APPENDIX A

Drill Cutting Log and Geologic Classification Test Well #2 (abandoned)

MORRISON-MAIERLE, INC.
DRILL CUTTING SAMPLE DESCRIPTIONS

TEST WELL #2 - GILLETTE MADISON PIPELINE PROJECT

MD KB to GL 9.715 feet

Sample Depth Interval (feet KB)	Lithology	Description
		Fall River Formation Top Truncated by Land Surface
0 - 19	CLAYSTONE	No sample, driller described as gray clay. **0-19 ft BGL** (lower Fall River Fm., mudstone unit)
19 - 34	SILTSTONE	Core samples consist of very hard gray siltstone with carbonaceous seams and tan, laminated, micaceous siltstone. **19-34 ft BGL** (lower Fall River Fm., siltstone unit)
		Lakota Formation – Top - 34 feet
34 - 40	CLAYSTONE	Variagated lt. gray to dark maroon, trace hard, rounded, vf, quartz sandstone. (Upper Lakota Fm.)
40 - 50	SANDSTONE	Lt. gray, m-c, very angular, quartz sand, white cement (no acid to check cement) 2-3% quartz pebbles. (Lower Lakota Fm.)
50 - 60	SANDSTONE	Lt. to med gray, c-vc, quartz sand, very angular, includes 10-12% iron pyrite cemented layers, 3-4% heavily ferrunginous layers with dark maroon cement. (Lower Lakota Fm.)
60 - 70	SANDSTONE	White, vf, subrounded, quartz sand with minor m-c sand. No acid to check white cement. 1-2% pyrite-cemented sandstone with trace of gray claystone. (Lower Lakota Fm.)
70 - 80	SANDSTONE	White,vf qtz sand in white cement, very hard. (Lower Lakota Fm.)
80 - 90	SANDSTONE	As above. (Lower Lakota Fm.)

MD KB to GL 9.715 feet

Sample Depth Interval (feet KB)	Lithology	Description
90 - 100	SANDSTONE	As above, 10% c-vc, angular qtz sand w/pyrite cmt, trace maroon-cemented sandstone. (Lower Lakota Fm.)
100 - 110	SANDSTONE	White, vf qtz sand in white cement is 60% of interval, 20% hard gray claystone, 20% m-c, angular qtz sand, some with pyrite cement, trace of siltstone in sample. (Lower Lakota Fm.)
120 - 130	CLAYSTONE	Lt. yel brn, sandy, silty, blocky, with 5-8% hard vfs interbeds. (Morrison Fm.)
		Morrison Formation - Top 132 feet
130 - 140	MUDSTONE	Dk gray, 5% hard dk gry bn sis & vfs. (Morrison Fm.)
140 - 150	CLAYSTONE	Dk gray, firm, sticky, slightly sandy, clay completely remolded by drill bit, material on shale shaker indicates about 5% hard, laminated, black mudstone and/or sandy shale. (Morrison Fm.)
150 - 160	CLAYSTONE	As above, sandy. (Morrison Fm.)
160 - 170	CLAYSTONE	As above. (Morrison Fm.)
170 - 180	CLAYSTONE	As above. (Morrison Fm.)
180 - 190	CLAYSTONE	Medium gray, interbedded with v. thin, soft, vf sandstone. Ss is rounded qtz w/10% lithics. (Morrison Fm.)
190 - 200	CLAYSTONE	As above. (Morrison Fm.)

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200 - 210	SANDSTONE & CLAY	Lt. gray, vf sandstone with white cmt and 5-8% chert grains and v soft lt. gray clay. (Morrison Fm.)
210 - 220	SANDSTONE	Lt. gray, vf, friable, white cmt and 5-8% black chert grains, w/25-30% soft gray clay. (Morrison Fm.)
230 - 240	CLAYSTONE	V. dk gray, sandy, v. soft, 1-2% interbedded vf sandstone, trace carbonaceous material, trace iron pyrite. (Morrison Fm).
	Redwater Shale Member of Sundance Formation - Top 240 feet	
240 - 250	CLAYSTONE	Lt. greenish gray, soft, w/20% dk gray mudstone, trace pytite. (Redwater sh mbr Sundance Fm).
250 - 260	MUDSTONE	V. dk brown to dk brownish red, traces v hard sandy black shale. (Redwater sh mbr Sundance Fm).
260 - 270	SHALE	Lt. greenish gray and soft clay shale with lt. greenish gray hard sis and v dk brown, microxtln limestone in equal amounts. (Redwater sh mbr Sundance Fm)
270 - 280	SANDSTONE	Lt red to white, vf-f, soft friable interbedded w/soft gray to dk rd bn mudstone. (Redwater sh mbr Sundance Fm)
280 – 290	SANDSTONE	Lt. gray to white vf qtz w/white cmt and 2% dark accessory mineral; includes similar vf sandy siltstone. (Redwater sh mbr Sundance Fm)
290 - 300	SANDSTONE	As above. Traces lt. gry to greenish gry clay. (Redwater sh mbr Sundance Fm)
300 - 310	SANDSTONE	As above. Traces pyrite. (Redwater sh mbr Sundance Fm)

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Sample Depth Interval (feet KB)	Lithology	Description
310 - 320	SANDSTONE	White, vf qtz, silty, white matrix (no acid to check cmt), soft, friable. (Redwater sh mbr Sundance Fm)
320 - 330	SANDSTONE	As above. (Redwater sh mbr Sundance Fm)
330 - 340	SILTSTONE	Gray, soft, few chips dk gray clay, shaley sis. (Redwater sh mbr Sundance Fm)
340 - 350	SILTSTONE	Dk gray, sandy w/vfs, includes some mudstone or clay that has sand and silt incorporated by drill bit, shaley sis. (Redwater sh mbr Sundance Fm)
350 - 360	MUDSTONE	Medium gray, v silty, almost siltstone, but too much clay. Probably shaley sis remolded by bit. (Redwater sh mbr Sundance Fm)
360 – 370	SILTSTONE	Med. Gray, sandy, soft. (Redwater sh mbr Sundance Fm)
370 - 380	SILTSTONE	As above w/10% hard dk gy vf glauconitic ss, 5-8% chert grains, 1% pyrite and 8-10% glauc. (Redwater sh mbr Sundance Fm)
380 - 390	SANDSTONE	Dk gray, glauc, vf, qtz w/10% chert, hard. (Redwater sh mbr Sundance Fm)
390 - 400	SILTSTONE	Gray, soft, w/layers of thin hard vf, cmtd ss, heavy iron pyrite on ss partings and 10% pyrite in ss matrix, cuttings stiff with clay that is not distinguishable in microcscope, remolded shaley siltstone or interlaminated sis, ss & sh. (Redwater sh mbr Sundance Fm)

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Sample Depth Interval (feet KB)	Lithology	Description
400 – 410	SILTSTONE	Gray, soft, w/sandy sis laminae, stiff with clay as above, shaley sis or sis w/clay laminae. (Redwater sh mbr Sundance Fm)
410 - 420	SILTSTONE	As above, shaley sis or sis w/clay laminae. (Redwater sh mbr Sundance Fm)
420 - 430	SHALE	Black to v dk gy, silty, w/few hard layers, 3-4 mm thick, cmt sis, tr pyrite. (Redwater sh mbr Sundance Fm)
430 - 440	SHALE	As above, no pyrite. (Redwater sh mbr Sundance Fm)
440 - 450	SHALE	V dk gy, clay shale, fissile. (Redwater sh mbr Sundance Fm)
450 - 460	SHALE	As above, tr pyrite. (Redwater sh mbr Sundance Fm)
460 - 470	MUDSTONE	Dk gy, silty, includes 10% black fissile shale and 10% shalely sis. (Redwater sh mbr Sundance Fm)
470 - 480	SHALE	V dk gy, fissile, 10% silty mudstone. (Redwater sh mbr Sundance Fm)
480 - 490	SHALE	V dk gy, fissile, sandy w/2-4% glauconite. (Redwater sh mbr Sundance Fm)
490 - 500	SHALE	Gray, soft, sandy w/some v soft, v-f, clayey sand. Probable thin ss laminae in soft clay shale or sandy clay shale. (Redwater sh mbr Sundance Fm)
500 - 510	SILTSTONE	Lt gy, soft, shaley w/few hard cmtd dk gy sis layers. (Redwater sh mbr Sundance Fm)
510 - 520	SANDSTONE	Med – lt gy, vf, silty, hard, 10% soft white vf ss, clayey w/lt gy soft clay. Traces glauconite in hard sands. (Redwater sh mbr Sundance Fm)

MD KB to GL 9.715 feet

Sample Depth Interval (feet KB)	Lithology	Description
520 - 530	SANDSTONE	White, vf qtz, rounded, soft w/white matrix, minor lt greenish-gray soft clay. (Redwater sh mbr Sundance Fm)
530 - 540	SILTSTONE	Reddish brown, hard to soft sis, tabular chips indicate bedding, some vf sandy sis. (Redwater sh mbr Sundance Fm)
540 - 550	SILTSTONE	As above with 10% soft lt gy clay. (Redwater sh mbr Sundance Fm)
550 - 560	SILTSTONE	Shaley, 90% gray, soft, clayey sis & 10% whitish gray to lt reddish brown sis.
560 - 570	SILTSTONE	Reddish brown to lt gray laminated, some clay content in sample. (Redwater sh mbr Sundance Fm)
570 – 580	SHALE	V lt gray, silty. Mostly soft clay shale w/silty layers or partings. (Redwater sh mbr Sundance Fm)
	LAK Member of Sundance Formation - Top 582 feet	
580 - 590	SANDSTONE	V lt gy, vf, qtz, rounded, v soft/friable. (LAK mbr Sundance Fm)
590 - 600	GYPSUM	White, massive. (LAK mbr Sundance Fm)
600 - 610	SANDSTONE	V lt gray, vf, qtz, rounded, white cmt. (LAK mbr Sundance Fm)
610 - 620	SANDSTONE	As above. (LAK mbr Sundance Fm)
620 – 630	SILTSTONE	Lt gy siltstone, few hard layers, qtz silt, white matrix and slightly shaley where soft, silica cemented in hard layers. (LAK mbr Sundance Fm)

MD KB to GL 9.715 feet

Sample Depth Interval (feet KB)	Lithology	Description
Hulett Sandstone Member of Sundance Formation - Top 618 feet		
630 - 640	SILTSTONE	Lt gy siltstone, few hard layers, qtz silt, white matrix and slightly shaley where soft, silica cemented in hard layers. (Hulett ss mbr Sundance Fm)
Stockade-Beaver Shale Member of Sundance Formation - Top 644 feet		
640 - 650	SILTSTONE	As above. (Stockade Beaver sh mbr Sundance Fm)
650 - 660	SILTSTONE	Dk gray, and dk gray silty mudstone, shalely sis. (Stockade Beaver sh mbr Sundance Fm)
680 - 690	SILTSTONE	Dk gray, trace fissile shale. (Stockade Beaver sh mbr Sundance Fm)
690 - 700	SILTSTONE	As above. (Hulett ss mbr Sundance Fm)
700 - 710	SHALE	Silty, v dark gray, hard, fissile, to very soft. (Stockade Beaver sh mbr Sundance Fm)
710 - 720	CLAYSTONE	Silty, dk gray, soft, w/few pieces fissile dk gray shale. (Stockade Beaver sh mbr Sundance Fm)
720 - 730	SHALE	Dk gray, fissile. (Stockade Beaver sh mbr Sundance Fm)
730 - 740	SHALE	As above. (Stockade Beaver sh mbr Sundance Fm)

MD KB to GL 9.715 feet

Sample Depth Interval (feet KB)	Lithology	Description
Canyon Springs Sandstone Member of Sundance Formation - Top 740 feet Unit is 719-730 feet on GAMMA RAY		
740 - 750	SANDSTONE	Lt gray to white, vf, rounded qtz,w/white matrix. (Canyon Springs ss mbr Sundance Fm)
Spearfish Formation - Top 750 feet Unit Top is at 730 feet on GAMMA RAY		
Note: The soft siltstones and silty mudstones throughout the Spearfish Fmtn. appear to be weakly cemented with calcareous cement, samples return as a silty mud slurry with occasional competent chips, which when cleaned and a fresh faced opened, weakly effervesce with 10% HCl. However, the majority of silty-mud slurry will violently effervesce. It appears that the siltstone-mudstone-drilling fluid slurry contains significant amounts of calcareous material, apparently as a byproduct of pulverization of the parent material by the bit. The hard (well indurated) sandstones and siltstones do not effervesce and do not indicate calcareous cement.		
750 - 760	SILTSTONE & SANDSTONE	Dk red, vc sis, vfs. (Spearfish Fm.)
760 - 770	MUDSTONE	Dk red, silty. (Spearfish Fm.)
770 - 780	MUDSTONE	Dk red, includes a few laminae of hard, red, gypsiferous, sis. (Spearfish Fm.)
780 - 790	MUDSTONE	Dk red, silty. (Spearfish Fm.)
830 - 840	SILTSTONE	Dk red coarse gr sis, mixture of hard and soft (~50/50), soft sis has visible gypsum on partings & in pores. Occasional 1-2mm nodules of gypsum. (Spearfish Fm.)
840 - 850	SILTSTONE	As above. (Spearfish Fm.)

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Sample Depth Interval (feet KB)	Lithology	Description
850 - 860	SILTSTONE	As above. (Spearfish Fm.)
860 - 870	SILTSTONE	Dk red, poorly indurated, weakly calcareous, minor med gray claystone interbeds. (Spearfish Fm.)
870 - 880	MUDSTONE	Dk red, silty with thin, hard sis laminations. weakly calcareous (Spearfish Fm.)
880 - 890	SILTSTONE	As above. (Spearfish Fm.)
890 - 900	SILTSTONE	Dk red mixture of hard and soft (~60/40), soft sis has visible gypsum on partings. Weakly calcareous (Spearfish Fm.)
900 - 910	MUDSTONE	Dk red, silty w/ 20% thinly laminated hard sis, thin dark gray claystone laminations, Minor gypsum. (Spearfish Fm.)
910 - 920	MUDSTONE	As above (Spearfish Fm.)
920 - 930	SILTSTONE	Dk red mixture of hard and soft (~40/60), soft sis has visible gypsum on partings. Weakly calcareous (Spearfish Fm.)
930 - 940	MUDSTONE	Dk red, silty. Weakly calcareous (Spearfish Fm.)
940 - 950	SILTSTONE	Dk red, medium to well indurated. (Spearfish Fm.)
950 - 960	MUDSTONE	Dk red interbedded with thin, hard sis laminations and occasional dk gray claystone. Difficult to keep in sample if washed. Weakly calcareous (Spearfish Fm.)
960 - 970	SILTSTONE	Dk red, well indurated. (Spearfish Fm.)

Sample Depth Interval (feet KB)	Lithology	MD KB to GL 9.715 feet Description
970 - 980	MUDSTONE	Dk red, silty, common gypsum nodules along partings. Thin, hard sis laminations. Samples wash away to just hard siltstone if not careful during sample prep. Weakly calcareous (Spearfish Fm.)
980 - 990	MUDSTONE	As above. (Spearfish Fm.)
990 - 1000	MUDSTONE	As above. (Spearfish Fm.)
1000 - 1010	SILTSTONE	Dk red, predominantly well indurated with thin dk gray claystone interbeds. (Spearfish Fm.)
1010 - 1020	SILTSTONE	As above. (Spearfish Fm.)
1020 - 1030	MUDSTONE	Dk red, silty, common gypsum nodules and minor anhydrite along partings, ~20% clay content in MS. Thin, hard sis laminations. Weakly calcareous (Spearfish Fm.)
1040 - 1050	SILTSTONE	As above. (Spearfish Fm.)
1050 - 1060	SILTSTONE	Dk red, predominantly well indurated with thin dk gray claystone interbeds. (Spearfish Fm.)
1060 - 1070	SILTSTONE	As above (Spearfish Fm.)
1070 - 1080	MUDSTONE	Dk red,silty, w/ thin dk greenish gray CS. occasional gypsum and anhydrite.20-25% clay content; difficult to keep in sample if washed. Weakly calcareous (Spearfish Fm.)
1080 - 1090	MUDSTONE	As above. (Spearfish Fm.)
1090 - 1100	MUDSTONE	As above. (Spearfish Fm.)
1100 - 1110	MUDSTONE	As above. (Spearfish Fm.)

MD KB to GL 9.715 feet

Sample Depth Interval (feet KB)	Lithology	Description
1110 - 1120	MUDSTONE	As above. (Spearfish Fm.)
1120 - 1130	MUDSTONE	As above. (Spearfish Fm.)
1130 - 1140	MUDSTONE	As above. (Spearfish Fm.)
1140 - 1150	MUDSTONE	As above. (Spearfish Fm.)
1150 - 1160	SILTSTONE	Dk red, moderately hard, abundant gypsum. (Spearfish Fm.)
1160 - 1170	SILTSTONE	Dk red, soft, 10-15% clay content. Weakly calcareous (Spearfish Fm.)
1170 - 1180	ANHYDRITE	White to rose, massive finely crystalline with interbedded Dk red, soft sis. (Spearfish Fm.)
1180 - 1190	SILTSTONE	Dk red, mixture of hard and soft, 70/30, soft - weakly calcareous. (Spearfish Fm.)
1190 - 1200	SILTSTONE & MUDSTONE	Dk red, moderately indurated sis and dk red ms; 10-15% clay content, Weakly calcareous. Occasional thin dk gray claystone laminae. (Spearfish Fm.)
1200 - 1210	SILTSTONE & MUDSTONE	As above. (Spearfish Fm.)
1210 - 1220	MUDSTONE	Dk Red silty, approx. 20% clay content. (Spearfish Fm.)
1220 - 1230	MUDSTONE	Dk Red silty, 15%. abundant gypsum (10-15%). (Spearfish Fm.)

Sample Depth Interval (feet KB)	Lithology	MD KB to GL 9.715 feet Description
1230 - 1240	MUDSTONE	Dk Red silty, W/ thin laminations of hard dk red sis and opaque anhydrite. Minor white gypsum (< 5%). (Spearfish Fm.)
1240 - 1250	MUDSTONE	As above. (Spearfish Fm.)
1250 - 1260	ANHYDRITE	Lt tan to white, translucent to opaque, finely crystalline, with thin white gypsum (10%) and med gray claystone interbeds. (Spearfish Fm.)
1260 - 1270	MUDSTONE	Dk Red silty, W/ thin laminations of hard dk red sis and opaque anhydrite. Minor white gypsum (< 5%). (Spearfish Fm.)
1270 - 1280	MUDSTONE	As above with more gypsum (~10%). (Spearfish Fm.)
1280 - 1290	MUDSTONE	As above. (Spearfish Fm.)
1290 - 1300	MUDSTONE	Dk, red, silty with 20% thin, hard dk red sis and minor med gray, weak sis. No gypsum or anhydrite. (Spearfish Fm.)
1300 - 1310	MUDSTONE	As above. (Spearfish Fm.)
1310 - 1320	MUDSTONE	Dk red, silty, clay rich (~20-25%) with 10% white gypsum. (Spearfish Fm.)
1320 - 1330	MUDSTONE	As above with no gypsum and 5-10% med gray claystone. (Spearfish Fm.)
1330 - 1340	SILTSTONE	Dk red hard 70/30 mixture of hard and soft with minor, thin med gray claystone lamintations. (Spearfish Fm.)
1340 - 1350	SILTSTONE	As above. (Spearfish Fm.)
1350 - 1360	SILTSTONE	As above. (Spearfish Fm.)

MD KB to GL 9.715 feet

Sample Depth Interval (feet KB)	Lithology	Description
1360 - 1370	MUDSTONE	Dk red, silty with 30% hard dk red sis and minor white gypsum.. (Spearfish Fm.)
1370 - 1380	MUDSTONE	As above. (Spearfish Fm.)
1380 - 1390	MUDSTONE	Dk red, slightly silty clay rich. (Spearfish Fm.)
1390 - 1400	ANHYDRITE	Lt tan to white, translucent to opaque, finely crystalline, with thin white gypsum (10%) and med gray claystone interbeds. (Spearfish Fm.)
	Minnekahta Limestone Formation - Top 1399 feet	
1400 - 1410	LIMESTONE	Lt to medium tan, massive, aphanitic with local euhedral secondary crystallization of calcite and pyrite. Oil staining and seepage from pores and fractures. Decreasing with depth (Minnekahta Fm.)
1410 - 1420	LIMESTONE	Lt to medium tan, massive, aphanitic with local euhedral secondary crystallization of calcite and pyrite. Minor oil staining and seepage. (Minnekahta Fm.)
1420 - 1430	LIMESTONE	Lt greenish gray, massive, aphanitic with local euhedral secondary crystallization of calcite and pyrite. Minor oil staining and seepage. (Minnekahta Fm.)
	Opeche Shale Formation - Top 1438 feet	
1430 - 1440	SILTSTONE	Dk purplish red, mixture of hard and soft, 70/30 respectively. (Opeche Fm.)
1440 - 1450	MUDSTONE	Reddish orange, silty with thinly laminated dk red, well indurated sis. (Opeche Fm.)

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Sample Depth Interval (feet KB)	Lithology	Description
1450 - 1460	MUDSTONE	Dk red, silty with thinly laminated, well indurated sis. (Opeche Fm.)
1460 - 1470	GYPSUM	White, massive with abundant anhydrite stringers approximately 60% gyp.40% anh. (Opeche Fm.)
1470 - 1480	MUDSTONE	Dk red, silty with thinly laminated, well indurated sis. (Opeche Fm.)
1480 - 1490	MUDSTONE	As above. (Opeche Fm.)
1490 - 1500	MUDSTONE	As above. (Opeche Fm.)
Minnelusa Formation - Top 1500 feet		
1500 - 1510	CLAYSTONE	Lt greenish gray, moderately hard (competent chips common on shaker). (Minnelusa Fm.)
1510 - 1520	SANDSTONE	Lt greenish gray, vf to silt, subrnd to rnd, well sorted quartzose, 5% chert. Abundant pyrite concretions. Slightly calcareous. (Minnelusa Fm.)
1520 - 1530	SANDSTONE	As above (Minnelusa Fm.)
1530 - 1540	SANDSTONE	Dk gray f to m, sub-rnd to rnd, Qtzose. Calcite cemented. Weakly indurated, porous. Oil staining along pores. Well sorted. Minor pyrite concretions. (Minnelusa Fm.)
1540 - 1550	SANDSTONE	As above (Minnelusa Fm.)
1550 - 1560	SANDSTONE	As above (Minnelusa Fm.)
1560 - 1570	SANDSTONE	As above (Minnelusa Fm.)

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Sample Depth Interval (feet KB)	Lithology	Description
1570 - 1580	SANDSTONE	Dk gray vf to m, sub-rnd to rnd, Qtzose. Calcite cemented. Dirty (~5-10% mud matrix) Weakly indurated, porous. Oil staining along pores. poorly sorted. Minor pyrite concretions. (Minnelusa Fm.)
1580 - 1590	SANDSTONE	Very light tan, vf to f, sub-rnd to rnd, well sorted loose sand. Slightly calcareous. Sample likely biased as lost circulation at 1585 sample collected as drilling resumes as accumulation on non-operable shakers. Logged due to prevalence of fine sand in drilling fluid. It is believed to be mostly representative of fmtn where circulation lost. (Minnelusa Fm.)
1590 - 1600	SILTSTONE	Lt tan to white, well indurated. Interbedded with 30% Dk greenish gray claystone, hard. Weakly calcareous. (Minnelusa Fm.)
1600 - 1610	SANDSTONE	Lt gray to white, vf to f grnd, mixture of hard and soft beds including zones that return samples composed of calcite cemented amalgamations of loose grains roughly the size of very coarse sand. (Minnelusa Fm.)
1610 - 1620	SANDSTONE	As above (Minnelusa Fm.)
1620 - 1692	HOLE ADVANCED TO 1692 FEET IN MINNELUSA WITH POOR SAMPLE RECOVERY DUE TO DRILLING WITH FORMATION WATER AND COMPLETE LOSS OF DRILL FLUID CIRCULATION. ON DECEMBER 22, 2011, CAVING MATERIAL CUT OFF CIRCULATION OF FORMATION WATER TO DRILL BIT AND FLOODED REVERSE CIRCULATION WITH FORMATION WATER ENDED AT A TOTAL DEPTH OF 1692 FEET KB.	