Comprehensive Field Load Test and Geotechnical Investigation Program for Development of LRFD Recommendations of Driven Piles on IGM (FHWA Pooled Fund Study TPF-5-391)

12th TAC Conference Meeting (October 25th, 2021)

Lead Agency: WYDOT

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Duration: Five Years (2019-2023)

Participants: WYDOT, CDOT, IADOT, ITD, MDT, KDOT, and NDDOT

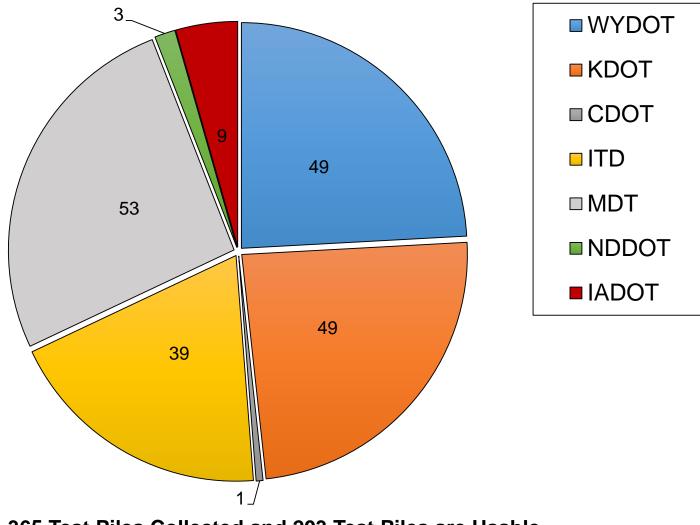


UNIVERSITY OF WYOMING

Meeting Agenda

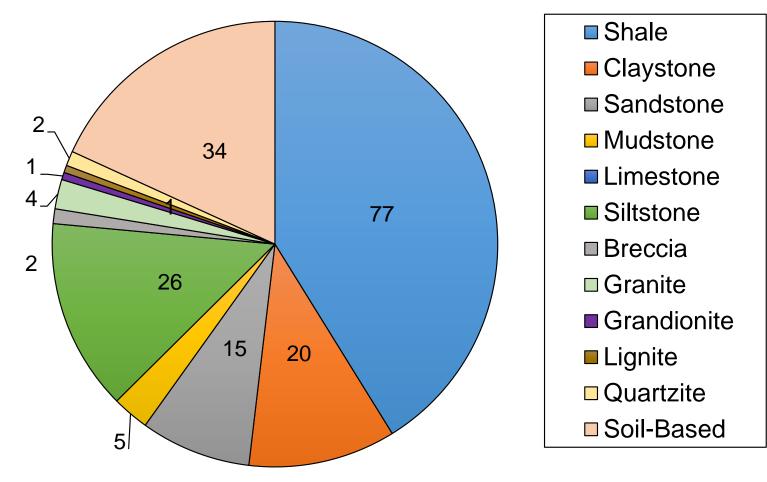
- Summary of Pile Load Test Data
- Electronic Database
- Identification of Bridge Sites
- Pile Load Test Results: NDDOT Cherry Creek Project
- Piles in Rock-Based IGMs
- Variability Analysis: LRFD Calibration
- Variability Analysis: R-Shiny
- Research Team
- Project Schedule
- Project Progress
- Technology Transfer

Task I-1: Summary of Test Pile Data



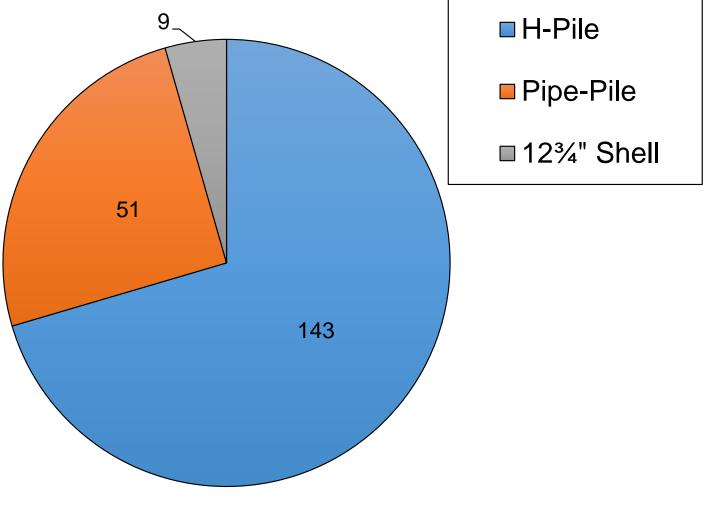
365 Test Piles Collected and 203 Test Piles are Usable

Distribution of Test Piles in Known IGMs



187 Usable Test Piles into Known IGMs

Distribution of Pile Types



203 Usable Test Pile Types

| Discla New I | | ntanaPile | | JNIVERSI df WYOMI | | | | |
|------------------|---------------|----------------------|---|----------------------|-------------|--------------------|----------------------------|-----|
| ID 🚽 | County - | Project Number + | Pile Type | Design Load (kip) | Date Driven | Pile Toe Elevation | Pile embedment at EOD (ft) | • H |
| 1 | Rosebud | STPB 44303(2) | 16" steel pipe pile with conical point with 0.5" wall thickness | 457 | 8/6/2015 | 2460.1 | 28.34 | De |
| 2 | Blaine | STPB 9003(50) | 16" steel OEP with 0.5" wall thickness | 560 | 6/19/2018 | 2305.7 | 82.2 | |
| 3 | Blaine | STPB 9003(50) | 16" steel OEP with inside fit cut shoe with 0.5" wall thickness | 500 | 5/22/2018 | 2311.6 | 50.3 | |
| 4 | Blaine | STPB 9003(50) | 16" steel OEP with inside fit cut shoe with 0.5" wall thickness | 560 | 4/17/2018 | 2312.6 | 76.2 | |
| 5 | Fergus | BR 81-1(11)34 | 24" steel CEP with 0.75" wall thickness | 1057 | 8/15/2007 | 3560.4 | 46.3 | |
| 6 | Fergus | BR 81-1(11)34 | 24" steel CEP with 0.75" wall thickness | 1057 | 8/20/2007 | 3569.5 | 35.3 | |
| 7 | Prairie | BR 253-1(11)4 | 20" steel OEP with 0.5" wall thickness | 674 | | | | |
| 8 | Prairie | BR 253-1(11)4 | 24" steel CEP with 0.75" wall thickness | 832 | 3/21/2007 | 2251.31 | 57.97 | |
| 9 | Musselshell | STPB 9033(27) | 16" steel OEP with inside fit cut shoe with 0.5" wall thickness | 455 | 7/11/2017 | 2896.5 | 32.7 | 1 |
| 10 | Lewis & Clark | IM-NHPB 15-4(128)192 | HP 14 X 117 | | | | | |
| 11 | Lewis & Clark | IM-NHPB 15-4(128)192 | 16" steel pipe pile with conical point with 0.5" wall thickness | | | | | |
| 12 | Lewis & Clark | IM-NHPB 15-4(128)192 | 16" steel pipe pile with conical point with 0.5" wall thickness | | | | | |
| 13 | Lewis & Clark | IM-NHPB 15-4(128)192 | 16" steel pipe pile with conical point with 0.5" wall thickness | | | | | |
| 14 | Lewis & Clark | IM-NHPB 15-4(128)192 | 16" steel pipe pile with conical point with 0.5" wall thickness | | | | | |
| 15 | Lewis & Clark | IM-NHPB 15-4(128)192 | 16" steel pipe pile with conical point with 0.5" wall thickness | 700 | 6/6/2016 | 3927 | 29.47 | |
| 16 | Lewis & Clark | IM-NHPB 15-4(128)192 | 16" steel pipe pile with conical point with 0.5" wall thickness | 670 | 5/3/2016 | 3905.2 | 32.16 | |
| 17 | Lewis & Clark | IM-NHPB 15-4(128)192 | 16" steel pipe pile with conical point with 0.5" wall thickness | 650 | 5/11/2016 | 3912.4 | 48.47 | |
| 18 | Lewis & Clark | IM-NHPB 15-4(128)192 | 16" steel pipe pile with conical point with 0.5" wall thickness | 700 | 3/27/2017 | 3927.5 | 29 | |
| 19 | Lewis & Clark | IM-NHPB 15-4(128)192 | 16" steel pipe pile with conical point with 0.5" wall thickness | 700 | 3/27/2017 | 3928.5 | 27.98 | |
| 20 | Lewis & Clark | IM-NHPB 15-4(128)192 | 16" steel pipe pile with conical point with 0.5" wall thickness | 670 | 5/9/2017 | 3909.9 | 27.5 | |
| 21 | Lewis & Clark | IM-NHPB 15-4(128)192 | 16" steel pipe pile with conical point with 0.5" wall thickness | 650 | 4/10/2017 | 3912.8 | 48.2 | |
| 22 | Golden Valley | BR 9019(12) | 16" steel OEP with inside fit cut shoe with 0.5" wall thickness | 638 | 12/14/2011 | 3459.9 | 27.5 | |
| 23 | Valley | BR 9053(104) | 20" steel OEP with 0.5" wall thickness | 610 | 9/13/2013 | 2413.8 | 45 | |

| -8 | Pile | Load | Tests | List | × |
|----|------|------|-------|------|---|

Pile Load Tests List

| | | KansasI | Pile K | ansa | ç 🛛 | | VIVERSIT | | |
|-------|---------------|------------------------------------|-----------------------------|---------------------|-------------|------------------------|------------------------------|---------------|------------------------|
| New P | ile Load Test | | Depart | ment of Transporta | | VP OF | Wyomii | NG | |
| ID 🗸 | County | Project Number | - Pile Type - | Design Load (kip) - | Date Driven | - Pile Toe Elevation - | Pile embedment at EOD (ft) - | Hammer Type 🛛 | EOD Hammer Stroke (ft) |
| 1 | Franklin | 68-30 KA-2097-01 | HP 12x53 | 190 | | 877.15 | 26 | Delmag D19-42 | 7.5 |
| 2 | Barton | 4-5 KA-0040-01 | HP 10×42 | 132 | 3/6/2013 | 1698.6 | 79 | Delmag D19-42 | 7.0 |
| 3 | Barton | 4-5 KA-0040-01 | HP 12×63 | 232 | 3/6/2013 | 1692.86 | 72 | Delmag D19-42 | 8.0 |
| 4 | Finney | 23-28 KA-0045-01 | HP 10×42 | 153 | 2/7/2014 | 2520.3 | 58 | Delmag D19-42 | 8.0 |
| 5 | Finney | 23-28 KA-0045-01 | HP 12×63 | 252 | 2/7/2014 | 2518.1 | 50 | Delmag D19-42 | 8.8 |
| 6 | Finney | 23-28 KA-0045-01 | HP 12×63 | 226 | 2/7/2014 | 2520.9 | 50 | Delmag D19-42 | |
| 7 | Sheridan | 24-90 KA-0041-01 | 2.75" diameter shell filled | v 130 | 4/2/2014 | 2420.11 | 55 | Delmag D16-32 | 8.0 |
| 8 | Sheridan | 24-90 KA-0041-01 | 2.75" diameter shell filled | x 212 | | 2435.2 | 33 | Delmag D16-32 | 8.5 |
| 9 | Sheridan | 24-90 KA-0041-01 | 2.75" diameter shell filled | v 216 | | 2442.2 | 8 | Delmag D16-32 | 9.0 |
| 10 | Sheridan | 24-90 KA-0041-01 | 2.75" diameter shell filled | v 208 | 2/3/2014 | 2431.3 | 41 | Delmag D16-32 | 7.5 |
| 11 | Sheridan | 24-90 KA-0041-01 | 2.75" diameter shell filled | 1 208 | 4/2/2014 | 2435.29 | 33 | Delmag D16-32 | 9.0 |
| 12 | Sheridan | 24-90 KA-0041-01 | 2.75" diameter shell filled | v 193 | | 2441.2 | 27 | Delmag D16-32 | 8.5 |
| 13 | Sheridan | 24-90 KA-0041-01 | 2.75" diameter shell filled | v 193 | | 2435.2 | 27.05 | Delmag D16-32 | 7.0 |
| 14 | Sheridan | 24-90 KA-0041-01 | 2.75" diameter shell filled | v 120 | | 2438.1 | 42.9 | Delmag D16-32 | 7.5 |
| 15 | Sheridan | 24-90 KA-0041-01 | 2.75" diameter shell filled | 120 | | 2438.1 | 42.90 | Delmag D16-32 | 8.0 |
| 16 | Sedgwick | 235-87 KA-0161-04 | HP 10×42 | 228 | | 1225.53 | 105 | Delmag D19-32 | 6.0 |
| 17 | Sedgwick | 235-87 KA-0161-04 | HP 10×42 | 228 | | 1227 | 80 | Delmag D19-32 | 7.0 |
| 18 | Sedgwick | 235-87 KA-0161-04 | HP 10×42 | 228 | 2/10/2017 | 1224.08 | 105 | Delmag D19-32 | 7.5 |
| 19 | Sedgwick | 235-87 KA-0161-04 | HP 10×42 | 228 | | 1225.2 | 84 | Delmag D19-32 | 7.0 |
| 20 | Sedgwick | 235-87 KA-0161-04 | HP 12×74 | 224 | | 1218.1 | 60 | Delmag D30-02 | 8.5 |
| 21 | Sedgwick | 235-87 KA-0161-04 | HP 12×74 | 332 | | 1218.1 | 70 | Delmag D30-02 | 8.5 |
| 22 | Sedgwick | 235-87 KA-0161-04 | HP 12×74 | 336 | | 1221.4 | 67 | Delmag D30-02 | 8.8 |
| 23 | Sedgwick | 235-87 KA-0161-04 | HP 12×53 | 222 | | 1227.53 | 73 | Delmag D30-02 | 8.5 |
| 24 | Sedgwick | 235-87 KA-0161-04 | HP 12×63 | 308 | | 1215.06 | 68 | Delmag D30-02 | 8.8 |
| 25 | Sedgwick | 235-87 KA-0161-04 | HP 12×74 | 356 | 11/8/2016 | 1218.9 | 47 | Pileco D30-32 | 7.8 |

| Discla | - | | | | | A UN | IIVERSIT' | V | |
|--------|---------------|------------------|------------|-----------------------|------------|---------|------------------------------|---------------|---------------------|
| New P | ile Load Test | VyoPile I | | DEPARTMENT | | | V YOMIN | | |
| D - | County - | Project Number 🚽 | Pile Type | - Design Load (kip) - | | | Pile embedment at EOD (ft) - | Hammer Type 🛛 | EOD Hammer Stroke (|
| 1 | Laramie | 1102005 | HP 14 X 73 | 258 | 2/16/2012 | 5390.54 | 37.6 | Delmag D16-32 | 7.5 |
| 2 | Laramie | 1102005 | HP 14 X 73 | 322 | 11/17/2011 | 5400.55 | 68.3 | Delmag D16-32 | 10.0 |
| 3 | Natrona | N212084 | HP 14 X 73 | 169 | 10/9/2012 | | 24.3 | MVE D-19 | 10.5 |
| 4 | Goshen | N253081 | HP 14 X 73 | 216 | 10/23/2012 | 3989.67 | 100 | MVE D19 | 10.5 |
| 5 | Hot Springs | 0900013 | HP 14 X 73 | 248 | 7/2/2013 | 5154.5 | 27 | ICE 42-S | 10.8 |
| 6 | Sublette | STP-BROS 0C23039 | HP 12 X 53 | 300 | 1/6/2015 | 7076.85 | 23 | APE D19-42 | 11.2 |
| 7 | Laramie | 1806198 | HP 12 X 53 | 188 | 5/4/2015 | 5029.6 | 87.9 | Delmag D16-32 | 11.5 |
| 8 | Laramie | 1806198 | HP 12 X 53 | 188 | 4/30/2015 | 5047.5 | 75.4 | Delmag D16-32 | 11.5 |
| 9 | Laramie | 1806198 | HP 12 X 53 | 202 | 5/7/2015 | 5032.73 | 53,6 | Delmag D16-32 | 8.6 |
| 10 | Laramie | 1806198 | HP 12 X 53 | 202 | 5/13/2015 | 5014.15 | 35.3 | Delmag D16-32 | |
| 11 | Laramie | 1806198 | HP 12 X 53 | 292 | 5/14/2015 | 5016.36 | 38 | Delmag D16-32 | |
| 12 | Laramie | 1806198 | HP 12 X 53 | 172 | 1/29/2015 | 5069.44 | 46.7 | Delmag D16-32 | |
| 13 | Laramie | 1806198 | HP 12 X 53 | 172 | 1/29/2015 | 5072.16 | 44.4 | Delmag D16-32 | |
| 14 | Laramie | 1806198 | HP 12 X 53 | 172 | 1/28/2015 | 5070.26 | 44.7 | Delmag D16-32 | |
| 15 | Laramie | 1806198 | HP 12 X 53 | 172 | 1/28/2015 | 5070.03 | 46.4 | Delmag D16-32 | 9.4 |
| 16 | Natrona | N212084 | HP 14 X 89 | 372 | 1/28/2013 | N/A | 20.5 | MVE D-19 | 8.8 |
| 17 | Goshen | N253081 | HP 14 X 73 | 216 | 1/16/2013 | 4022.3 | 99.2 | Delmag D16-32 | 8.8 |
| 18 | Goshen | N253081 | HP 14 X 73 | 216 | 1/17/2013 | 3982.5 | 139 | Delmag D16-32 | 8.7 |
| 19 | Carbon | 0804234 | HP 12 X 53 | 207 | 5/5/2010 | 6672 | 41.2 | MVE M-19 | 10.0 |
| 20 | Park | 0C11060 | HP 12 X 53 | 120 | 5/26/2009 | 6178.67 | 19.5 | MKT DE 40 | 8.8 |
| 21 | Park | 0C11060 | HP 12 X 53 | 120 | 5/27/2009 | 6171.61 | 36 | MKT DE 40 | 9.5 |
| 22 | Park | 0C11058 | HP 14 X 73 | 162 | 4/18/2006 | 4070.09 | 45 | Delmag D19-42 | 9.6 |
| 23 | Teton | PEB-681 | HP 12 X 53 | | 5/15/1995 | 5961 | 31 | IHC S-35 | 10.0 |
| 24 | Teton | PEB-681 | HP 12 X 53 | | 5/15/1995 | 5956 | 36.5 | IHC S-35 | 8.9 |
| 25 | Teton | PEB-681 | HP 12 X 53 | | 5/15/1995 | 5953 | 39.5 | IHC S-35 | 8.0 |
| 26 | Park | 031-1(61) | HP 14 X 73 | | 10/21/1998 | 5921.72 | 69.75 | ICE 42-S | 8.2 |
| 27 | Park | 031-1(44) | HP 14 X 73 | | 10/17/1996 | 6618.12 | 41 | ICE 42-S | 7.8 |
| 28 | Park | 031-1(44) | HP 14 X 73 | | 10/16/1996 | 6622.2 | 32 | ICE 42-S | |

Pile Load Tests List

New Pile Load Test

IdahoPile



| ID 🚽 | County - | Project Number 🚽 | Pile Type 🚽 | Design Load (kip) 👻 | Date Driven 🚽 | Pile embedment at EOD (ft) 🚽 | Hammer Type 🗣 | EOD blow/ft 🚽 |
|------|------------|------------------|------------------------------|---------------------|---------------|------------------------------|----------------|---------------|
| 1 | Washington | BR-3110(127) | HP 14x117 | 400 | 4/1/2008 | 37 | Delmag D-19-42 | 58 |
| 2 | Washington | BR-3110(127) | HP 14x117 | | 1/15/2009 | | Delmag D-19-42 | |
| 3 | Washington | BR-3110(127) | HP 14x117 | 400 | 6/26/2008 | 36 | Delmag D-19-42 | 187 |
| 4 | Washington | BR-3110(127) | HP 14x117 | 400 | 5/8/2009 | 37 | Delmag D-19-42 | 118 |
| 5 | Washington | BRF-3112(051) | HP 14x117 | | 3/25/2013 | | | |
| 6 | Washington | BRF-3112(051) | HP 14x117 | | 3/25/2013 | | | |
| 7 | Washington | BRF-3112(051) | | | | | | |
| 8 | Washington | BRF-3112(051) | | 575 | | 41.6 | ICE I-30 | 590 |
| 9 | Washington | A013(395) | HP 14x117 | 520 | 4/17/2017 | 68.9 | ICE I-30v2 | 73 |
| 10 | Washington | A013(395) | HP 14x117 | 520 | 4/24/2017 | 68.9 | ICE I-30v2 | 52 |
| 11 | Payette | A013(390) | HP 14x117 | 400 | 6/28/2018 | 42.9 | APED36-26 | 31 |
| 12 | Payette | A013(390) | HP 14x117 | | 8/6/2018 | 54.4 | APED36-27 | 44 |
| 13 | Elmore | A013(947) | HP 14x117 | | 6/13/2015 | 38 | ICE I-30v2 | 52 |
| 14 | Elmore | A013(947) | HP 14x117 | | 5/26/2015 | 39.9 | ICE I-30v2 | 64 |
| 15 | Elmore | A013(947) | HP 14x117 | | 6/4/2015 | 23.8 | | 77 |
| 16 | Elmore | A013(947) | HP 14x117 | | 6/5/2015 | 35.9 | | 69 |
| 17 | Valley | A013(394) | HP 12x74 | 450 | 8/1/2018 | 56 | APE D30-42 | 60 |
| 18 | Valley | A013(394) | HP 12x74 | 450 | 8/1/2018 | 38 | APE D30-42 | 60 |
| 19 | Valley | A013(394) | 1-in thk OEP (filled w/ 4 ks | | 7/18/2018 | 61 | APE D30-42 | 52 |
| 20 | Valley | A013(394) | 1-in thk OEP (filled w/ 4 ks | | 9/10/2018 | 51.8 | APE D30-42 | 61 |
| 21 | Latah | A013(450) | 5-in thk OEP (filled w/ 3 ks | 430 | 7/27/2018 | 48 | ICE I-30 V2 | 23 |

| E Pile L | Pile Load Tests List × | | | | | | | | | | | | | | | | |
|----------|------------------------|---------------------|---------------|------|-----------|------------------------------|-----------------|------|---------------|--|-----------------------|-----------|--|---|------------------------|----------------------------|---------------|
| ⊯Discl | | owaPile | @ IOW/ | ADOT | OF V | niversit Wyomin | °V √G | | @Disc | | hDakotaPi | No | NDD95 th Dakota partment of Transportation | | UNI of W | versit Vomin | y IG |
| ID + | | Project Number | Pile Type | | | Pile embedment at EOD (ft) - | Hammer Type 💂 H | | ID 🚽 | County , | Project Number - | Pile Type | • Design Load (kip) | Date Driven | · Pile Toe Elevation · | Pile embedment at EOD (ft) | - Hammer Type |
| 1 | Franklin | BRF-065-7(35)38-35 | HP 10 X 57 | 250 | 5/5/2020 | 37.6 | Delmag D19-42 | 7.5 | 1 | the second s | HPP-TIP-TCP-1-094(078 | HP 14×102 | 360 | 3/27/2007 | 1540.5 | 90 | Delmag D3 |
| 2 | Franklin | BRF-065-7(35)38-35 | HP 10 X 57 | 250 | 5/5/2020 | 68.3 | Delmag D19-42 | 10.0 | | 1777 C | HPP-TIP-TCP-1-094(078 | HP 14×102 | 360 | 3/27/2007 | 1533.5 | 97 | Delmag D3 |
| 3 | Rockwell | BRF-065-8(57)38-17 | HP 14 X 73 | 250 | 6/19/2020 | 24.3 | Delmag D19-42 | 10.5 | 4 | | | | 300 | and the second se | | | |
| 4 | Rockwell | BRF-065-8(57)38-17 | HP 10 X 42 | 300 | 6/19/2020 | 100 | Delmag D19-42 | 10.5 | 5 | | ty SS-7-806(014)306 | HP 12×53 | | 7/13/2021 | 1953.5 | 67.5 | Delmag D 30 |
| 5 | Wapello | NHSX-063-2(120)3H-9 | HP 10 X 57 | 248 | 11/8/2020 | 27 | Delmag D-22 | 10.8 | * <u>(New</u> | 2 | | | | | | | |
| 6 | Adair | BRF-092-3(36)38-01 | HP 10 X 57 | 300 | 3/8/2020 | 23 | Delmag D-22 | 11.2 | | | | | | | | | |
| 7 | Davis | BRF-012-2(32)38-75 | HP 12 X 53 | 214 | 6/5/2021 | 87.9 | APE D 19-42 | 11.5 | | | | | | | | | |
| 8 | Davis | BRF-012-2(32)38-75 | HP 12 X 53 | 214 | 6/5/2021 | 75.4 | APE D 19-42 | 11.5 | | | | | | | | | |
| 9 | Davis | BRF-012-2(32)38-75 | HP 12 X 53 | 214 | 6/5/2021 | 53.6 | APE D 19-42 | 8.6 | | | | | | | | | |

| 📑 Pile Lo | ad Tests List X | | | | | | | |
|-----------|---------------------------|-----------------------------|---------------------|------------------------------|--------------------|----------------------------|---------------------|--------------------------|
| Oisclair | ColoradoPil | e 106 | | RADO nt of Transpo | | | | |
| New P | Pile Load Test | | | • | Ň | P OF WY | OMP | |
| / ID 🚽 | County - Project Number - | Pile Type 🚽 | Design Load (kip) 🚽 | Date Driven 🚽 | Pile Toe Elevation | Pile embedment at EOD (ft) | Hammer Type 🚽 | EOD Hammer Stroke (ft) 🚽 |
| 1 | 37-UR-135 | HP 14*89 | | | | | Delmag D-25-32 | |
| 2 | 37-UR-135 | HP 14*89 | | | | | Delmag D-25-32 | |
| 3 | 37-UR-135 | HP 14*89 | | | | | Delmag D-25-32 | |
| 4 | 37-UR-135 | HP 14*89 | | 4/10/1998 | | 19.5 | Delmag D-25-32 | |
| 5 | B-24-A0 | | | | | | | |
| 6 | BR 0062-013 | HP 12*53 | | 7/8/2005 | | 50 | 19-32 Open Ended I | 6.5 |
| 7 | BR 0062-013 | HP 12*53 | | 6/27/2005 | | 64 | 19-32 Open Ended I | 6.5 |
| 8 | BR 0062-013 | HP 12*53 | | 6/30/2005 | | 48 | 19-32 Open Ended I | 6.5 |
| 9 | BR 0062-013 | HP 12*53 | | 6/30/2005 | | 78 | 19-32 Open Ended I | 6.5 |
| 10 | BR 0062-013 | HP 12*53 | | 7/8/2005 | | 50 | 19-32 Open Ended I | 6.5 |
| 11 | BR 0072-015 | HP 12*74 | | 8/13/2009 | | 39 | D19-42 open Ended | 7.0 |
| 12 | BR 0101-024 | HP 14*89 | | 12/14/2009 | 4700 | 15.6 | APE Model D30-42 | 12.5 |
| 13 | BR 0101-024 | HP 14*89 | | 12/14/2009 | 4700 | 16.6 | APE Model D30-42 | 12.5 |
| 14 | BR 0251-162 | HP 12 x 74 | | | | | | |
| 15 | BR 0362-027 | | | | | | | |
| 16 | BR 0853-023 | P 12*53 (2:12 Battered Pile | | 3/21/1997 | 4575.1 | 59 | erminghammer B-350 | 8.0 |
| 17 | BR 1151-012 | | | | | | | |
| 18 | BR 2854-105 | HP 12 x 74 | | | | | | |
| 19 | BR 287-3(061) | HP 12*74 | | 10/11/2000 | | 42.2 |)19-32 open ended d | 8.0 |
| 20 | BR 5502-031 | HP 12*53 | | 9/14/2001 | | 18 | D19-32 Open ended | 7.0 |
| 21 | RP 5502-052 | LID 17*\$4/Dattared) | | 10/6/2000 | 0735 5 | 27.5 | 20-27 Onan andad T | 7.0 |

Electronic Database Demo

| | ▤ﻙ੶᠙੶ፄ੶▼ | | | | IdahoPile | : Database- D:\Database Devo | elopment\IdahoPile\Id | lahoPile.accdb (Access | 2016) - Access | | Ha |
|---------|---|--------------------|-------------------|--------------------------|------------------------|------------------------------|-----------------------|------------------------|----------------------------|--------------------------|-----------|
| | File Home Create Exte | rnal Da | ta Da | atabase Tools | Help 🔎 Tell ı | me what you want to do | | | | | |
| | All Access Objects 💿 | ~ | 📲 Pile Lo | oad Tests List $	imes$ | | | | | | | |
| | Search | ρ | @Discla | aimer | | IDAHO | | | | | |
| | Tables | â | Discie | | | | | | NHV/E | DCIT | |
| | Average Subsurface Profile | Â | | Ι | lahoPile | | | | NIVE | N311 | У |
| | 🛄 Idaho Counties | | | | | TRANSP | INITIAL | A. A. | WIX IC | | |
| | Nominal Unit End Bearing | | New F | Pile Load Test | | ORTATION C | | N 🚺 OF | $W \vee U$ | M = M | |
| | Nominal Unit Shaft Resistance | | ∠ ID ⊣ | County - | Project Number | | Design Load (kip) 💂 | Date Driven - Pi | le embedment at EOD (ft) 🚽 | Hammer Type 🚽 H | EOD blow. |
| Table — | Pile Load Test Records | | 1 | Washington | BR-3110(127) | HP 14x117 | 400 | 4/1/2008 | 37 | Delmag D-19-42 | 58 |
| | Pile Types | | 2 | Washington | BR-3110(127) | HP 14x117 | | 1/15/2009 | | Delmag D-19-42 | |
| | | | 3 | Washington | BR-3110(127) | HP 14x117 | 400 | 6/26/2008 | 36 | Delmag D-19-42 | 187 |
| | Static Load Test Results | | 4 | Washington | BR-3110(127) | HP 14x117 | 400 | 5/8/2009 | 37 | Delmag D-19-42 | 118 |
| | Queries | * | 5 | Washington | BRF-3112(051) | HP 14x117 | | 3/25/2013 | | | |
| Query — | 🗾 Usable test piles | | 6 | Washington | BRF-3112(051) | HP 14x117 | | 3/25/2013 | | | |
| | | | 7 | Washington | BRF-3112(051) | | 676 | | 11.6 | LOP L 20 | 500 |
| | Forms | ~ | 8 | Washington | BRF-3112(051) | 110.14.117 | 575 | 4/15/2015 | 41.6 | ICE I-30 | 590 |
| | 🗐 About | | 9 | Washington Washington | A013(395) A013(395) | HP 14x117 HP 14x117 | 520 520 | 4/17/2017 4/24/2017 | 68.9 68.9 | ICE I-30v2 ICE I-30v2 | 73 52 |
| | 🔳 Average Subsurfacce Profile Subform | | 10 11 | Payette | A013(390) | HP 14x117 HP 14x117 | 400 | 6/28/2018 | 42.9 | APED36-26 | 32 |
| | Nominal Unit End Bearing Subform | | 11 | Payette | A013(390) | HP 14x117 HP 14x117 | 400 | 8/6/2018 | 54.4 | APED36-20 APED36-27 | 44 |
| Form — | | | 12 | Elmore | A013(947) | HP 14x117 | | 6/13/2015 | 38 | ICE I-30v2 | 52 |
| | 🔳 Nominal Unit Shaft Resistance Subforn | n <mark>2</mark> – | 14 | Elmore | A013(947) | HP 14x117 | | 5/26/2015 | 39.9 | ICE I-30v2 | 64 |
| | Pile Load Test Records | | 15 | Elmore | A013(947) | HP 14x117 | | 6/4/2015 | 23.8 | | 77 |
| | Pile Load Tests List | | 16 | Elmore | A013(947) | HP 14x117 | | 6/5/2015 | 35.9 | | 69 |
| | | | 17 | Valley | A013(394) | HP 12x74 | 450 | 8/1/2018 | 56 | APE D30-42 | 60 |
| | Static Load Test Results Subform | | 18 | Valley | A013(394) | HP 12x74 | 450 | 8/1/2018 | 38 | APE D30-42 | 60 |
| | | - 1 | 19 | Valley | A013(394) | 1-in thk OEP (filled w/ 4 ks | | 7/18/2018 | 61 | APE D30-42 | 52 |
| | | | 20 | Valley | A013(394) | 1-in thk OEP (filled w/ 4 ks | | 9/10/2018 | 51.8 | APE D30-42 | 61 |
| | | | 21 | Latah | A013(450) | 5-in thk OEP (filled w/ 3 ks | 430 | 7/27/2018 | 48 | ICE I-30 V2 | 23 |
| | | | 22 | Latah | A013(450) | 5-in thk OEP (filled w/ 3 ks | | | 42.9 | ICE I-30 V2 | 52 |
| | | | ••• | ~ * | 1010/050 | | | | ~ ~ ~ | | |

Home Screen

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| Search_ | Q | Disclar | aimer | | IDAHO | | 1 🗳 n | INTIN / D | DCIT | | All Tables 0 " | | Project Number + | State | + County + | Bridge/Structure | → Pile Location → LRF | FD Factored load (+ |
| Idaho Counties | * | | | 1 1 1 1 | | * | | | K > | | Search D | 1 | BR-3110(127) | D | Washington | US-95S Snake River Bridge | 'ile 2 at Abutment | 400 |
| Idaho Counties : Table | | | | dahoPile | | 5 | | | | y | Idaho Counties 🏾 🕆 | 2 | BR-3110(127) | D | Washington | US-95S Snake River Bridge | ile 20 at Abutment | |
| Nominal Unit End Bearing | * | | | | | New York | S. S | $\mathbf{W} I \mathbf{v}$ | | | Idaho Counties : Table | 3 | BR-3110(127) | ID | Washington | US-95S Snake River Bridge | 'ile 1 at Abutment | 400 |
| Nominal Unit End Bearing : Table | | New F | Pile Load Test | | | A CONTRACTOR | | $\sum \left(\frac{X}{4} \right)$ | $\Lambda \Lambda \Pi \Lambda$ | | | 4 | BR-3110(127) | D | Washington | US-95S Snake River Bridge | ile 32 at Abutment | 400 |
| Nominal Unit Shaft Resistance | * | | | - | TATION D | E | | <u>r vv yx</u> | | | Nominal Unit End Bearing 🏾 🕆 | 5 | BRF-3112(051) | ID | Washington | US-95 Weiser River Bridge | Pile 2 at Pier 1 | |
| Nominal Unit Shaft Resistance : Tabl | le | ाD न | ~ | Project Number | ~* | Design Load (kip) | | Pile embedment at EOD (ft) | | | Nominal Unit End Bearing : Table | 6 | BRF-3112(051) | D | Washington | US-95 Weiser River Bridge | 'ile 2 at Abutment | |
| Pile Load Test Records | \$ | 1 | Washington Washington | BR-3110(127) BR-3110(127) | HP 14x117 HP 14x117 | 400 | 4/1/2008 1/15/2009 | 37 | Delmag D-19-42 Delmag D-19-42 | 58 | Nominal Unit Shaft Resistance 3 | 7 | BRF-3112(051) | ID | Washington | US-95 Weiser River Bridge | Pile 2 at Pier 1 | |
| Pile Load Test Records : Table | | 2 | Washington | BR-3110(127) BR-3110(127) | HP 14x117 HP 14x117 | 400 | 6/26/2008 | 36 | Delmag D-19-42 Delmag D-19-42 | 187 | Nominal Unit Shaft Resistance : Table | 8 | BRF-3112(051) | D | Washington | US-95 Weiser River Bridge | Pile 10 at Pier 1 | 575 |
| | | 4 | Washington | BR-3110(127) | HP 14x117 | 400 | 5/8/2009 | 37 | Delmag D-19-42 | 118 | | 9 | A013(395) | D | Washington | SH-51 Snake River Bridge | 'ile 1 at Abutment | 520 |
| Usable test piles | | 5 | Washington | BRF-3112(051) | HP 14x117 | | 3/25/2013 | | č | | Pile Load Test Records 🏾 🕆 | 10 | A013(395) | D | Washington | SH-51 Snake River Bridge | Pile at Abutment 2 | 520 |
| Pile Load Test Records | | 6 | Washington | BRF-3112(051) | HP 14x117 | | 3/25/2013 | | | | Pile Load Test Records : Table | 10 | A013(390) | ID | Pavette | SH-52 UPRR Bridge | 'ile 4 at Abutment | 400 |
| Pile Load Tests List | | 7 | Washington | BRF-3112(051) | | | | | | | | 12 | A013(390) | D | Payette | SH-52 UPRR Bridge | 'ile 4 at Abutment : | 400 |
| Pile Types | * | 8 | Washington | BRF-3112(051) | TTD 4.4.44 | 575 | | 41.6 | ICE I-30 | 590 | Usable test piles | 13 | A013(947) | ID | Elmore | I-84B UPRR Bridge | vile 5 at Abutment | |
| Pile Types : Table | | 9 | Washington Washington | A013(395) A013(395) | HP 14x117 HP 14x117 | 520 520 | 4/17/2017 4/24/2017 | 68.9 | ICE I-30v2 ICE I-30v2 | 73 52 | Pile Load Test Records | | | | Elmore | - | 'ile 5 at Abutment : | |
| Static Load Test Results | | 10 | Pavette | A013(390) | HP 14x117 HP 14x117 | 400 | 6/28/2018 | 42.9 | APED36-26 | 32 | | 14 | A013(947) | ID | | I-84B UPRR Bridge | | |
| | ~ | 12 | Pavette | A013(390) | HP 14x117 | 400 | 8/6/2018 | 54.4 | APED36-27 | 44 | Pile Load Tests List | 15 | A013(947) | ID | Elmore | I-84B UPRR Bridge | Pile 5 at Pier 1 | |
| Static Load Test Results : Table | | 13 | Elmore | A013(947) | HP 14x117 | | 6/13/2015 | 38 | ICE I-30v2 | 52 | Pile Types 🏾 🕆 🚽 | 16 | A013(947) | ID | Elmore | I-84B UPRR Bridge | Pile 12 at Pier 2 | |
| Average Subsurface Profile | * | 14 | Elmore | A013(947) | HP 14x117 | | 5/26/2015 | 39.9 | ICE I-30v2 | 64 | Pile Types : Table | 17 | A013(394) | ID | Valley | SH-55 NF Payette River Bridge | 'ile 4 at Abutment | 450 |
| Average Subsurface Profile : Table | | 15 | Elmore | A013(947) | HP 14x117 | | 6/4/2015 | 23.8 | | 77 | | 18 | A013(394) | ID | Valley | SH-55 NF Payette River Bridge | vile 7 at Abutment : | 450 |
| Unrelated Objects | × | 16 | Elmore | A013(947) | HP 14x117 | | 6/5/2015 | 35.9 | | 69 | Static Load Test Results | 19 | A013(394) | ID | Valley | SH-55 NF Payette River Bridge | 'ile 1 at Center Pie | |
| | | 17 | Valley | A013(394) | HP 12x74 | 450 450 | 8/1/2018 | 56 | APE D30-42 | 60 | Static Load Test Results : Table | 20 | A013(394) | D | Valley | SH-55 NF Payette River Bridge | 'ile 4 at Center Pie | |
| | | 18 | Valley Valley | A013(394) A013(394) | HP 12x74 1-in thk OEP (filled w/ 4 ks | | 8/1/2018 7/18/2018 | 38 | APE D30-42 APE D30-42 | 60 52 | Average Subsurface Profile * | 21 | A013(450) | ID | Latah | Robinson Park Road Bridge | 'ile 1 at Abutment | 430 |
| | - | 20 | Valley | A013(394) A013(394) | 1-in thk OEP (filled w/ 4 ks | | 9/10/2018 | 51.8 | APE D30-42 APE D30-42 | 61 | 5 | 22 | A013(450) | D | Latah | Robinson Park Road Bridge | 'ile 8 at Abutment : | |
| | | 20 | Latah | A013(450) | 5-in thk OEP (filled w/ 3 ks | 430 | 7/27/2018 | 48 | ICE I-30 V2 | 23 | Average Subsurface Profile : Table | 23 | A018(853) | ID | Caribou | SH-34 Tincup Creek Bridge | 'ile 1 at Abutment | |
| | | 22 | Latah | A013(450) | 5-in thk OEP (filled w/ 3 ks | | | 42.9 | ICE I-30 V2 | 52 | Unrelated Objects ¥ | 24 | A018(853) | ID | Caribou | SH-34 Tincup Creek Bridge | lile 7 at Abutment : | |
| | | 23 | Caribou | A018(853) | HP 12x74 | | 10/26/2018 | 31.6 | Delmag D-19-42 | 228 | 100 | 25 | A014(023) | ID | Lemhi | SH-28 Lemhi River Bridge | 'ile 2 at Abutment | |
| | | | ~ * | | | | | | n | | | | | 10 | | and a second second | | |

Pile Load Test List Form

Pile Load Test Record

8 File

| 🔚 🏷 + 🖓 + 🔻 IdahoRile : Database DavletopmentijdahoRilei accdb (Access 2016) - Access 🚺 😽 Ha | I le Load Test Records | – 🗆 X |
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| File Home Create External Data Database Tools Help 🔑 Tell me what you want to do | | |
| All Tables • • • Piet tood Test Lite • Servit. • • • • • • • • • • • • • • • • • • • | UNIVERSITY Pile Load Test Record Form OF WYOMING All Record Data Entered? | |
| Nominal Unit Shaft Resistance * | #Print @Close | |
| Pile Load Text Records 8 2 Vashington B8/5110(127) 119 14:117 10 0.05000 36 Delmap D-19-42 1187 Image: Distribution of the state of the stat | D: Project No. BR-3110(127) County: Washington State: ID Bridge/Structure: US-95S Snake River Bridge Pile Location: Pile 2 at Abutment 1 1. Pile Size. HP 14x117 2. Date Driven. 4/1/2008 3. LRFD Pile Load (kips). 400 4. ASD Load (kip). Delmag D-19-42 | |
| | 6. Pile Embedment at EOD (ft) | |
| Additional | 7. Elevation at the Top of the Test Pile (ft) | |
| Information | 8. Elevation at the Bottom Tip of the Test Pile (ft). Subsurface Profile Nominal Unit Shaft Resistance (ksf) Nominal Unit Endbearing (ksf) Driving Information Dynamic Test and Analysis Results Stati | |
| for Test | Average Subsurfacce Profile Record Comments: | |
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Pile Load Test Record Form (Data View)

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| Idaho Counties * | | | 🔹 🧥 🎽 丨 | | R CIT | | |
| Idaho Counties : Table | IdahoPile | | | | I ICJI | y | All Record Data Entered? |
| Nominal Unit End Bearing * | | | S | \mathbf{W}/\mathbf{x} | | \frown | |
| Nominal Unit End Bearing : Table | New Pile Load Test | Contraction of the second | N 🚺 (| of X / V(| \mathcal{M} | Т | ©Print ©Close |
| Nominal Unit Shaft Resistance * | D - County - Project Number | Pile Type Design | Load (kip) - Date Driven | Pile embedment at EOD (ft) | Hammer Type - E0 | D blow/: | |
| Nominal Unit Shaft Resistance : Table Pile Load Test Records | 1 Washington BR-3110(127) | HP 14x117 | 400 4/1/2008 | 37 | Delmag D-19-42 | 58 | ID: (New) Project No. |
| Pile Load Test Records : Table | 2 Washington BR-3110(127) 3 Washington BR-3110(127) | HP 14x117 HP 14x117 | 1/15/2009 400 6/26/2008 | 36 | Delmag D-19-42 Delmag D-19-42 | 187 | |
| Usable test piles | 4 Washington BR-3110(127) | HP 14x117 | 400 5/8/2009 | 37 | Delmag D-19-42 | 118 | County: State: State: |
| Pile Load Test Records | 5 Washington BRF-3112(051) | HP 14x117 | 3/25/2013 3/25/2013 | | | | |
| Pile Load Tests List | 6 Washington BRF-3112(051) 7 Washington BRF-3112(051) | HP 14x117 | 3/25/2013 | | | | Bridge/Structure: |
| Pile Types | 8 Washington BRF-3112(051) | | 575 | 41.6 | ICE I-30 | 590 | |
| Pile Types : Table | 9 Washington A013(395) 10 Washington A013(395) | | 520 4/17/2017 520 4/24/2017 | 68.9 68.9 | ICE I-30v2 ICE I-30v2 | 73 52 | Pile Location: |
| Static Load Test Results * | 11 Payette A013(390) | HP 14x117 | 400 6/28/2018 | 42.9 | APED36-26 | 31 | 1. Pile Size |
| Static Load Test Results : Table | 12 Payette A013(390) | HP 14x117 | 8/6/2018 | 54.4 | APED36-27 | 44 52 | 1. FIIG 5126 |
| Average Subsurface Profile * | 13 Elmore A013(947) 14 Elmore A013(947) | HP 14x117 HP 14x117 | 6/13/2015 5/26/2015 | | ICE I-30v2 ICE I-30v2 | 64 | 2. Date Driven |
| Average Subsurface Profile : Table | 15 Elmore A013(947) | HP 14x117 | 6/4/2015 | 23.8 | | 77 | |
| Unrelated Objects ¥ | 16 Elmore A013(947) 17 Valley A013(394) | HP 14x117 HP 12x74 | 6/5/2015 450 8/1/2018 | 35.9 | APE D30-42 | 69 60 | 3. LRFD Pile Load (kips) |
| | 18 Valley A013(394) | | 450 8/1/2018 | 38 | APE D30-42 APE D30-42 | 60 | |
| | 19 Valley A013(394) | 1-in thk OEP (filled w/ 4 ks | 7/18/2018 | 61 | APE D30-42 | 52 | 4. ASD Load (kip) |
| | 20 Valley A013(394) 21 Latah A013(450) | 1-in thk OEP (filled w/ 4 ks 5-in thk OEP (filled w/ 3 ks | 9/10/2018 430 7/27/2018 | | APE D30-42 ICE I-30 V2 | 61 23 | 5. Type of Hammer Used |
| | 22 Latah A013(450) | 5-in thk OEP (filled w/ 3 ks | | 42.9 | ICE I-30 V2 | 52 | |
| | 23 Caribou A018(853) | HP 12x74 | 10/26/2018 | 31.6 | Delmag D-19-42 | 228 | 6. Pile Embedment at EOD (ft) |
| | | | | | | | |
| | | | | | | | 7. Elevation at the Top of the Test Pile (ft) |
| | | | | | | | 8. Elevation at the Bottom Tip of the Test Pile (ft) |
| | | | | | | | Subsurface Profile Nominal Unit Shaft Resistance (ksf) Nominal Unit Endbearing (ksf) Driving Information Dynamic Test and Analysis Results Stati |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | Average Subsurfacee Profile Record Comments: |
| | | | | | | | Layer +1 Geomaterial + Description + AASHTO Cla + Thickness (ft) + SPT N + (N1)60 + Unit wt (pc |
| | | | | | | | |
| | | | | | | | * 0 0 |
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| | | | | | | | Attachments (1): |
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Pile Load Test Record Form (New Input)

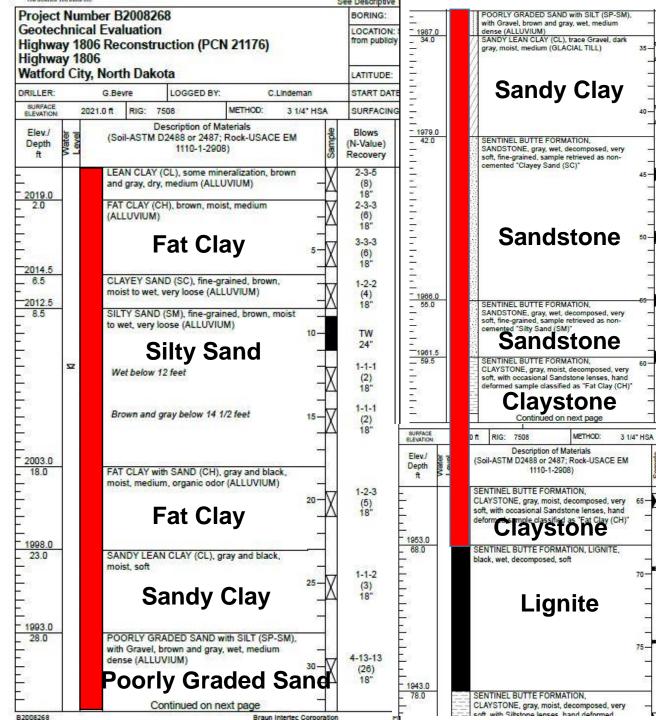
Task I-3: Summary of Bridge Projects for Field Tests

| DOT | Test | Bridge Sites | IGM Type |
|---------|-------------|---|---|
| WYDOT | 2 SLTs + | 1) Lodgepole Creek Bridge in 2019 | Siltstone |
| VV IDOT | PDAs | 2) I-80 Interchange Bridge in 2021 | Siltstone |
| | 2 SLTs + | 1) Wapello Bridge in 2020 | Shale |
| IADOT | PDAs | 2) Adair Bridge in 2020 | Shale |
| | 14 PDAs | 3) Bridge Projects for Dynamic Testing | Mainly Shale |
| KDOT | 2 SLTs+PDA | North Junction, Wichita in 2022 | Shale |
| CDOT | 3 SLTs+PDAs | Bridge I-05-V over Gunnison River in 2022 Bridge E-17-GX, York St under I-76 in 2022 Bridge J-17-XA, CO115 over Rock Creek Pass in 2023 | Shale Siltstone/Claystone Claystone |
| NDDOT | 1 SLT+PDA | 1) Cherry Creek Bridge in 2021 | Claystone/Lignite |





| Day | Date | Description |
|-----------|-------|---|
| Monday | 07/12 | Sensor Installation & Protection; Steel Angle Welding |
| Tuesday | 07/13 | Pile Installation; 1-hr Restrike |
| Wednesday | 07/14 | 24-hour Restrike; Load Frame Installation; Static Load Test Setup and Testing |



NDDOT Highway 1806 at Cherry Creek Bridge

Overburden: Fat Lean Clay, Silty Sand, Poorly Graded Sand and Sandy Clay (Glacial Till).

Pile: HP12x53

22-3-4 (7) 16"

2-3-4 (7) 17"

17-28 (28) 12"

16-19

(19)

20-22

(22)

21-35 (35) 12"

SURFACING

Blows

(N-Value)

Recovery

26-35 (35) 12"

25/3

(REF)

30/3*

(REF)

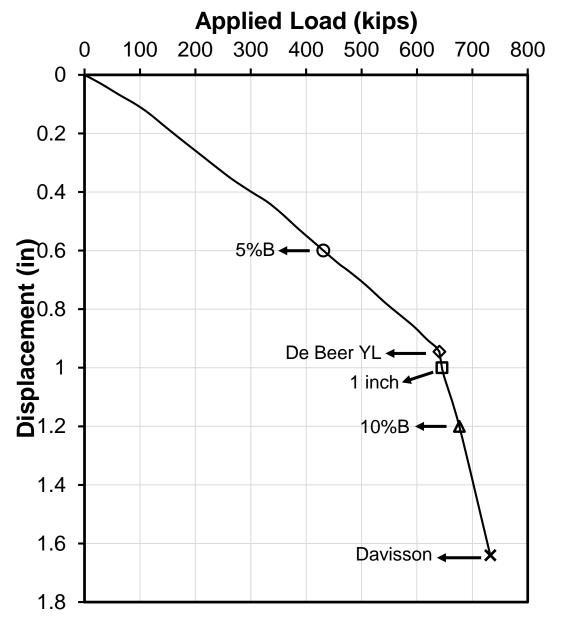
18-24

IGM: Sandstone, Claystone, Lignite

Hammer: Delmag D 30-32

| CAPWAP Analysis at Event | Embedded Pile Length (ft) | Bearing Layer | Total Resistance (kip) | Shaft Resistance (kip) | End Bearing (kip); % | Hammer Blow Count (b/ft) |
|---------------------------------------|---------------------------------|------------------|------------------------------|------------------------------|-------------------------|-----------------------------|
| Pile initial driving BN: 130 (E-1) | 50 | Sandstone | 165 | 134 | 31; 19.1 | 10 |
| Pile initial driving BN: 275 (E-2) | 60 | Sandstone | 288 | 246 | 42; 14.7 | 19 |
| Pile initial driving BN: 409 (E-3) | 66 | Claystone | 367 | 339 | 28; 7.6 | 25 |
| Pile initial driving BN: 442 EOD | 67 | Lignite | 429 | 403 | 26; 6.2 | 28 |
| 1-hr restrike | 67.52 | Lignite | 791 | 756 | 35; 4.5 | 192 |
| 24-hr restrike | 67.54 | Lignite | 820 | 785 | 35; 4.3 | 192+ |

Note: E=Event



| Failure Cr | iterion | R (kips) | R/Pu | S/B(%) |
|-----------------------------|--------------|----------|------|--------|
| | Davisson | 732.5 | 0.95 | 13.67 |
| Gradual Failure Methods | De Beer YL | 640.6 | 0.83 | 7.88 |
| | Fuller & Hoy | 640 | 0.83 | 7.88 |
| | Chin-Kondner | 1666.7 | 2.15 | - |
| Plunging Failure Methods | De Court | 1996.5 | 2.58 | - |
| | Van Der Veen | 860 | 1.2 | - |
| | 10%B | 676.5 | 0.87 | 10 |
| Settlement Based Methods | 5%B | 431.1 | 0.56 | 5 |
| | 1 inch | 645.2 | 0.83 | 8.33 |
| Others | Mazurkiwicz | 1000 | 1.29 | - |

NOTE: R= Total Resistance; P_u = Structural Capacity;

S = Settlement; B = Pile Dimension

| | | Unit Shaft resistance (ksf) | | | | | | | | | | |
|-----------|------------|-----------------------------|------|------|------|------------------|-------------------|---------|--|--|--|--|
| IGM | Depth (ft) | E-1 | E-2 | E-3 | EOD | 1-hr Restrike | 24-hr Restrike | SLT (D) | | | | |
| Sandstone | 42-50 | 0.6 | 1.95 | 3.15 | 3.35 | 7.3 | 7.72 | 3.68 | | | | |
| Sandstone | 50-60 | | 1.9 | 2.92 | 4.45 | 8.1 | 7.66 | 7.97 | | | | |
| Claystone | 60-66 | | | 0.9 | 0.57 | 2.32 | 2.33 | 5.47 | | | | |
| Lignite | 66-67.54 | | | | 0.52 | 1.7 | 1.74 | 3.83 | | | | |

Note: E-1=Pile initial driving BN130; E-2=Pile initial driving BN275; E-3=Pile initial driving BN409; SLT(D)= Static load test based on Davisson criterion.

| | | Unit End Bearing (ksf) | | | | | | | | | | |
|-----------|---------------|------------------------|-------|-------|-------|------------------|-------------------|---------|--|--|--|--|
| IGM | Depth (ft) | E-1 | E-2 | E-3 | EOD | 1-hr Restrike | 24-hr Restrike | SLT (D) | | | | |
| Sandstone | 50 | 32.04 | | | | | | | | | | |
| Sandstone | 60 | | 43.13 | | | | | | | | | |
| Claystone | 66 | | | 28.48 | | | | | | | | |
| Lignite | 67.5 to 67.54 | | | | 26.96 | 36.11 | 35.91 | 19.54 | | | | |

Note: E-1=Pile initial driving BN130; E-2=Pile initial driving BN275; E-3=Pile initial driving BN409; SLT(D)= Static load test based on Davisson criterion.

Phase II

Task II-2: Pile Resistance Estimation:

Rock-Based IGM Validation

Proposed Pile Resistance Estimation Methods For Piles in Rock-IGMs

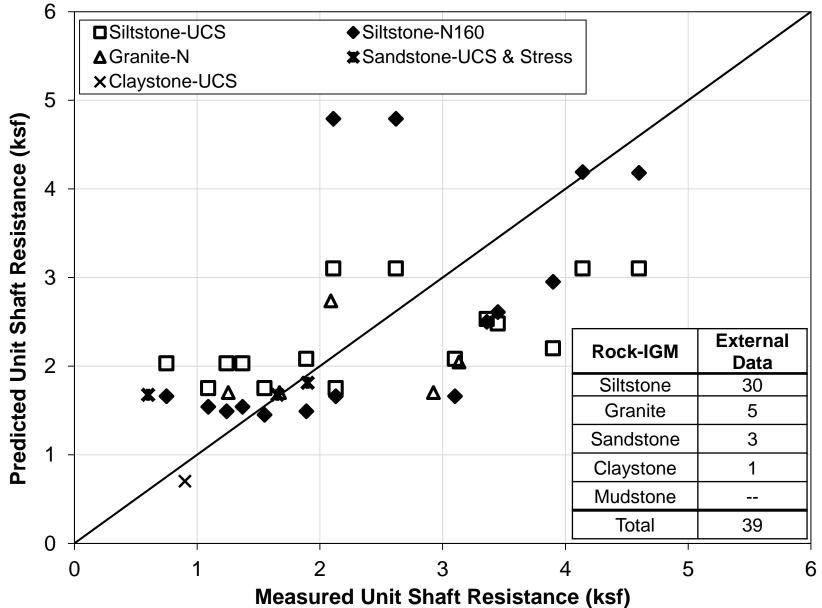
| Steel Pile Type | Rock-IGM | Proposed Static Equation for Unit Shaft Resistance (\overline{q}_s) |
|-----------------|-----------|--|
| H-Pile | Granite | $\hat{q}_s = \left[0.7\frac{N}{43} - 0.5\right]P_a$ |
| H & Pipe Pile | Siltstone | $\hat{q}_s = 0.45 q_u^{0.44} \text{ or } \hat{q}_s = 0.42 P_a \left[\frac{(N_1)_{60}}{16}\right]^{0.63}$ |
| H & Pipe Pile | Claystone | $\hat{q}_s = 0.74(q_u)^{0.305}$ |
| H & Pipe Pile | Mudstone | $\hat{q}_s = 6.19 \left[1 - e^{\left(-0.052 \frac{N \times \sigma'_v}{19} \right)} \right]$ |
| H-Pile | Sandstone | $\widehat{q_s} = \frac{2.8(q_u \times \sigma_v')}{19.58 + (q_u \times \sigma_v')}$ |

Proposed Pile Resistance Estimation Methods For Piles in Rock-IGM

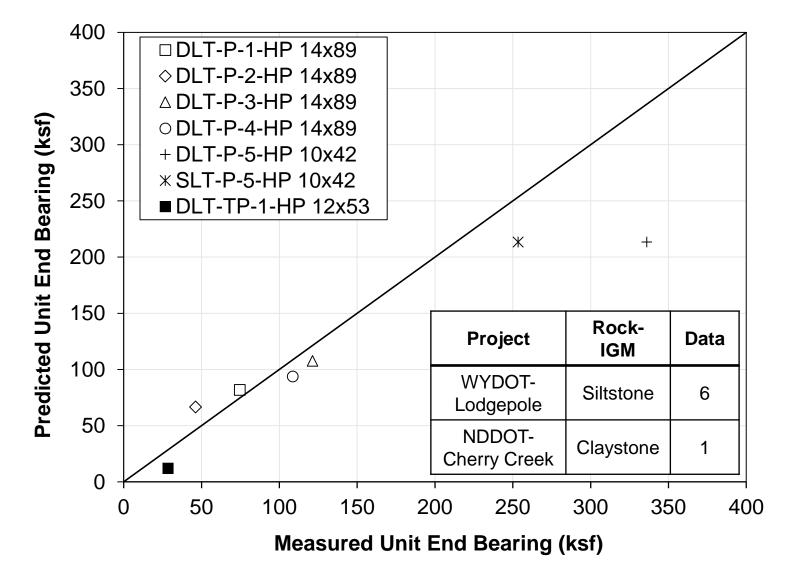
| Steel Pile Type | Rock-IGM | Proposed Static Equation for Unit End Bearing (\overline{q}_{p}) |
|-----------------|-----------------------------------|--|
| H & Pipe Pile | Siltstone | $\hat{q}_p = 12.9P_a \left[2.43^{\left(\frac{32.4N}{30D_B}\right)} \right]$ |
| H & Pipe Pile | Claystone | $\widehat{q_p} = \frac{313.27q_u}{20.96 + q_u}$ |
| Pipe Pile | Mudstone (Limited Sample Size) | $\widehat{q_p} = 35.71 q_u^{0.93}$ |

 D_B -Total pile penetration; P_a -Atmospheric pressure; q_u -Unconfined compressive strength

Rock-Based IGM Validation-Unit Shaft Resistance



Rock-Based IGM Validation-Unit End Bearing



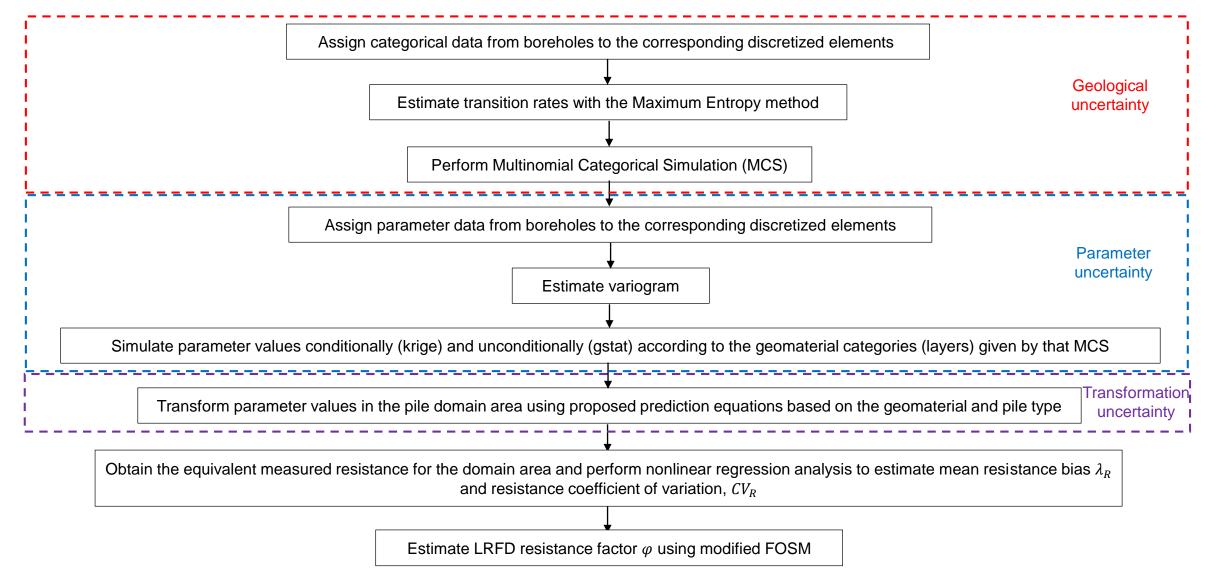
New Pile Data?

Task II-4: Variability Analysis (Spatial Uncertainty Consideration in The Development of LRFD Static Analysis Methods)

Introduction

- The need for spatial (parameter and geological) uncertainty:
 - The estimation of pile resistance during the design process depends on the geomaterial parameter and its associated uncertainty (inherent variability).
 - The characterization of geomaterial layer boundary positions is critical to the design of an adequate deep foundation (geological uncertainty).
- Objectives:
 - Formalize a procedure for characterizing and analyzing uncertainties in a design in which geomaterial and pile specific prediction equations have been obtained.
 - Consider cross-site uncertainties in estimation of LRFD resistance factor.

Method



LRFD Calibration

• Modified FOSM LRFD Calibration is given by:

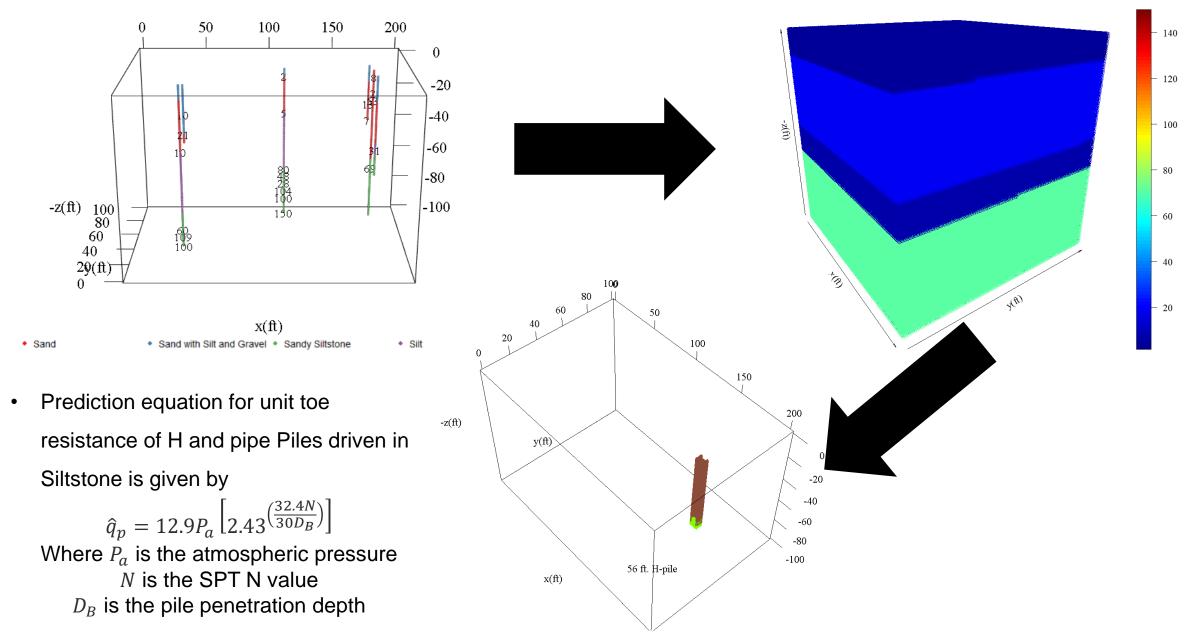
$$\varphi = \frac{\lambda_r \left(\gamma_D \times \frac{Q_D}{Q_L} + \gamma_L\right) \times \sqrt{\frac{1 + CV_Q^2}{1 + CV_R^2}}}{\left(\lambda_{QD} \times \frac{Q_D}{Q_L} + \lambda_{QL}\right) \times exp\left(\beta \times \sqrt{\ln\left((1 + CV_R^2) + (1 + CV_Q^2)\right)}\right)}$$
where; $\gamma_D = 1.25$, $\gamma_L = 1.75$, $\frac{Q_D}{Q_L} = 2$, $\lambda_{QD} = 1.08$, $\lambda_{QL} = 1.15$, $CV_{QD} = 0.128$, $CV_{Ql} = 0.18$, and
$$CV_Q^2 = \frac{\left(\lambda_{QD} \frac{Q_D}{Q_L} CV_{QD}\right)^2 + \left(\lambda_{QL} CV_{Ql}\right)^2}{\left(\lambda_{QD} \frac{Q_D}{Q_L}\right)^2 + 2\frac{Q_D}{Q_L}\lambda_{QD}\lambda_{QL} + \lambda_{QL}^2}$$

NHI (1998) assumed the coefficient of variation of the load CV_Q in the initial FOSM LRFD calibration as the equation below:

$$CV_Q^2 = CV_{QD}^2 + CV_{QL}^2$$

These equations resulted in lower than actual resistance factors. The FOSM resistance factor equation can be made closer to those of the FORM and Monte Carlo.

Example: Lodgepole Creek Site



LRFD Resistance Factors (End Bearing on Siltstone)

LRFD resistance factor considering **spatial** and transformation uncertainties

| Pile Types | Rock- | | | | | MFOSM | | | |
|---------------|-----------|----------------|--------------|---|--------|----------------------|----------------------|--|--|
| | Based | Sample Size | Mean Bias | Simulation Type | CV_R | β _T =2.33 | β _T =3.00 | | |
| | IGM | OILO | | .,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,, | | φ | φ | | |
| H & Pipe Pile | Siltstone | 20 | 1.00 | Conditional | 0.52 | 0.36 | 0.26 | | |
| H & Pipe Pile | Siltstone | 20 | 1.04 | Unconditional | 0.53 | 0.36 | 0.26 | | |

LRFD resistance factor considering transformation uncertainty alone

| | Rock- | | | | MFOSM | | | |
|---------------|-----------|----------------|--------------|--------|----------------------|----------------------|--|--|
| Pile Types | Based | Sample Size | Mean Bias | CV_R | β _T =2.33 | β _T =3.00 | | |
| | IGM | OIZC | Blas | | ф | ф | | |
| H & Pipe Pile | Siltstone | 20 | 1.03 | 0.47 | 0.42 | 0.31 | | |

Concluding Remarks

- A prediction equation is usually obtained using regression analysis based on a regional data set but may be used in different locations with the same geomaterial conditions. However, only the prediction error (transformation uncertainty) is considered.
- This study considers the spatial uncertainty involved in applying the prediction equation for the estimation of pile resistance and the LRFD resistance factor. Spatial uncertainty is incorporated by inputting the simulated parameter value into the prediction equation, and this results in a predicted resistance that adjusts for the spatial location.
- The study provides a background to study the effect of site investigation on pile design.

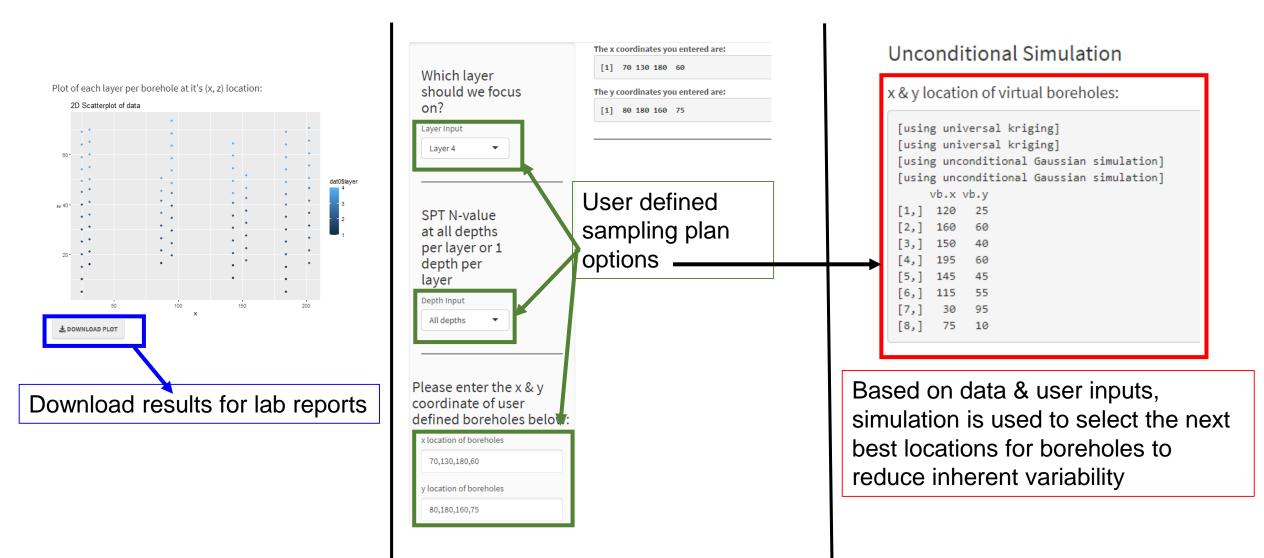
Task II-4: Variability Analysis (Additional Task: R-Shiny)

R-Shiny Demo

Application of R Shiny for Inherent Variability

| Inherent Variability | | | Navigation and current |
|--|---|---|--|
| Enter Data Explore Data Model Selection | Select Model Layer Pairwise Comparison | Borehole Sampling Plan Virtual Boreholes | options within the application |
| CSV or Text Viewer ? Choose CSV File BROWSE Iowa.csv | User provided data: Show 10 • entries ïSurface.Elevationft + BH | ? Search: I.No. ♦ Latitude ♦ Longitude ♦ Distanceftx.axis | |
| Upload complete | 1 650 | 1 40.98748 -92.40338 2 | 5 |
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| | | 1 40.98748 -92.40338 2 | ⁵ Please upload a .csv or .txt file and use the options below to format the data correctly. |
| Separator | matting options | 1 40.98748 -92.40338 2 | 5 |
| Comma | 8 650 | 1 40.98748 -92.40338 2 | 5 OK |
| Semicolon Tab | 9 650 | 1 40.98748 -92.40338 2 | 5 |
| Ouote | 10 650 | 1 40.98748 -92.40338 2 | 5 |
| None | Showing 1 to 10 of 92 entries | Previous 1 2 3 4 5 10 Next | |
| Double Quote Single Quote | | | _ |
| | | | |
| | Please check the data ma | tches the column names: | _ |
| Is this data 2D or | Show 10 v entries | Search: | |
| 3D? | $\mathbf{x} \Leftrightarrow \mathbf{y} \Leftrightarrow$ | z 💠 layer 💠 SPT N-Value | |
| Data Dimensions | 1 25 29 | 5 1 | |

Application of R Shiny for Inherent Variability



Next Steps

- Incorporate geological uncertainty through the layer boundaries
- Incorporate additional analyses for inherent variability
 - Conditional simulation
 - 1 depth per layer
- Test the production with additional datasets and users
- Develop user manual
- Implement a code maintenance plan



Project Schedule

| Took | Task Task Description | | 2019 | | | | 2020 | | | 2021 | | | 2022 | | | | 2023 | | | | |
|------|--------------------------------|----|------|----------------|-------|----|---------------|----------------|----|---------------|----------|----------|---------------|----|-----------|----|------|----|----|----|----|
| Task | Task Description | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 |
| I-1 | Historical Data Collection | | | | | | | $ \rightarrow$ | | | | | | | | | | | | | |
| I-2 | Electronic Database | | | Ç 22222 | | | | | | | | | | | | | | | | | |
| I-3 | Identify Project Sites | | | | | | | | | | | | | | | | | | | | |
| I-4 | Geotechnical Investigation | | | | | | | | | | | | \rightarrow | | | | | | | | |
| I-5 | Static Pile Load Test | | | | | | | | | | | | | | \mapsto | | | | | | |
| I-6 | Reporting | | | | | | | | | | | | | | | | | | | | |
| II-1 | Data Interpretation | | | 4 <u></u> | | | | | | | | | | | | | | | | | |
| II-2 | Pile Resistance Estimation | | | | ¢1111 | | | | | | | | | | | | | | | | |
| II-3 | Pile Setup/Relaxation | | | | | | | | | (<u>1111</u> | | | | | | | | | | | |
| 11-4 | Variability Analysis | | | | ¢ | | | hunn | | | | | | | | | | | | | |
| II-5 | LRFD Resistance Factors | | | | | | (<u>1111</u> | | | | | | | | | | | | | | |
| II-6 | Cost-Benefit Analysis | | | | | | | | | | (| | | | | | | | | | |
| II-7 | Outcome and Recommendations | | | | | | | | | | | 4 | | | | | | | | | |
| II-8 | Reporting | | | | | | | | | | | | | | | | | | | | |

September 30, 2021

Project Progress

| Task | Description | Expected Percent Completion (Time) | Actual Percent Completion | Difference | |
|------|---|---------------------------------------|------------------------------|------------|--|
| I-1 | Historical Pile Data Collection | 100.00% | 100.00% | 0.00% | |
| I-2 | Expand Electronic Database | 61.50% | 85.71% | 24.21% | |
| I-3 | Identify Bridge Projects for Field Test | 100.00% | 83.33% | -16.67% | |
| I-4 | Detailed Geotechnical Investigation | 100.00% | 58.33% | -41.67% | |
| I-5 | Innovative Static Load Tests | 100.00% | 41.67% | -58.33% | |
| I-6 | Reporting for Phase I | 49.73% | 0.00% | -49.73% | |
| II-1 | Geotechnical and Pile Data Interpretation | 100.00% | 100.00% | 0.00% | |
| II-2 | Pile Resistance Estimation | 62.55% | 92.86% | 30.31% | |
| II-3 | Pile Setup/Relaxation Investigation | 0.00% | 30.00% | 30.00% | |
| 11-4 | Variability Analysis | 37.31% | 40.00% | 2.69% | |
| II-5 | Development of LRFD Resistance Factors | 0.00% | 70.00% | 70.00% | |
| II-6 | Cost-Benefit Analysis | 0.00% | 10.00% | 10.00% | |
| ll-7 | Outcomes and Recommendations | 0.00% | 0.00% | 0.00% | |
| II-8 | Reporting for Phase II | 0.00% | 0.00% | 0.00% | |
| | Average Percent Completion | 50.79% | 50.85% | 0.06% | |

Technology Transfer Journal Manuscripts Submitted:

- 1) Oluwatuyi, O., Holt, B., Rajapakshage, R., Wulff, S.S., and Ng, K.W. "Inherent Variability Assessment from Sparse Property Data of Overburden Soils and Intermediate Geomaterials Using Random Field Approaches." *Georisk Journal*. (Review Submission)
- 2) Oluwatuyi, O., Rajapakshage, R., Wulff, S.S., and Ng, K.W. "Simulation of Geologic Uncertainty and Geomaterial Boundaries Using Spatial Markov Chains." *Acta Geotechnica*.
- 3) Islam, M.S., Ng, K.W., and Wulff, S.S. "Prediction of driven piles in shales considering weathering and time effects." *Canadian Geotechnical Journal*.
- Masud, N., Ng, K.W., Wulff, S.S., and Johnson, T. "Driven Piles in Fine Grained Soil-based Intermediate GeoMaterials." *Journal of Bridge Engineering*. (Revised Submission)
- 5) Islam, M.S., Ng, K.W., and Wulff, S.S. "Improved Wave Equation Analysis of Steel H-Piles in Shales Considering LRFD and Economic Impact Studies." *Journal of Bridge Engineering*.
- 6) Kalauni, H.K., Ng, K.W., Masud, N., and Wulff, S.S. "Improved Prediction Of Pile Resistances In Soil-based IGMs Using WEAP With LRFD Recommendations." *Deep Foundation Institute Journal*.

Technology Transfer

Journal Manuscripts In Preparation:

- 1) Oluwatuyi, O., Rajapakshage, R., Wulff, S.S., Ng, K.W. "An optimal site investigation plan through unified treatment of inherent variability and geological uncertainty."
- 2) Islam, M.S., Ng, K.W., Wulff, S.S. "Finite Element Analysis of Driven Piles in Intermediate GeoMaterials."
- 3) Masud, N., Ng, K.W., Wulff, S.S., and Johnson, T. "Driven piles in coarsegrained soil-based Intermediate GeoMaterials."
- 4) Kalauni, H.K., Ng, K.W., and Wulff, S.S. "Improved prediction of pile resistances in rock-based IGMs using WEAP."

Technology Transfer

Conference Manuscripts:

- Kalauni, H., and Masud, N. (2021). "Improved Estimation of Pile Resistances in Soil-based IGMs Using WEAP with LRFD Recommendations." *46th Annual Conference on Deep Foundation,* Las Vegas, NV. (Awarded Runner-up for the Deep Foundation Institute Student Paper Competition)
- Masud, N., Ng, K.W., Islam, S. and Wulff, S.S. "Static and dynamic pile load tests on steel H-piles in intermediate geomaterials." *ASCE GeoCongress* 2022, ASCE, March 20 to 23, Charlotte, NC. (Accepted)
- Masud, N., Ng, K.W., and Wulff, S.S. "New static analysis method for the estimation of driven piles resistances in siltstone." *ASCE GeoCongress 2022*, ASCE, March 20 to 23, Charlotte, NC. (Accepted)
- 4) Oluwatuyi, E.O., Rajapakshage, R., Wulff, S.S., and Ng, K.W. "Quantifying geological uncertainty using conditioned spatial Markov Chains." *ASCE GeoCongress 2022*, ASCE, March 20 to 23, Charlotte, NC. (Accepted)

Technology Transfer

Conference Presentation:

- 1) Kam Ng will Present in the ASCE Geo-Institute 6th Annual Web Conference (December 6th-10th, 2021).
- 2) Kam Ng was Selected as the ASCE 2022 Geo-Institute GeoCongress State of the Practice Speaker. (March 20-23, 2022).
- 3) Kalauni, H.K., Ng, K.W., and Wulff, S.S. "Improved prediction of pile resistances in rock-based IGMs using WEAP with LRFD recommendations." *TRB 2022 Annual Meeting.* (January 9-13, 2022).

Thank You for Your Participation

