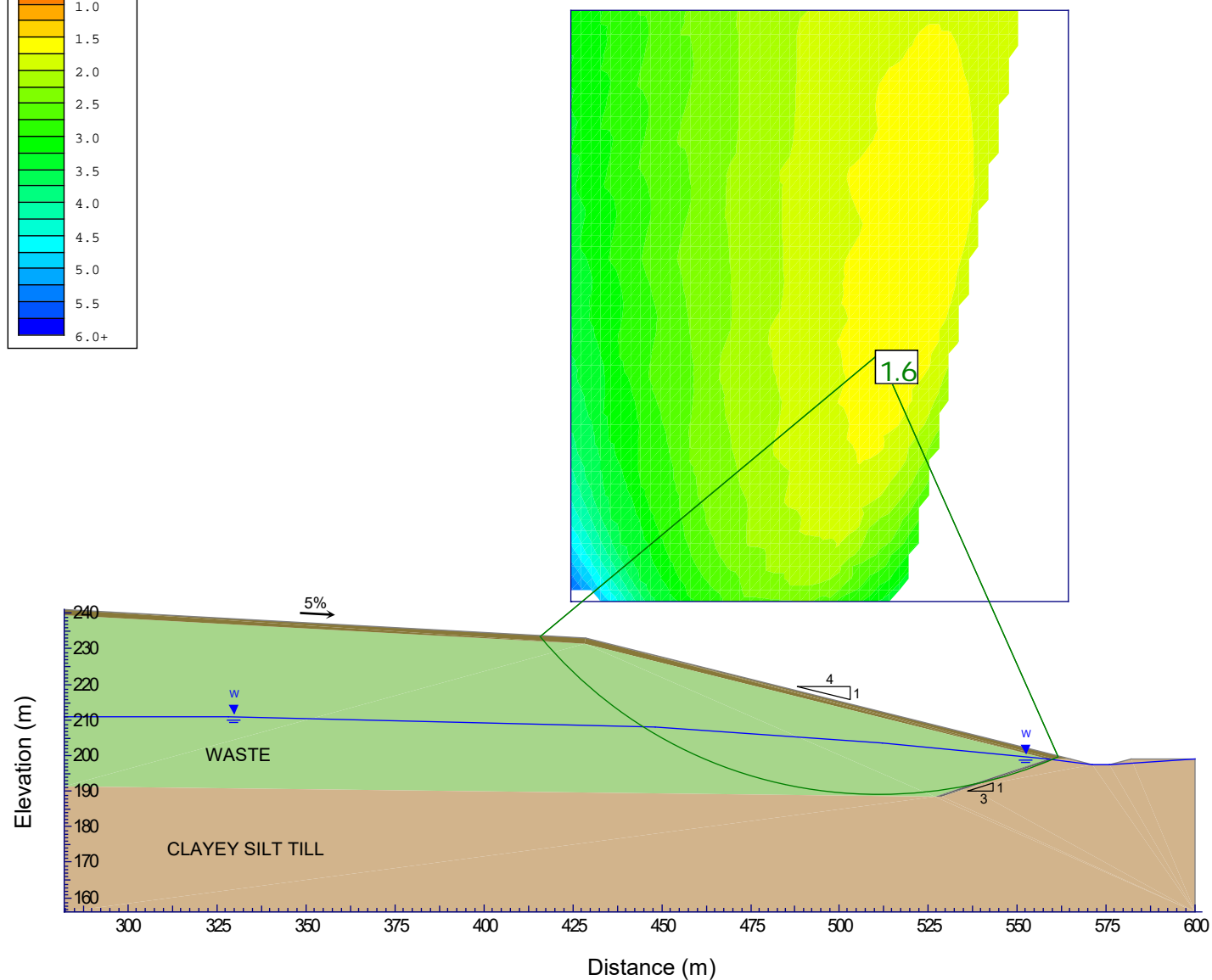
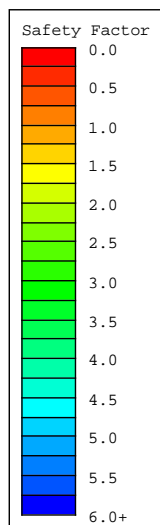
NOTES:
1. Drained Analysis



Ridge Landfill Slope Stability Analysis

Exterior Waste Slope (South and West Landfill Expansions) Figure D2

Leachate Mounding Case - Static



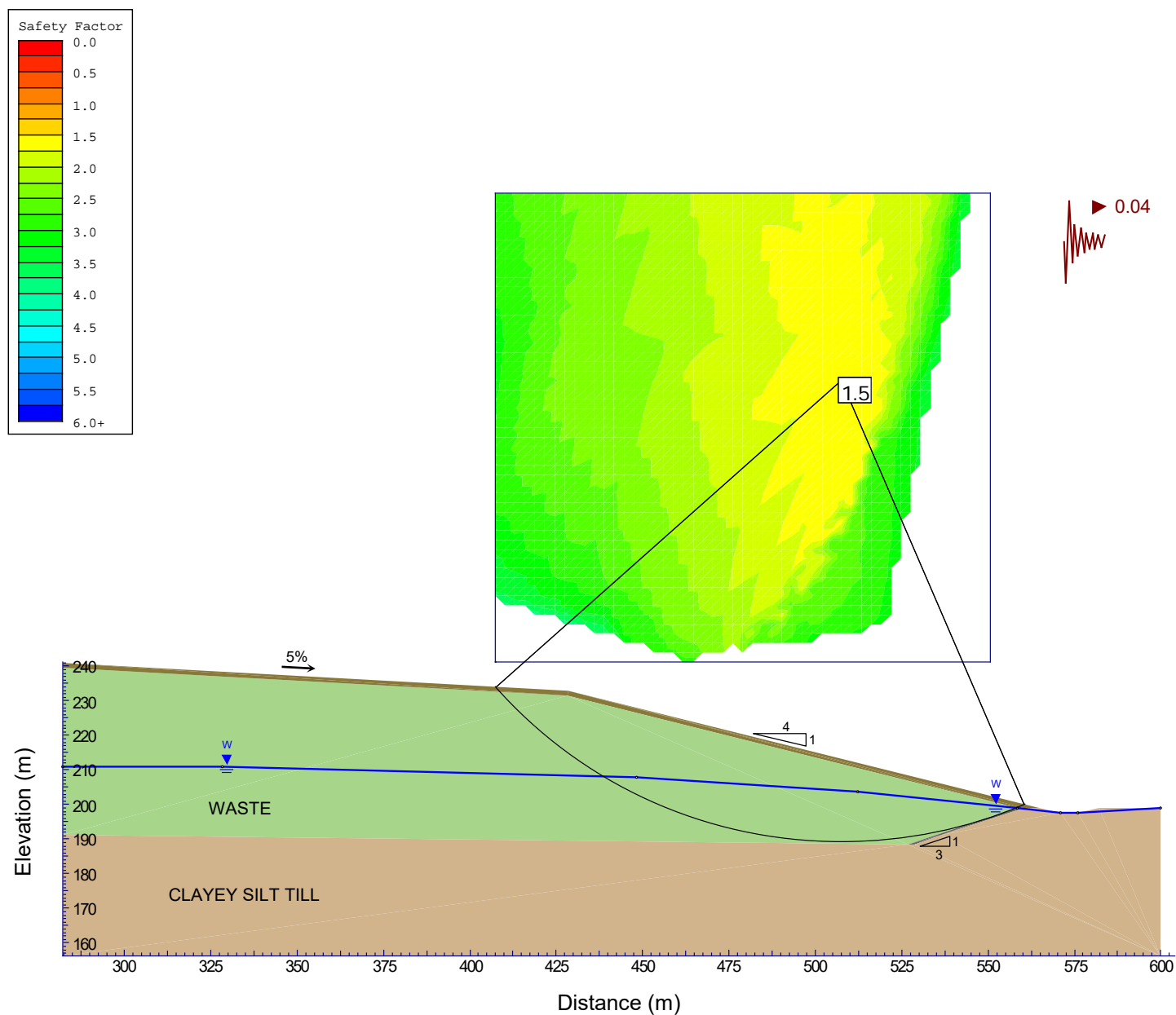
Material Name	Color	Unit Weight (kN/m ³)	Cohesion (kPa)	Phi (deg)
Clayey Silt Till		21	0	26
Final Clay Cover Material		21	0	26
Municipal Solid Waste		13	20	20
Recompacted Clay Side Slope		21	0	26

NOTES:

1. Drained Analysis



Ridge Landfill Slope Stability Analysis Exterior Waste Slope (South and West Landfill Expansions) Figure D3 Leachate Mounding Case - Pseudo-Static



Material Name	Color	Unit Weight (kN/m ³)	Cohesion (kPa)	Phi (deg)
Clayey Silt Till		21	235	
Final Clay Cover Material		21	235	
Municipal Solid Waste		13	20	20
Recompacted Clay Side Slope		21	235	

NOTES:
1. Undrained Analysis



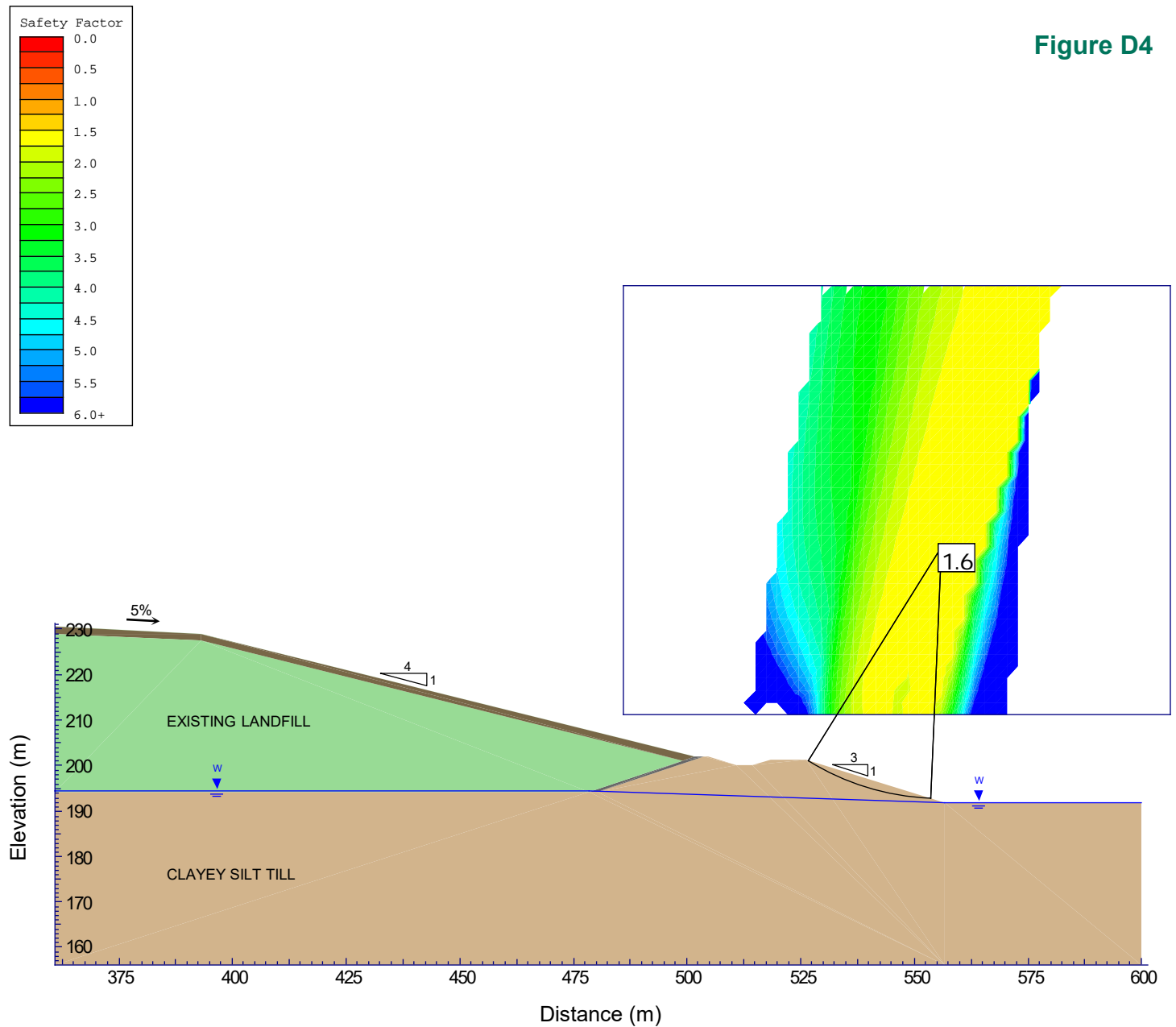
Ridge Landfill Slope Stability Analysis

Interior Waste Slope with Temporary Cell Excavation (South and West Landfill Expansions)

Interior Berm Failure

Normal Operating Condition - Static

Figure D4



Material Name	Color	Unit Weight (kN/m3)	Cohesion (kPa)	Phi (deg)
Clayey Silt Till		21	0	26
Final Clay Cover Material		21	0	26
Municipal Solid Waste		13	20	20
Recompacted Clay Side Slope		21	0	26

NOTES:
1. Drained Analysis



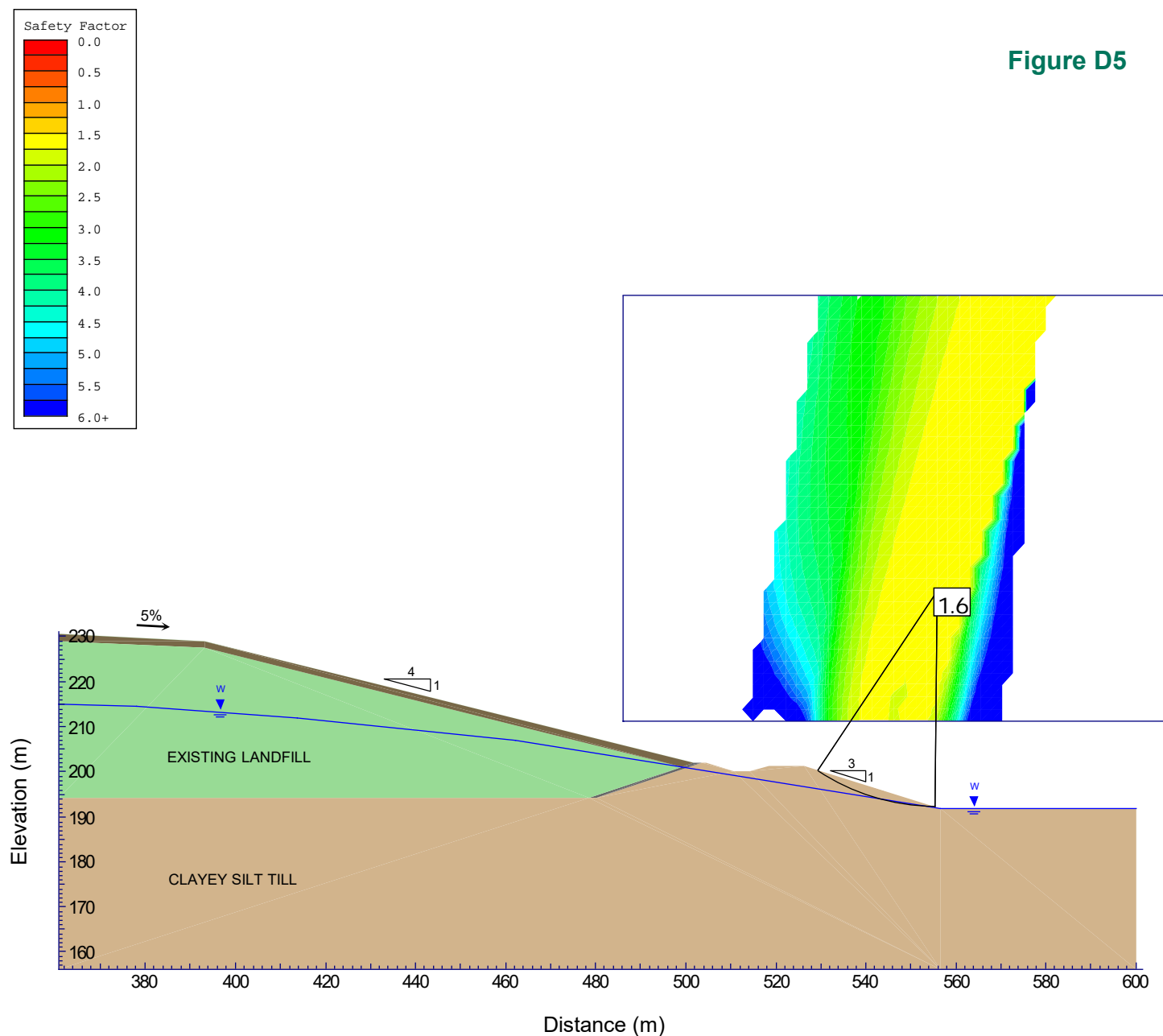
Ridge Landfill Slope Stability Analysis

Interior Waste Slope with Temporary Cell Excavation (South and West Landfill Expansions)

Interior Berm Failure

Leachate Mounding Case - Static

Figure D5



Material Name	Color	Unit Weight (kN/m ³)	Cohesion (kPa)	Phi (deg)
Clayey Silt Till		21	0	26
Final Clay Cover Material		21	0	26
Municipal Solid Waste		13	20	20
Recompacted Clay Side Slope		21	0	26

NOTES:
1. Drained Analysis



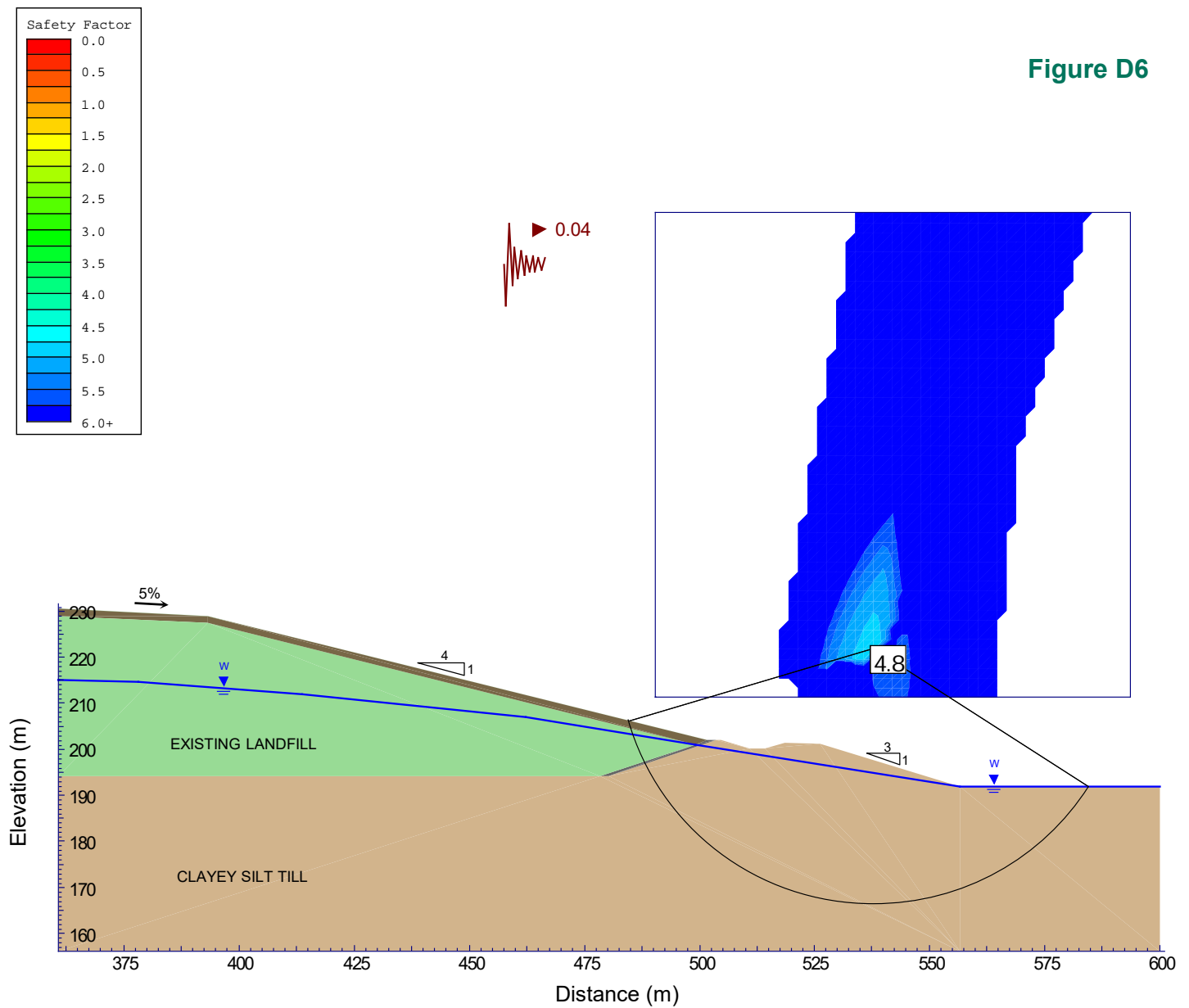
Ridge Landfill Slope Stability Analysis





Interior Waste Slope with Temporary Cell Excavation (South and West Landfill Expansions)

Interior Berm Failure

Leachate Mounding Case - Pseudo-Static

Figure D6



Material Name	Color	Unit Weight (kN/m ³)	Cohesion (kPa)	Phi (deg)
Clayey Silt Till		21	235	
Final Clay Cover Material		21	235	
Municipal Solid Waste		13	20	20
Recompacted Clay Side Slope		21	235	

NOTES:
1. Undrained Analysis



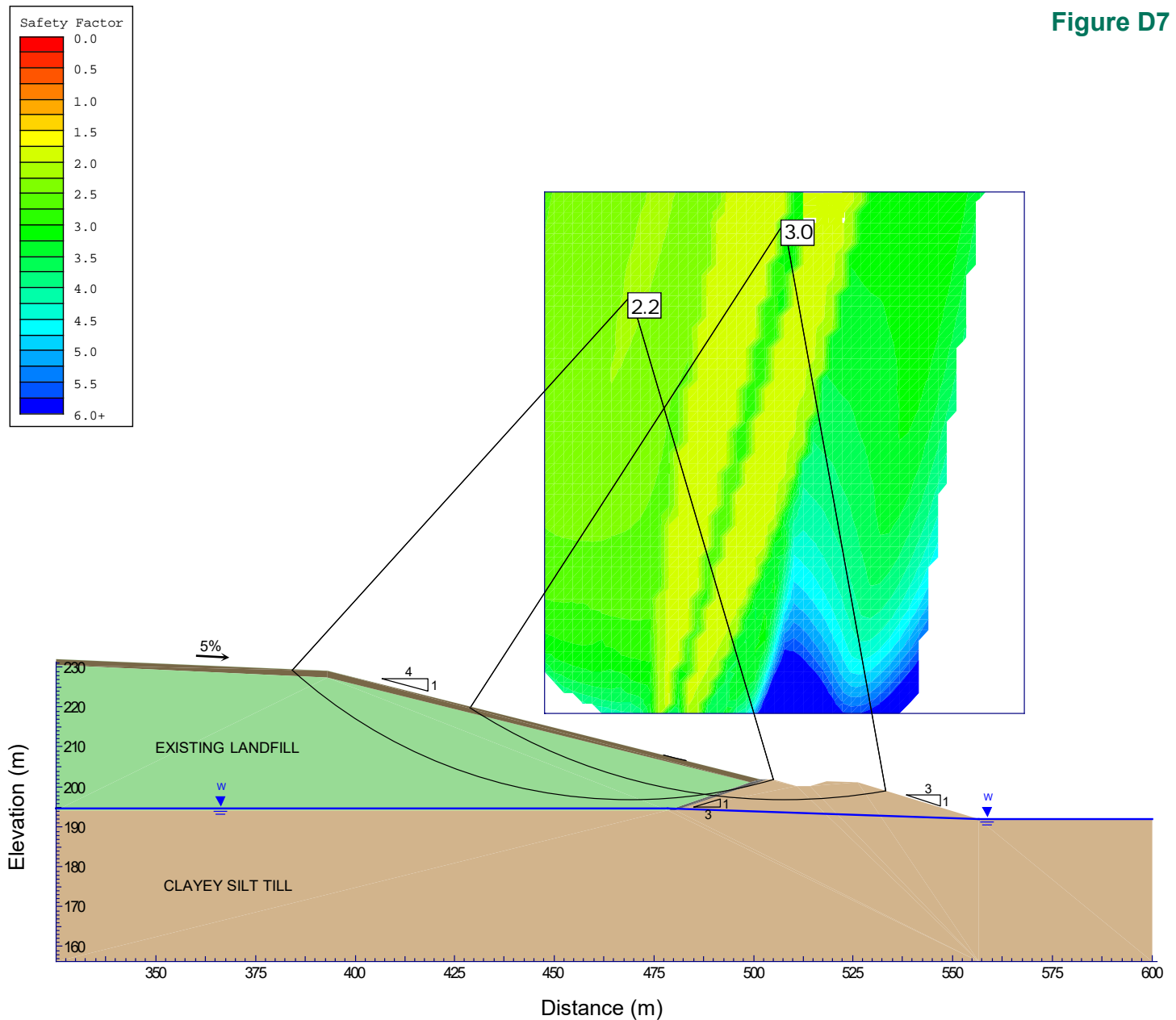
Ridge Landfill Slope Stability Analysis

Interior Waste Slope with Temporary Cell Excavation (South and West Landfill Expansions)

Rotational Failure of Interior Waste Slope and Deep Seated Failure Through Waste and Interior Berm

Normal Operating Condition - Static

Figure D7



Material Name	Color	Unit Weight (kN/m3)	Cohesion (kPa)	Phi (deg)
Clayey Silt Till		21	0	26
Final Clay Cover Material		21	0	26
Municipal Solid Waste		13	20	20
Recompacted Clay Side Slope		21	0	26

NOTES:
1. Drained Analysis



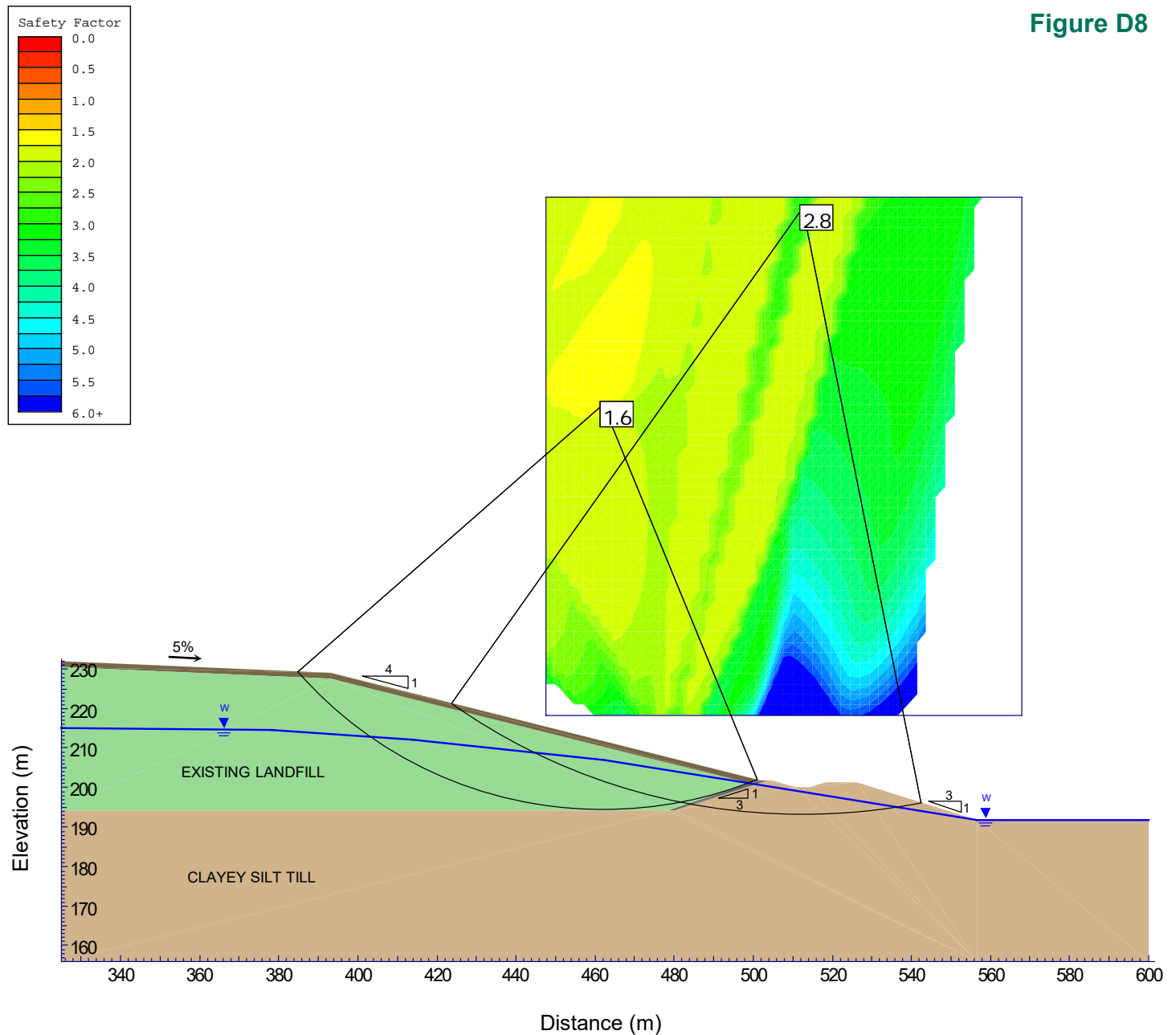
Ridge Landfill Slope Stability Analysis

Interior Waste Slope with Temporary Cell Excavation (South and West Landfill Expansions)

Rotational Failure of Interior Waste Slope and Deep Seated Failure Through Waste and Interior Berm

Leachate Mounding Case - Static

Figure D8



Material Name	Color	Unit Weight (kN/m ³)	Cohesion (kPa)	Phi (deg)
Clayey Silt Till		21	0	26
Final Clay Cover Material		21	0	26
Municipal Solid Waste		13	20	20
Recompacted Clay Side Slope		21	0	26

NOTES:
1. Drained Analysis



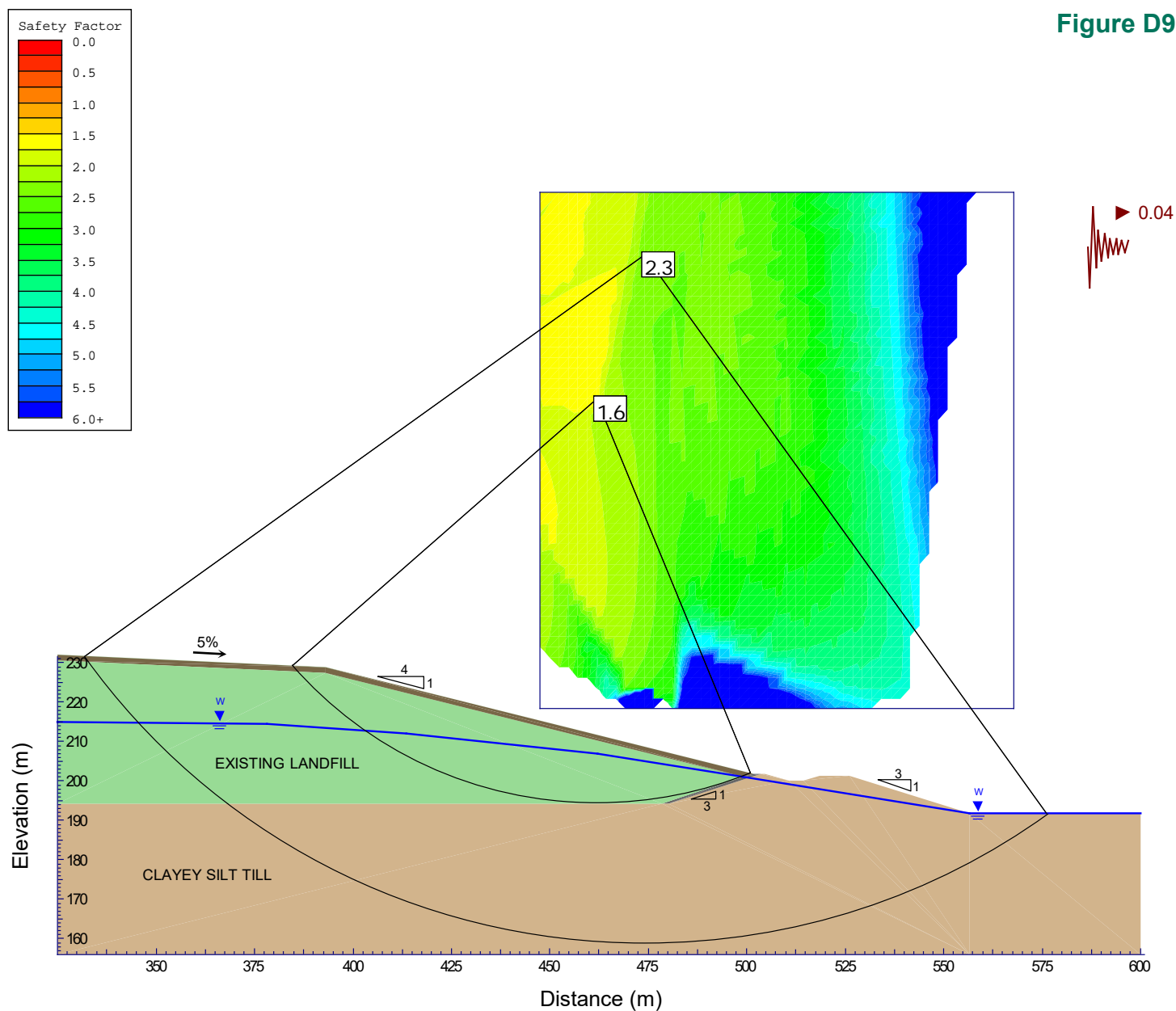
Ridge Landfill Slope Stability Analysis

Interior Waste Slope with Temporary Cell Excavation (South and West Landfill Expansions)

Rotational Failure of Interior Waste Slope and Deep Seated Failure Through Waste and Interior Berm

Leachate Mounding Case - Pseudo-Static

Figure D9



Material Name	Color	Unit Weight (kN/m ³)	Cohesion (kPa)	Phi (deg)
Clayey Silt Till		21	235	
Final Clay Cover Material		21	235	
Municipal Solid Waste		13	20	20
Recompacted Clay Side Slope		21	235	

NOTES:
1. Undrained Analysis



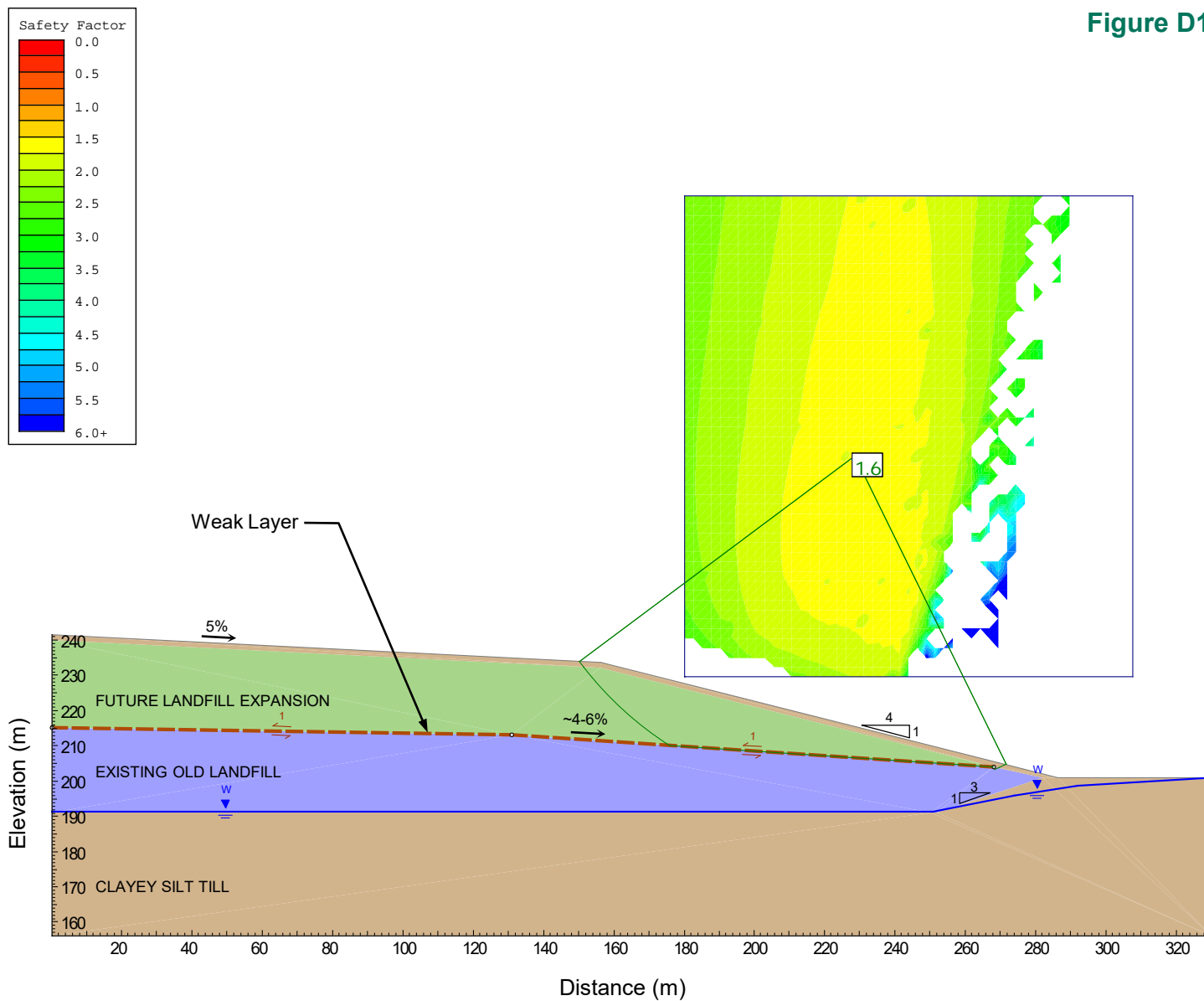
Ridge Landfill Slope Stability Analysis

Old Landfill Exterior Waste Slope

Rotational Failure of Exterior Waste Slope with Weak Layer Along Existing Waste - New Waste Interface

Normal Operating Conditions - Static

Figure D10



Material Name	Color	Unit Weight (kN/m ³)	Cohesion (kPa)	Phi (deg)
Clayey Silt Till	■	21	0	26
Final Clay Cover Material	■	21	0	26
Future Municipal Solid Waste	■	13	20	20
Existing Municipal Solid Waste	■	13	20	20
Weak Layer (Clayey Soil Cover)	■	21	0	26

NOTES:
1. Drained Analysis



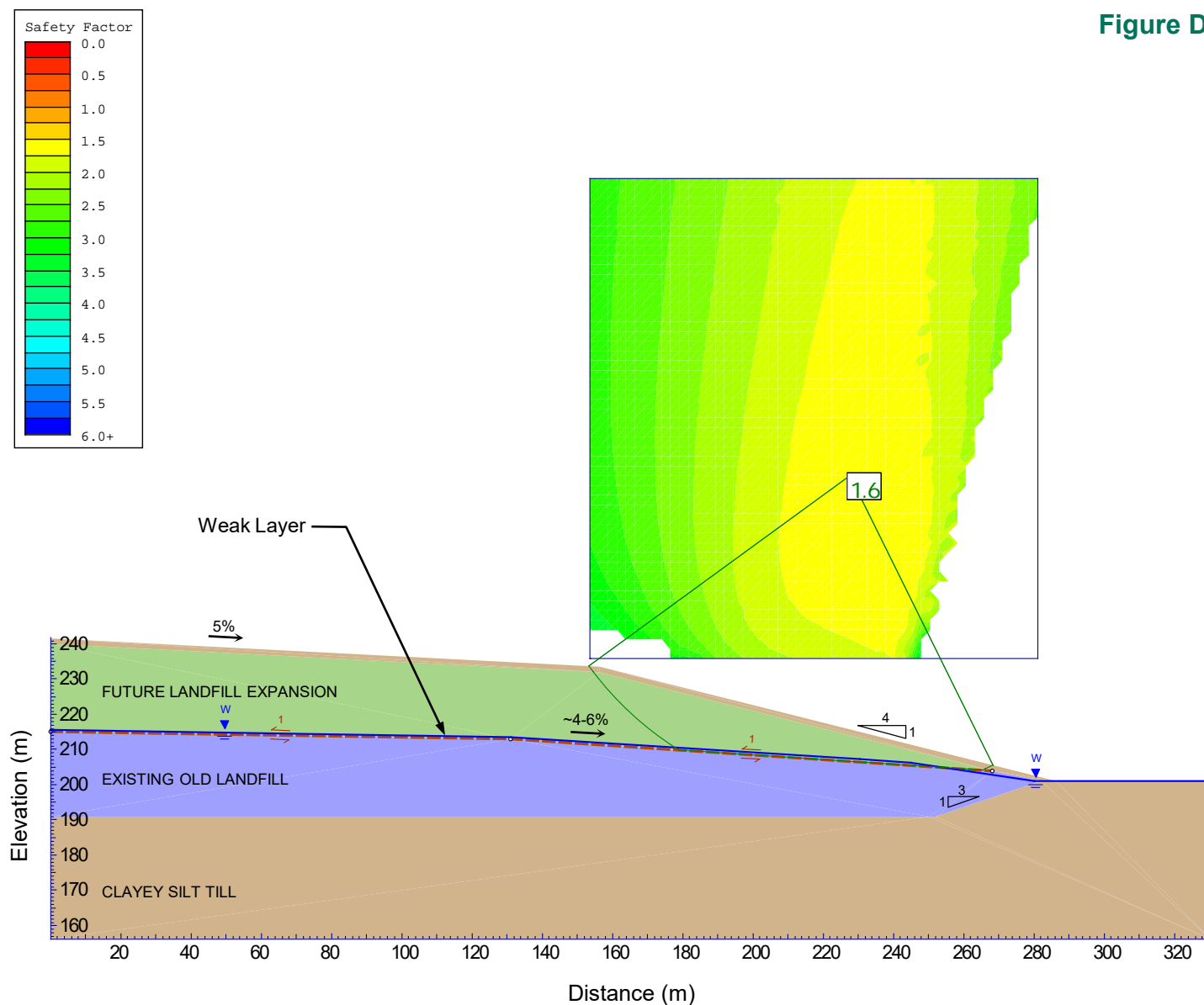
Ridge Landfill Slope Stability Analysis

Old Landfill Exterior Waste Slope

Rotational Failure of Exterior Waste Slope with Weak Layer Along Existing Waste - New Waste Interface

Normal Operating Conditions - Static

Figure D11



Material Name	Color	Unit Weight (kN/m ³)	Cohesion (kPa)	Phi (deg)
Clayey Silt Till	■	21	0	26
Final Clay Cover Material	■	21	0	26
Future Municipal Solid Waste	■	13	20	20
Existing Municipal Solid Waste	■	13	20	20
Weak Layer (Clayey Soil Cover)	■	21	0	15

NOTES:
1. Drained Analysis

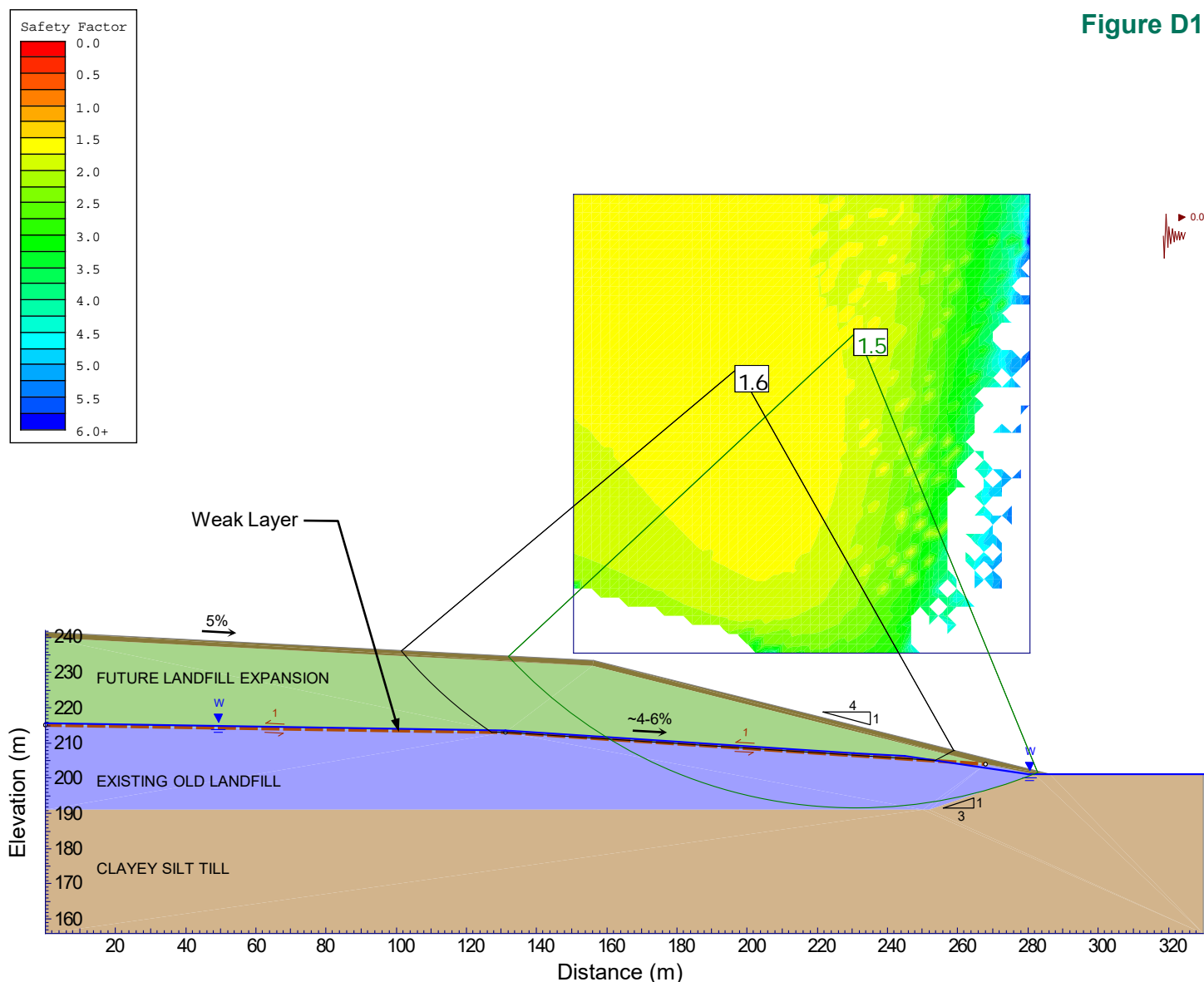


Ridge Landfill Slope Stability Analysis

Old Landfill Exterior Waste Slope

Rotational Failure of Exterior Waste Slope with Weak Layer Along Existing Waste - New Waste Interface
Normal Operating Conditions - Pseudo-Static

Figure D12



Material Name	Color	Unit Weight (kN/m ³)	Cohesion (kPa)	Phi (deg)
Clayey Silt Till	■	21	235	
Final Clay Cover Material	■	21	235	
Future Municipal Solid Waste	■	13	20	20
Existing Municipal Solid Waste	■	13	20	20
Weak Layer (Clayey Soil Cover)	■	21	47	

NOTES:
1. Undrained Analysis