Skyline Tension Behavior of Rigging Configurations Used in New Zealand Cable Logging

Hunter Harrill & Rien Visser

School of Forestry, University of Canterbury

Christchurch, New Zealand

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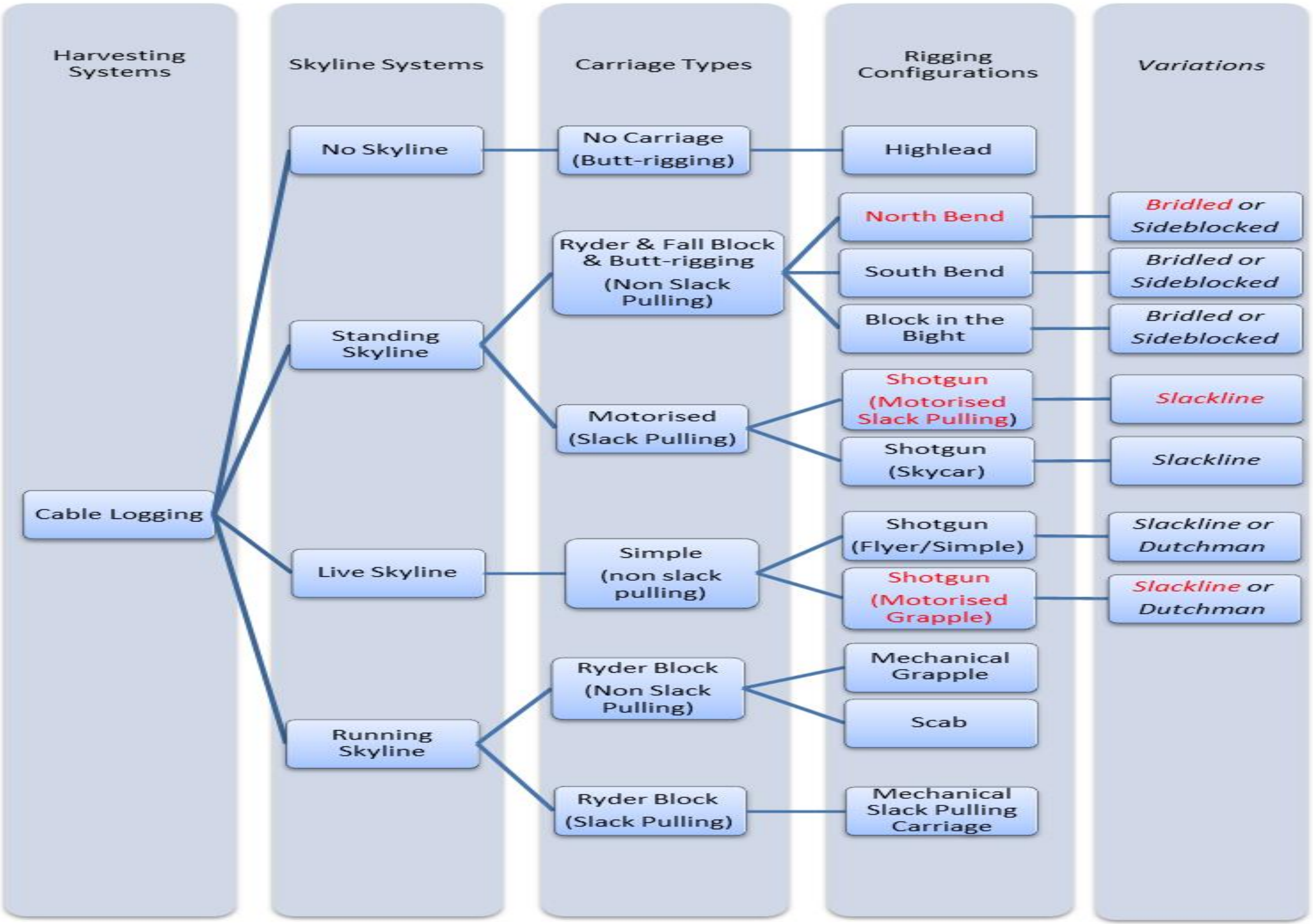
Introduction

Cable Logging Systems in NZ

- % of "Steep" harvest area is increasing 40 → 60%
- Inherently expensive compared to ground-based systems (↑capital & operating costs VS ↓ production)
- Lots of interest about different rigging configurations and their optimal application
- Improving our understanding may help improve profitability.


Harvesting Systems
Skyline Systems
Carriage Types
Rigging Configurations
Variations
Cable Logging
No Skyline
Standing Skyline
Live Skyline
Running Skyline
No Carriage (Butt-rigging)
Ryder & Fall Block & Butt-rigging (Non Slack Pulling)
Motorised (Slack Pulling)
Simple (non slack pulling)
Ryder Block (Non Slack Pulling)
Ryder Block (Slack Pulling)
Highlead
North Bend
South Bend
Block in the Bight
Shotgun (Motorised Slack Pulling)
Shotgun (Skycar)
Shotgun (Flyer/Simple)
Shotgun (Motorised Grapple)
Mechanical Grapple
Scab
Mechanical Slack Pulling Carriage
Bridled or Sideblocked
Bridled or Sideblocked
Bridled or Sideblocked
Slackline
Slackline
Slackline or Dutchman
Slackline or Dutchman

Skyline Tensions

- Planning → productivity → maximum log load (payload) and the resulting static tension in the skyline.
- Analysis techniques available but little research into actual dynamic operating tensions
- Few studies have measured the differences in productivity between various cable rigging configurations.
  - Less is known about the skyline tension behavior

NZ ACOP Rule: "The tension on the wire rope shall be restricted to 33 percent of its breaking load at all times."

Objectives

This study aimed to measure the dynamic skyline tensions of the three targeted rigging configurations in a series of case studies.

The objectives of the study were to:

- Quantify the average tension in regards to the safe working load and the frequency which the safe working load was exceeded.
- Quantify the peak skyline tensions for the cycle elements for each rigging configuration.
- Compare and contrast the payload-to-tension relationship for various rigging configurations.
- Investigate dynamic load behavior (amplifications) for each configuration and their associated causes.

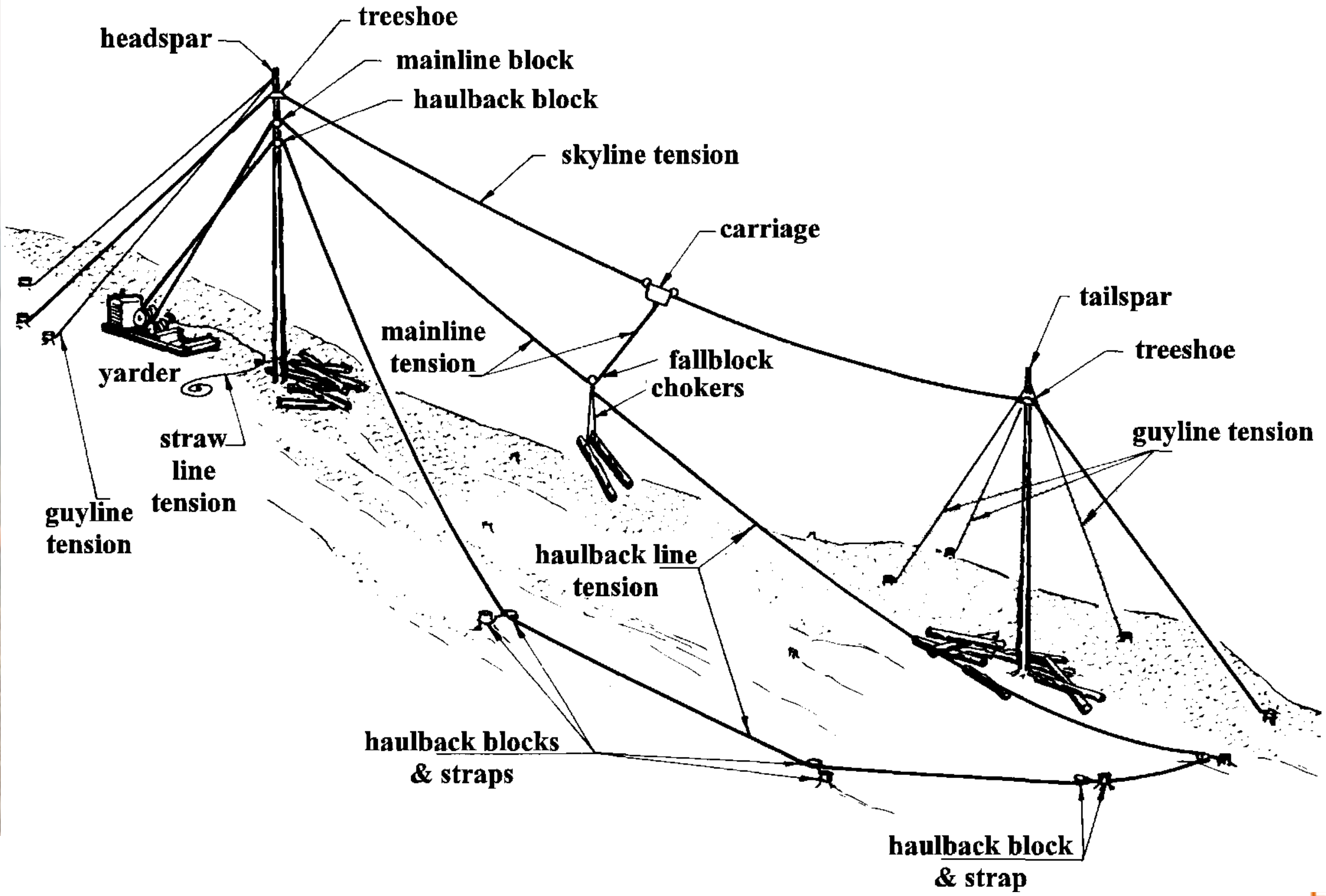
Study Sites and Equipment

Study Site	Region	Yarder	Yarding System	Configurations	Span (m)	Cord Slope (%)	Deflection (%)	Avg. Yarding Dist. (m)	Piece Size (m^3)
1	Canterbury	Madill 171	Live Skyline	Falcon Slackline	345	-26	6.1	249	1.6
					352	-27	5.9	185	
					364	-27	7.4	244	
2	Nelson	Madill 171	Live Skyline	Falcon Shotgun	316	-47	5.7	221	1.4
					338	-46	5.8	229	
3	Gisborne	BE-85	Standing Skyline	North Bend	940	-14	5.2	280	2.4
				North Bend Bridled	920	-14	5.1	124	
4	Gisborne	Madill 172	Standing Skyline	Acme S28 Slackline	335	-17	4.2	181	2.1
					330	-18	6.1	278	
5	Nelson	Berger C19	Live Skyline	Falcon Shotgun	602	-30	6.1	184	1.6
6	Marlborough	Dispatch-85	Standing Skyline	North Bend Bridled	1100	-43	3.8	311	2.4
7	Nelson	BE-70LT	Standing Skyline	North Bend	395	0	8.4	337	1.2
					398	1	10.1	248	
8	Otago	Madill 071	Standing Skyline	Acme S28 Slackline	284	-20	6.9	230	1.5
				Acme S28 Slackline	296	-21	6.2	191	
				Acme S28 Shotgun	354	-23	6.2	145	

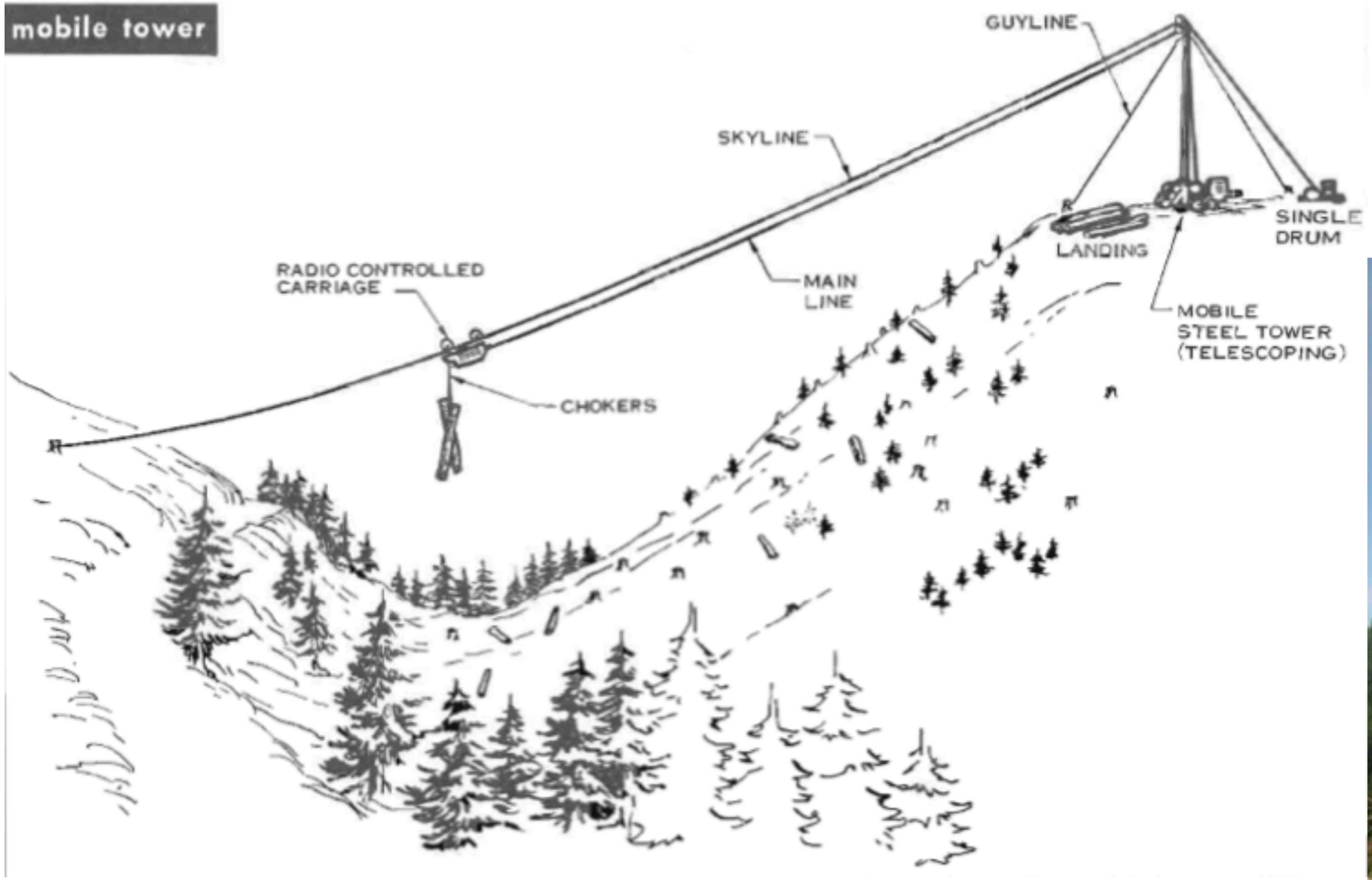
Operations Description

Yarder Model	Madill 171	BE-85	Madill 172	Berger C19	Dispatch-85	BE-70LT	Madill 071
Rated Engine Power (kW)	335	335	335	391	335	335	212
Tower Height (m)	22	26	22	22	26	21	14
Skyline Diameter (mm)	28.7	28.7	28.7	28.7	28.7	28.7	25.5
Skyline Safe Work Load (tonnes)	21.3	21.3	21.3	21.3	21.3	21.3	18.6
Mainline Diameter (mm)	22.3	19.1	19.1	22.3	25.5	19.1	19.1
Haulback Diameter (mm)	19.1	17.5	19.1	19.1	19.1	17.5	15.9
Carriage Type	Falcon	Fall Block	Acme S28	Falcon	Fall Block	FallBlock	Acme S28
Carriage Weight (kg)	2,200	1,000	860	2,200	1,000	1,000	860
Carriage Engine Power (kW)	43	0	21	43	0	0	21

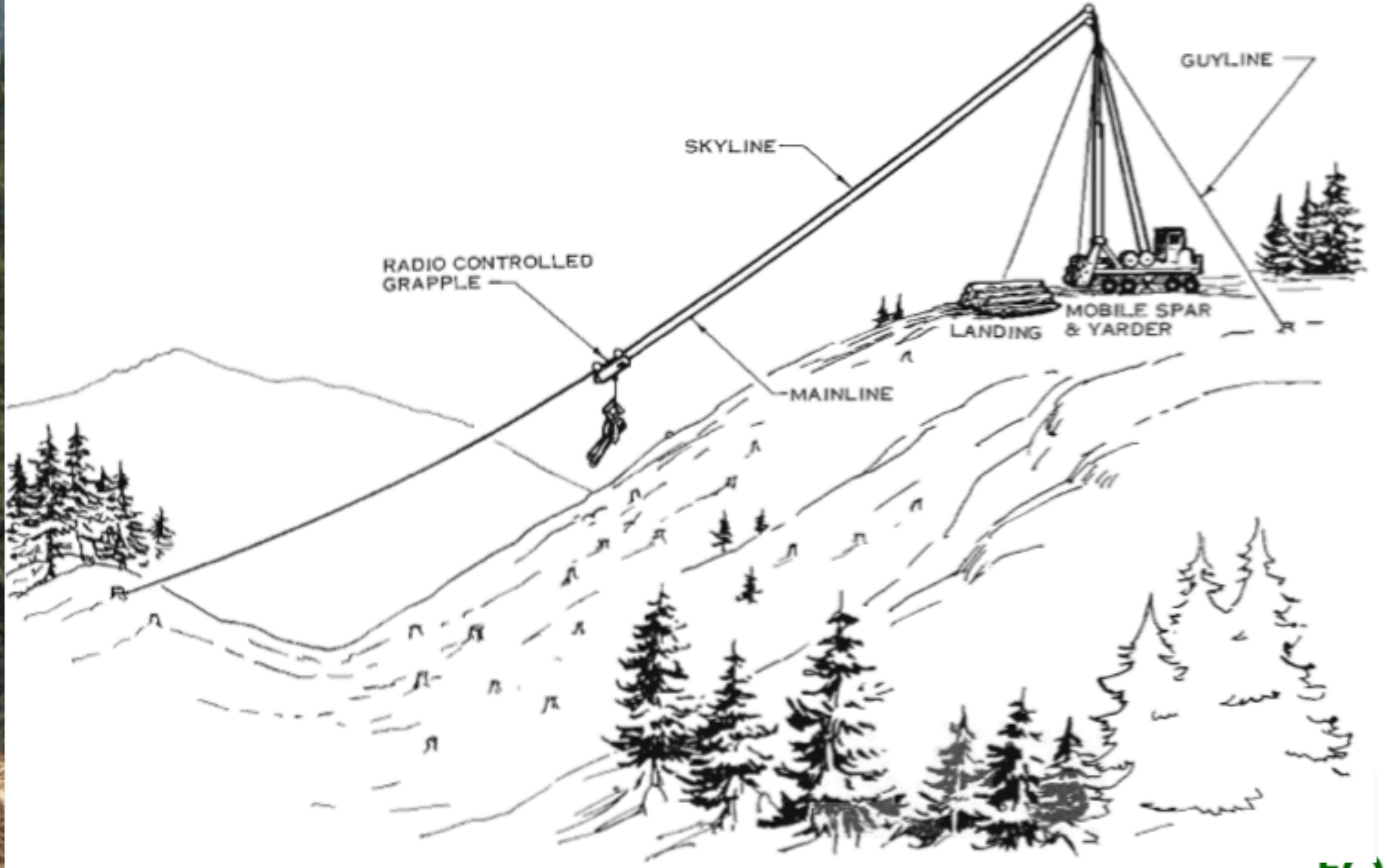
North Bend & North Bend Bridled



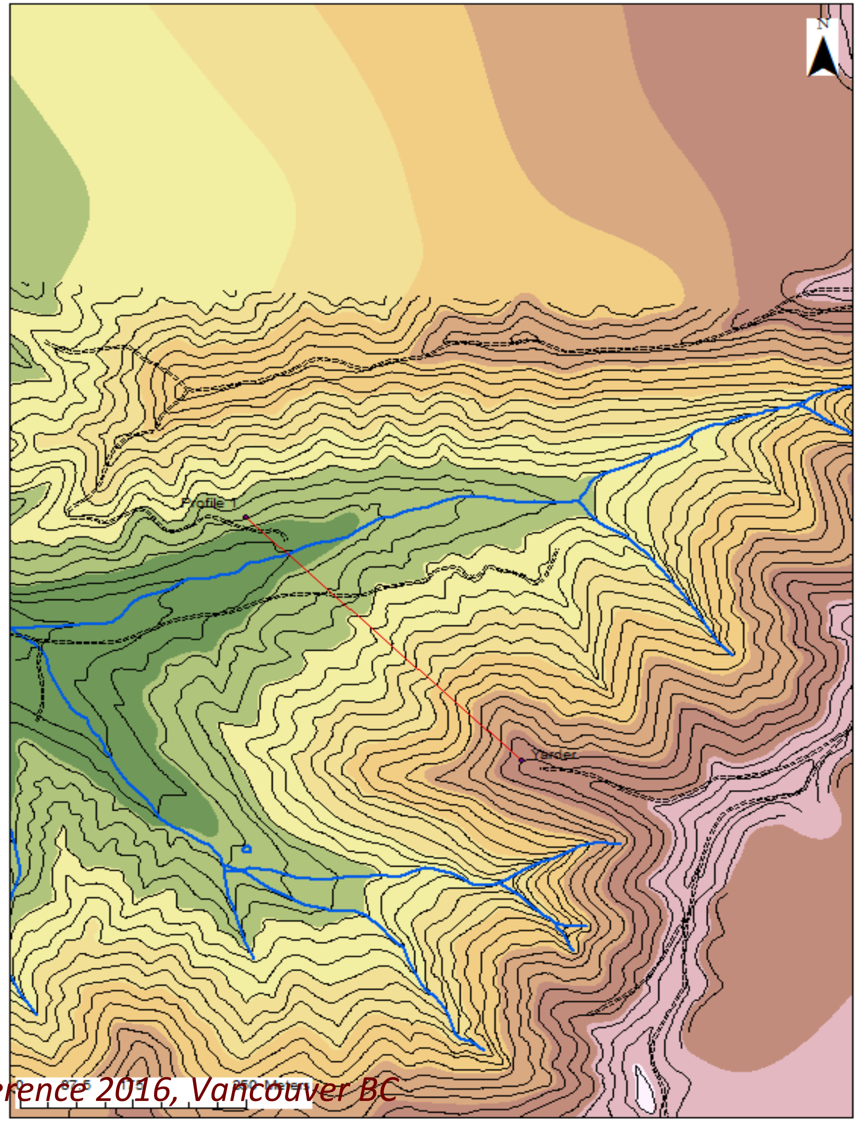
Acme Shotgun & Acme Slackline



Falcon Shotgun & Falcon Slackline



Methods: Position & Terrain Data



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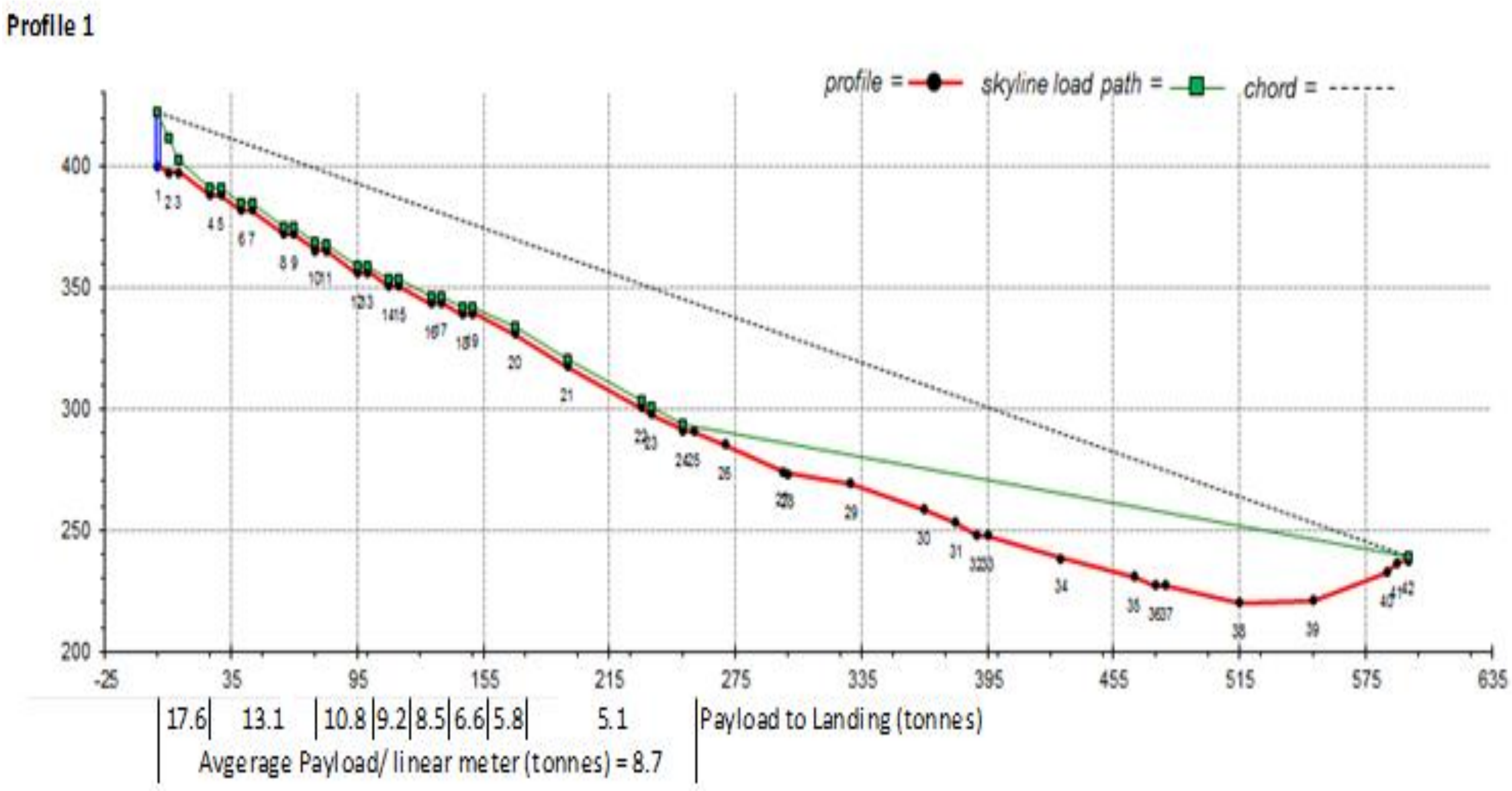
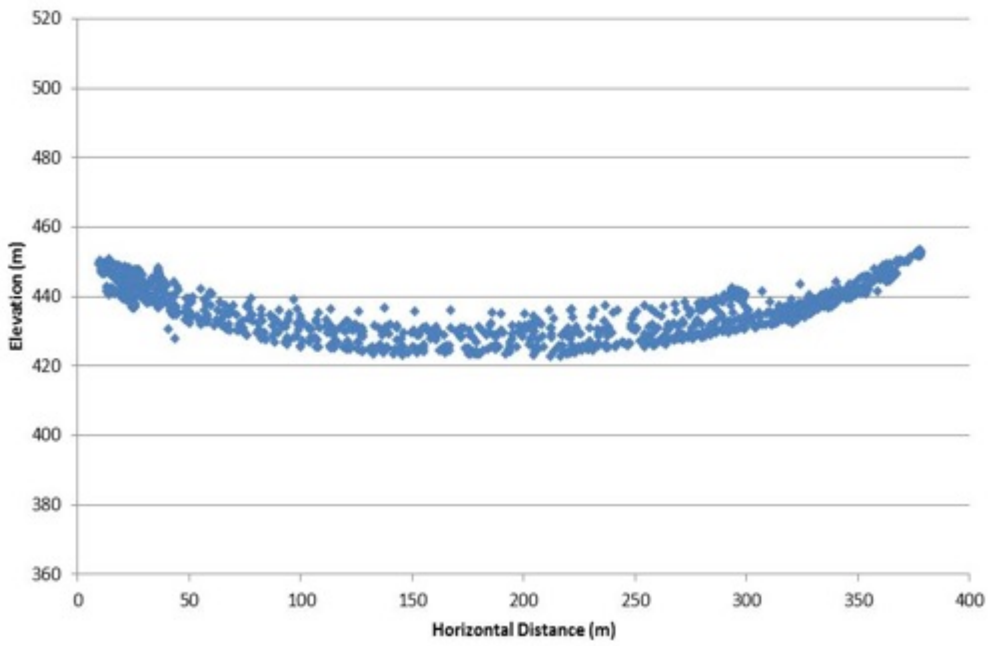
Methods: Payload Analysis



Methods: Carriage GPS Data

- Mounted hand-held GPS to carriage
- Recorded X, Y & Z positional data continuously at 0.5 Hz



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Methods: Time Study Data

- Measured each cycle & element time by stop watch
- Measured distances with laser range finder
- Researcher on landing collected piece size

Cycle (#)	Corridor (#)	Outhaul (min)	Distance (m)	Hook (min)	Pieces (#)	CyclVol (m³)	Inhaul (min)	Unhook (min)	Delays (min)	Cycle Time (min)
1	1	0.45	123	0.72	1	1.4	0.65	0.37	0.65	2.19
2	1	0.82	118	1.18	2	2.3	0.83	0.20	0.00	3.03
3	1	0.43	127	1.37	1	0.3	0.43	0.33	0.00	2.57
4	1	0.50	132	0.90	2	4.4	0.57	0.28	0.00	2.25
5	1	0.58	137	0.93	1	1.4	0.73	0.57	0.00	2.82
6	1	0.43	141	1.38	2	3.9	1.00	0.57	0.00	3.38
7	1	0.58	154	0.63	1	2.1	0.73	0.75	0.67	2.70
8	1	0.38	160	0.62	1	3.1	0.72	0.32	0.00	2.03
9	1	0.45	166	1.02	2	2.7	1.67	0.30	0.75	3.43
10	1	0.35	173	0.55	1	2.1	0.52	0.53	0.00	1.95
11	1	0.37	171	0.73	2	3.3	0.92	0.48	0.00	2.50
12	1	0.37	178	0.43	1	1.5	0.77	0.52	0.00	2.08
13	1	0.43	177	0.73	2	3.5	1.07	0.63	0.00	2.87
14	1	0.40	186	0.37	2	2.5	1.45	0.35	4.42	2.57
15	1	0.40	186	0.42	2	1.7	1.10	0.48	0.00	2.40
16	1	0.53	194	0.73	2	3.2	1.15	0.30	0.38	2.72
17	1	0.52	198	0.30	3	1.9	1.17	0.53	0.00	2.52
18	1	0.42	205	0.97	1	1.2	0.90	0.50	0.47	2.78
19	1	0.72	204	0.53	1	1.0	1.08	0.52	0.00	2.85
20	1	0.52	207	1.18	1	3.5	1.20	0.22	0.30	3.12
21	1	0.90	217	0.48	1	2.1	1.47	0.50	1.27	3.35
22	1	0.52	222	1.15	1	2.9	1.57	0.50	0.77	3.73
23	1	0.43	209	1.05	1	0.8	1.73	0.23	2.55	3.45
24	1	0.42	222	0.68	1	3.7	1.38	0.43	0.00	2.92
25	1	0.50	220	0.98	1	1.3	1.20	0.63	0.00	3.32
26	1	0.40	219	1.35	1	0.2	1.63	0.22	0.60	3.60
27	1	0.55	226	0.42	1	4.7	1.55	0.52	0.00	3.03
28	1	0.50	235	0.53	1	2.8	1.43	0.47	0.00	2.93
29	1	0.37	252	0.73	1	2.8	1.72	0.78	0.00	3.60
30	1	0.25	130	1.28	1	1.8	0.67	0.57	0.00	2.77
31	1	0.27	144	1.13	1	0.7	0.80	0.45	0.00	2.65
32	1	0.42	152	0.42	2	0.8	0.68	0.32	0.00	1.83
33	1	0.45	245	1.25	1	1.6	1.42	0.45	0.57	3.57
34	1	0.77	239	0.85	1	1.8	1.35	0.20	0.85	3.17
Min		**0.25**	**118**	**0.30**	**1.0**	**0.2**	**0.43**	**0.20**	**0.00**	**1.83**
Max		**0.90**	**252**	**1.38**	**3.0**	**4.7**	**1.73**	**0.78**	**4.42**	**3.73**
Avg		**0.48**	**184**	**0.82**	**1.4**	**2.2**	**1.10**	**0.44**	**0.42**	**2.84**
SD		**0.14**	**39**	**0.33**	**0.5**	**1.2**	**0.38**	**0.15**	**0.88**	**0.51**

Methods: Tension Monitoring Data

- Collected continuously at 10 Hz to capture dynamic behaviour

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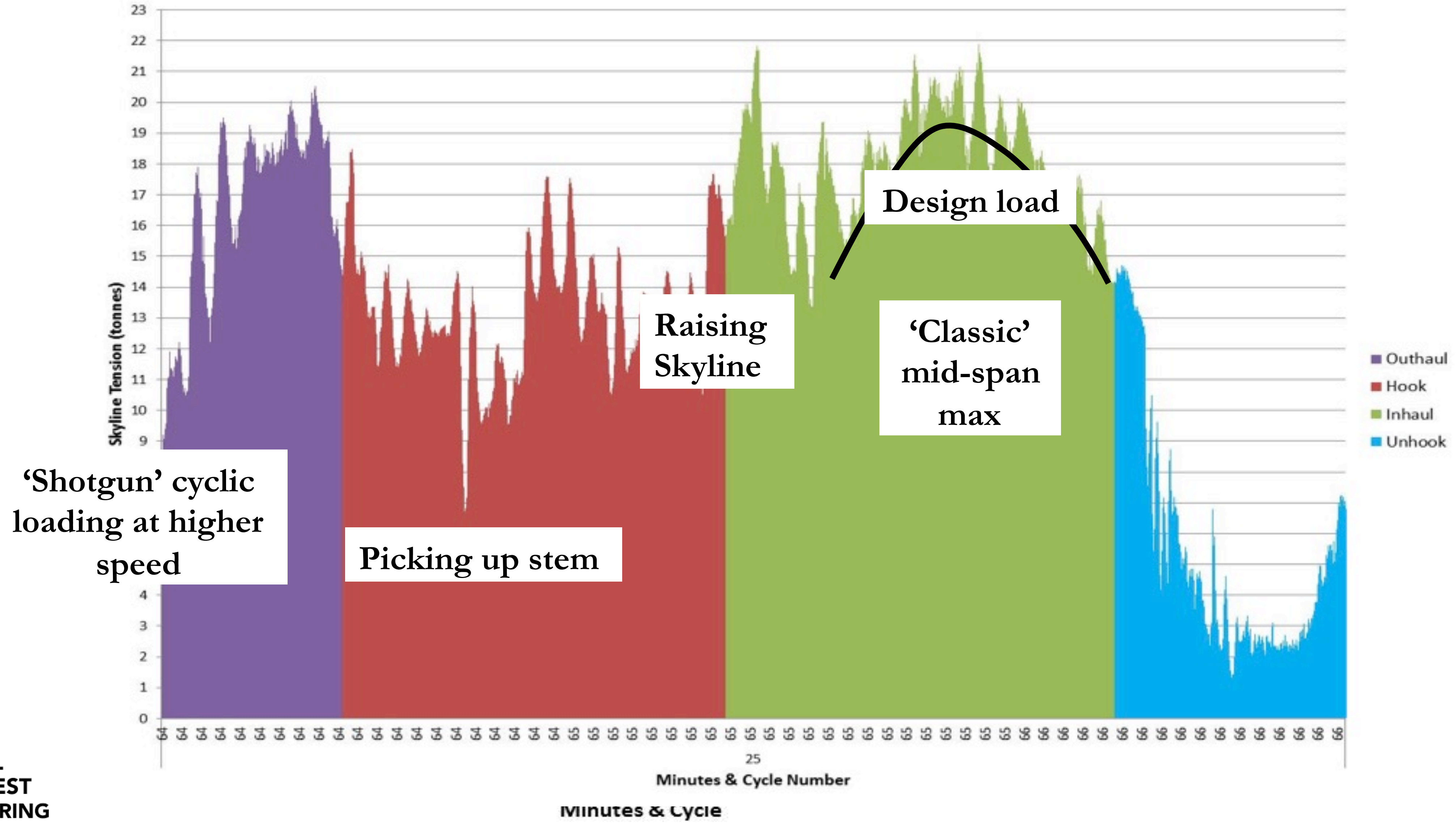
Results



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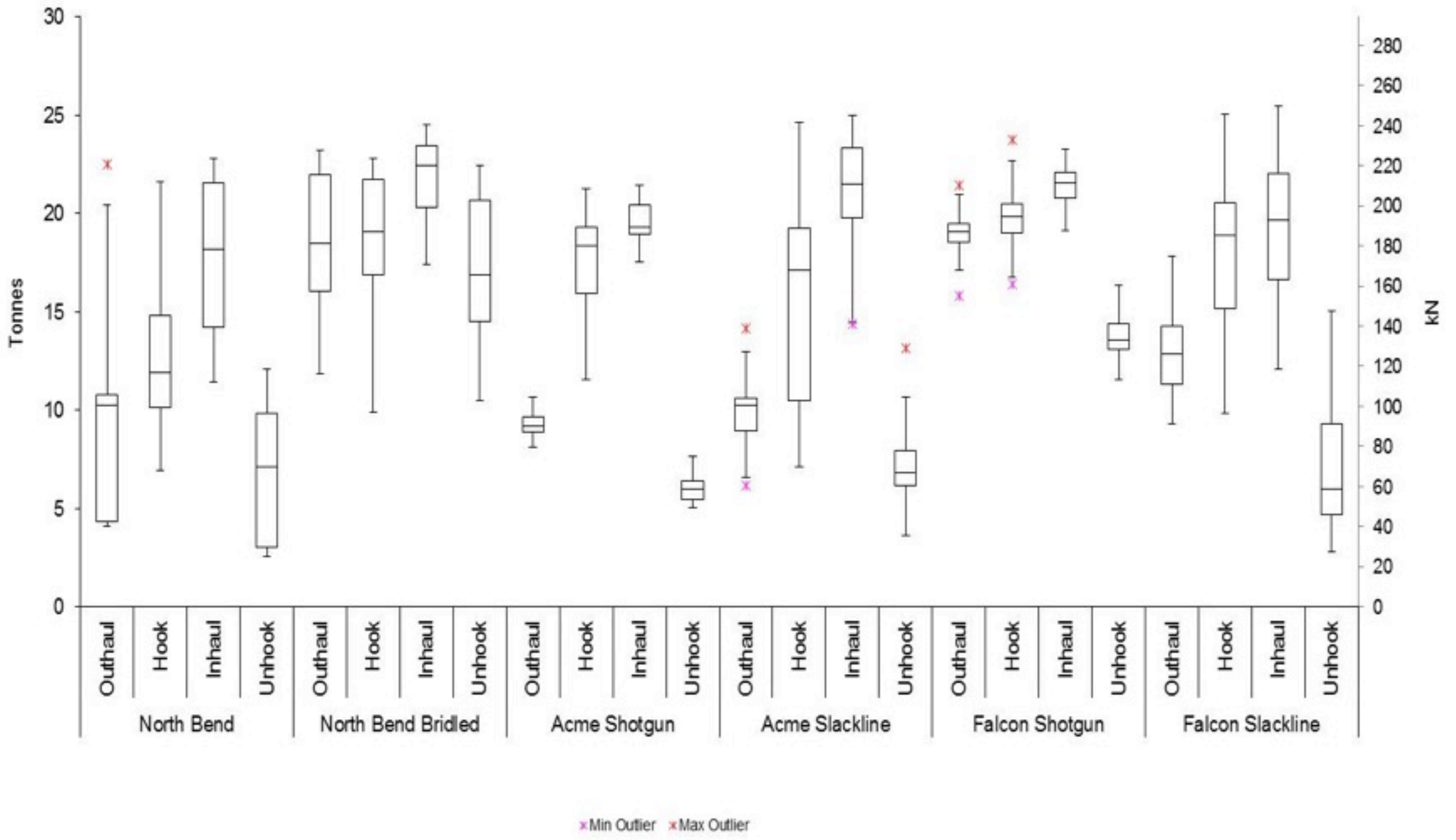
Observed Peak and Average Tensions



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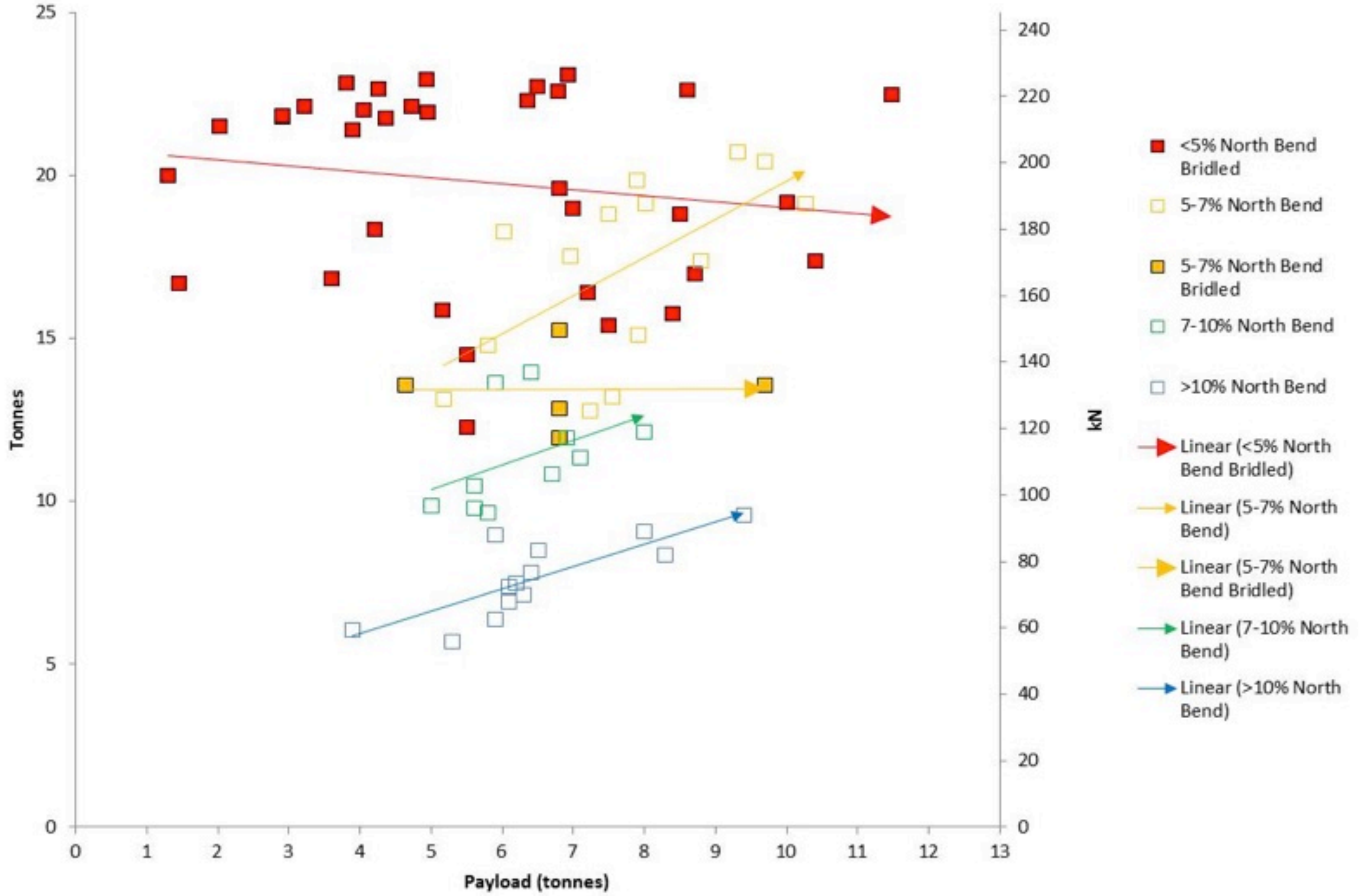
Payload to Tension Relationship



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Dynamic load magnitudes

Measurement	North Bend	North Bend Bridled	Acme Shotgun	Acme Slackline	Falcon Shotgun	Falcon Slackline
Average Breakout Tension Increase [a] (tonnes)	5.6	3.6	10.7	8.5	12.3	16.3
Coefficient of Variation	76%	107%	25%	62%	27%	23%
Average Breakout Tension Factor [b]	1.0	0.4	1.6	1.4	2.4	10.2
Coefficient of Variation	97%	166%	31%	95%	85%	36%
Average Maximum Cyclic Load Amplitude [c] (tonnes)	5.3	2.6	6.3	5.5	5.8	7.3
Coefficient of Variation	87%	89%	70%	52%	37%	39%
Average Maximum Cyclic Load Factor [d]	0.9	0.2	0.9	1.0	1.1	4.6
Coefficient of Variation	81%	106%	64%	90%	79%	51%
Sample Size (n)	37	38	15	49	63	54

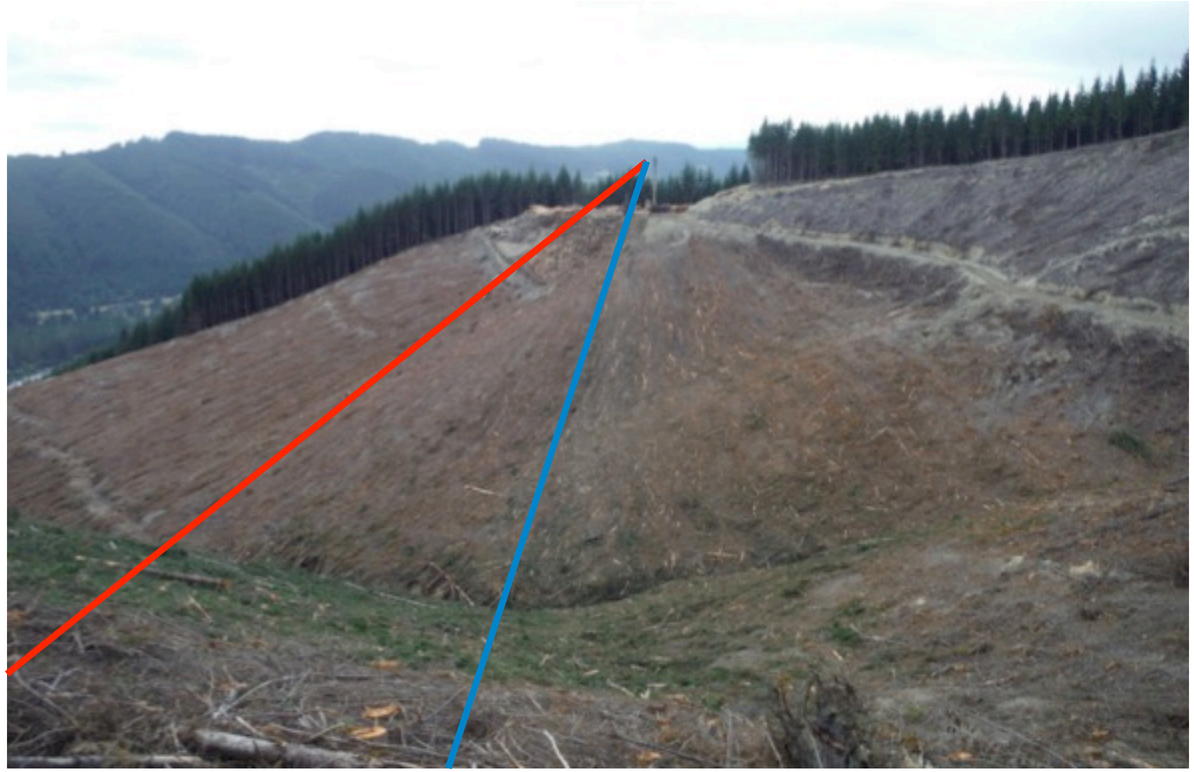
[a] Breakout Tension Increase = Peak Breakout Tension - Skyline Pretension

[b] Breakout Tension Factor = (Peak Breakout Tension - Skyline Pretension)/Skyline Pretension

[c] Maximum Cyclic Load Amplitude = greatest peak to peak change in skyline tension in a single cycle.

[d] Maximum Cyclic Load Amplitude Factor = Maximum Cyclic Load Amplitude/Skyline Pretension

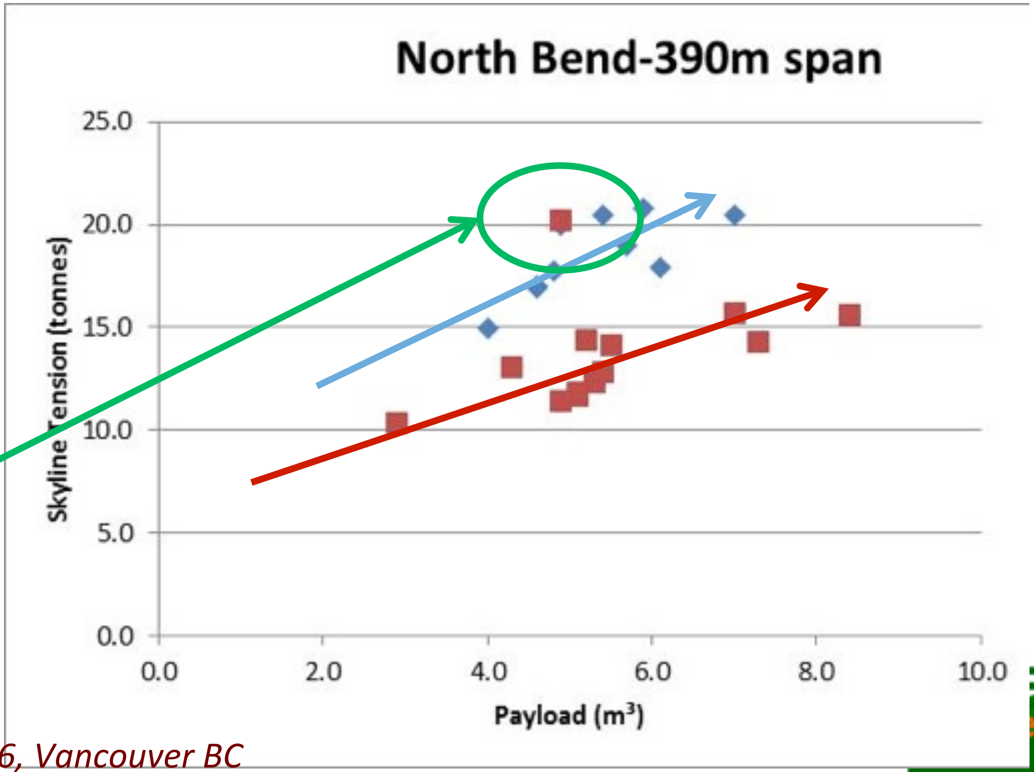
Breakout Amplifications



North-Bend:

Two corridors, 10% (*red*) and 8% (*blue*) deflection..

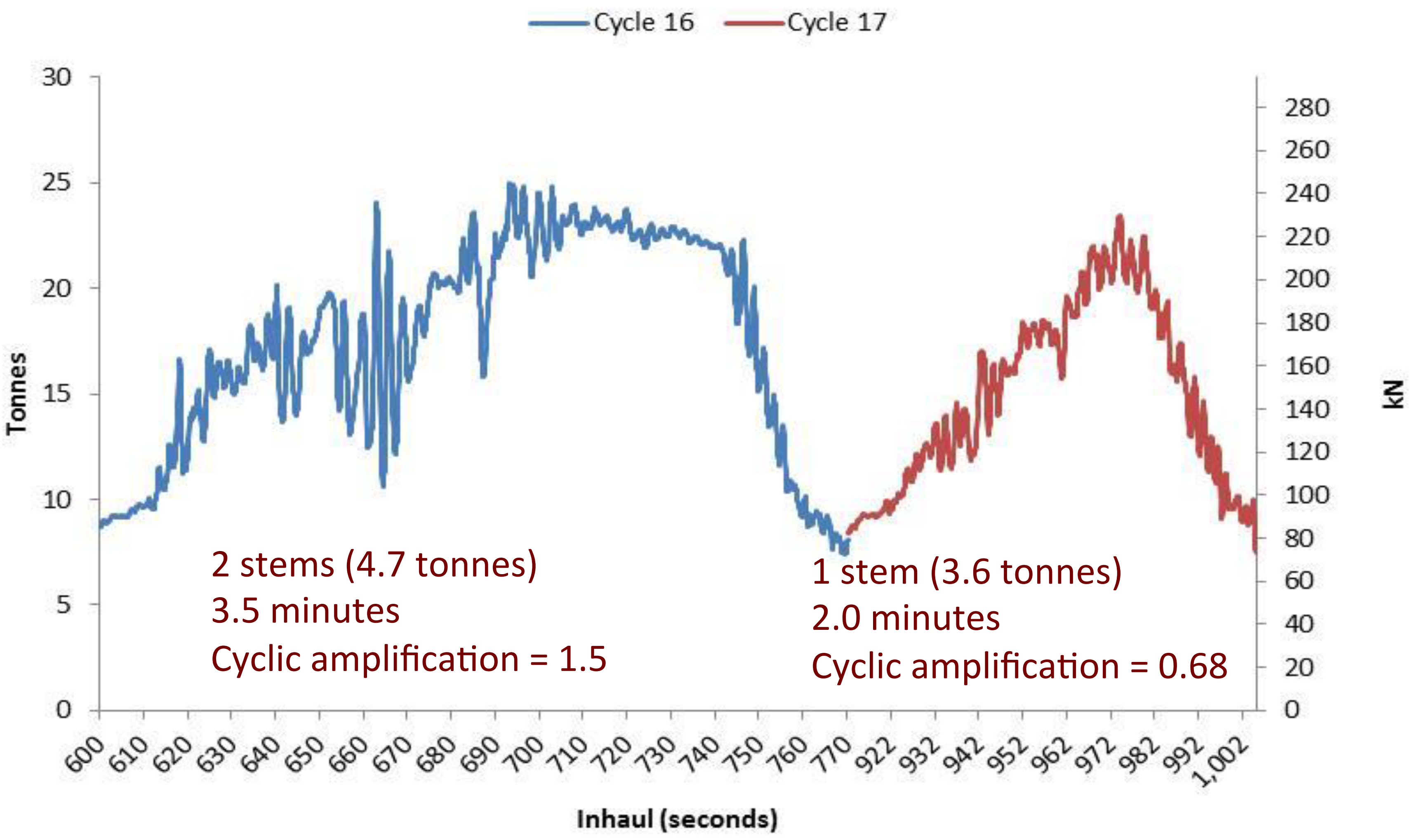
Clear difference in max skyline tension!



+ details from video!

i.e. Outlier 4.9m^3 load got hung-up in gully, hence high peak tension


Cyclic load amplifications: Partial vs Full Suspension



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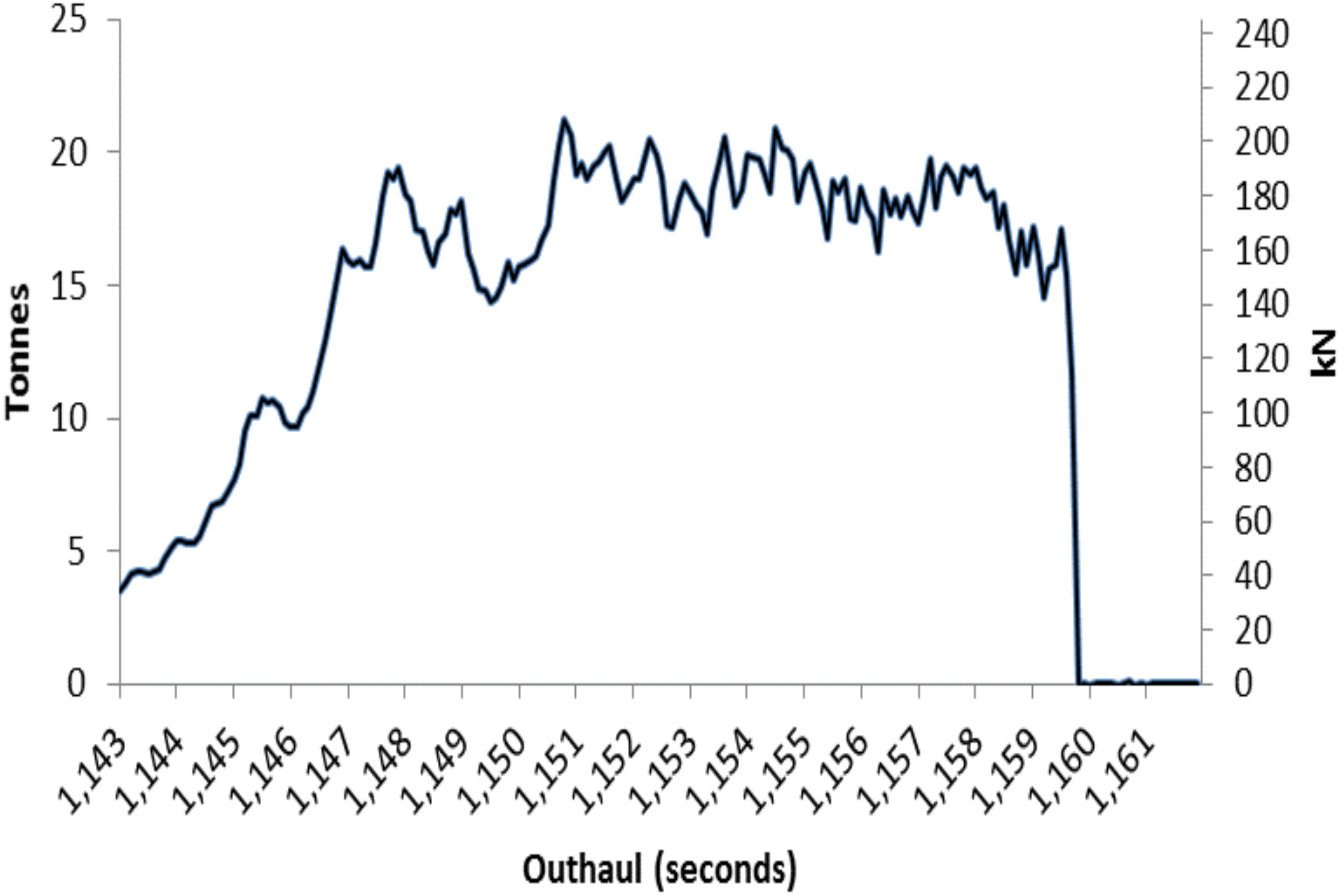
High Frequency Cyclic Loads



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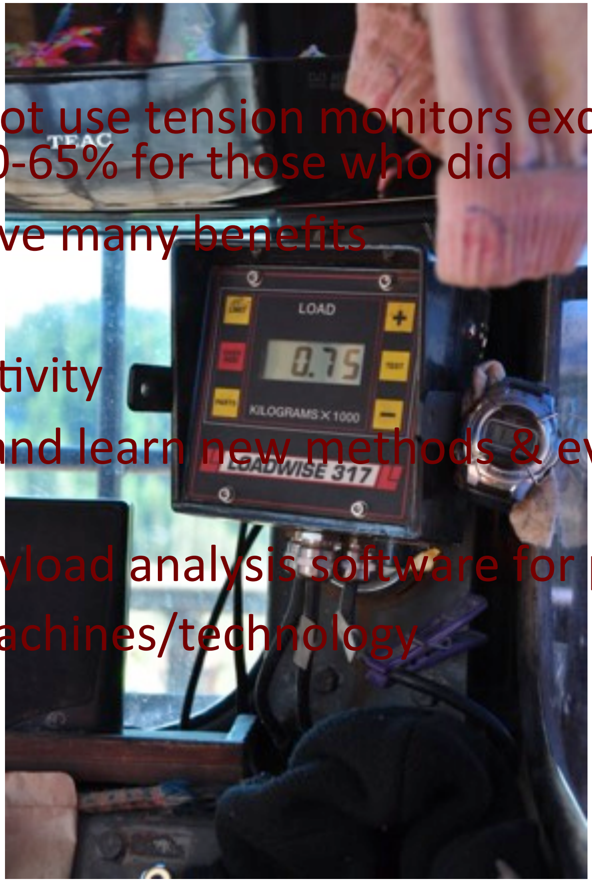
Recommendations

- Industry should consider installing tension monitors on all yarders



- Operators who did not use tension monitors exceeded SWL 75-95% of all cycles compared to 0-65% for those who did
- Tension monitors have many benefits
  - Ensure safety
  - Improve productivity
  - Help introduce and learn new methods & evaluate alternative techniques
  - Help validate payload analysis software for planning
  - Evaluate new machines/technology

Conclusion

- 259 cycles were recorded
  - 137 (53%) exceeded the SWL
- Clear differences in average and tensions between configurations!
  - Further studies into efficiency of rigging configurations needed
- Peak tensions differ by cycle element
- Payload to tension relationship consistent for standing skyline, less so for live skylines
  - Operator has strong influence
- Dynamic load amplifications are sometimes severe but can be managed through effective tension monitoring

Questions?

The results and figures discussed in this presentation were part of a larger project called *"Rigging Configurations Efficiency Case Studies"* sponsored by Future Forests Research Ltd.