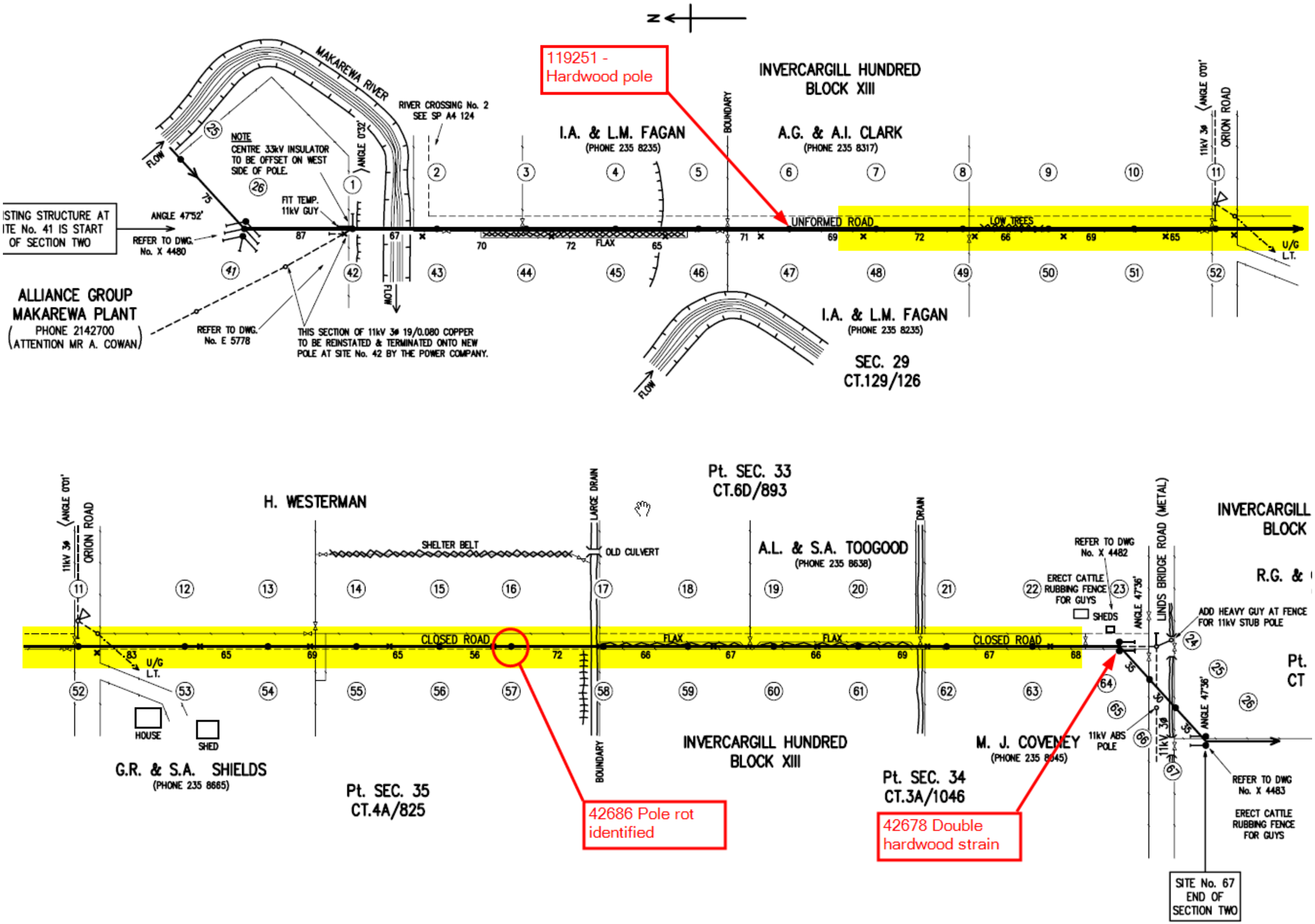
5:55am on 7th August 2014

- 1 km section of the Underwood- North Makarewa subtransmission line collapsed during a period of high winds
- 16 softwood poles toppled in the direction of the prevailing wind
- Initiated by rotten softwood pole


119251 - Hardwood pole
42686 Pole rot identified
42678 Double hardwood strain
INVERCARGILL HUNDRED BLOCK XIII
I.A. & L.M. FAGAN (PHONE 235 8235)
A.G. & A.I. CLARK (PHONE 235 8317)
MAKAREWA RIVER
RIVER CROSSING No. 2 SEE SP A4 124
NOTE CENTRE 33kV INSULATOR TO BE OFFSET ON WEST SIDE OF POLE.
FIT TEMP. 11kV GUY
ANGLE 47°52'
REFER TO DWG. No. X 4480
ISTING STRUCTURE AT ITE No. 41 IS START OF SECTION TWO
ALLIANCE GROUP MAKAREWA PLANT PHONE 2142700 (ATTENTION MR A. COWAN)
REFER TO DWG. No. E 5778
THIS SECTION OF 11kV 3ø 19/0.080 COPPER TO BE REINSTATED & TERMINATED ONTO NEW POLE AT SITE No. 42 BY THE POWER COMPANY.
UNFORMED ROAD
LOW TREES
FLAX
BOUNDARY
ORION ROAD
ANGLE 0°01'
U/G L.T.
SEC. 29 CT.129/126
H. WESTERMAN
SHELTER BELT
OLD CULVERT
LARGE DRAIN
Pt. SEC. 33 CT.6D/893
A.L. & S.A. TOOGOOD (PHONE 235 8638)
CLOSED ROAD
DRAIN
REFER TO DWG No. X 4482
ERECT CATTLE RUBBING FENCE FOR GUYS
SHEDS
LINDS BRIDGE ROAD (METAL)
ANGLE 47°36'
ADD HEAVY GUY AT FENCE FOR 11kV STUB POLE
INVERCARGILL BLOCK
R.G. &
Pt. CT
HOUSE
SHED
G.R. & S.A. SHIELDS (PHONE 235 8665)
Pt. SEC. 35 CT.4A/825
INVERCARGILL HUNDRED BLOCK XIII
M. J. COVENEY (PHONE 235 8045)
11kV ABS POLE
Pt. SEC. 34 CT.3A/1046
REFER TO DWG No. X 4483
ERECT CATTLE RUBBING FENCE FOR GUYS
SITE No. 67 END OF SECTION TWO


27/08/2014 13:11

Standard confusion

	ESR84	NZS4203/NZS3605
Wind pressure (Pa)	850	1081
Softwood strength factor	$\frac{1}{2} = 0.5$	$1.16 \times 0.71 \times 0.76 = 0.65$

Pole Number	Pre-event AS/NZS7000	Pre-event Actual design	Pre-event ESR84	Pre-event NZS4203	Post-event AS/NZS7000	Comment
37079	171%	108%	143%	123%	171%	Softwood
37078	130%	82%	108%	98%	130%	Softwood
37077	130%	82%	108%	98%	130%	Softwood
40876	130%	81%	107%	97%	130%	Softwood
119251	57%	42%	56%	50%	57%	Hardwood
117875	146%	91%	120%	108%	45%	Softwood
42694	133%	83%	110%	99%	42%	Softwood
42693	122%	77%	102%	92%	39%	Softwood
42692	163%	103%	136%	118%	52%	Softwood
42691	155%	96%	127%	114%	50%	Softwood
42690	167%	105%	138%	121%	54%	Softwood
42689	140%	87%	115%	103%	45%	Softwood
42688	128%	80%	106%	96%	41%	Softwood
42687	134%	84%	111%	99%	43%	Softwood
42686	116%	73%	97%	87%	37%	Softwood (Rotten)
42685	164%	104%	138%	118%	53%	Softwood
42684	134%	84%	111%	99%	43%	Softwood
42683	142%	88%	117%	104%	45%	Softwood
42682	169%	107%	142%	121%	54%	Softwood
42681	166%	105%	139%	119%	53%	Softwood
42680	177%	114%	151%	126%	81%	Softwood
42679	Strain					Hardwood strain
42678	116%	73%	97%	83%	116%	Softwood
42677	82%	54%	71%	62%	82%	Softwood

HICKSON TIMBER PRODUCTS LIMITED

Specification of the
Strength & Quality
of

ELECTROPOLES

for
Transmission Line Applications

Part 1 **Physical Description**

The terms of this section follow the existing NZS 3605:1977 Specification for load bearing round timber piles and poles and are generally in line with ANSI 05.1:1979 Specifications and dimensions for wood poles.

All Hickson Electropoles supplied to this Specification will meet the following criteria:

Sweep one plane / one direction	max 6mm/m
Sweep two plane / two directions	max 3mm/m
Short crook	max 25mm
Checks	max D/4
End splits	None
Knots individual	max 50mm
Knots groups	max D/4
Nodal swelling	max 10mm
Spiral grain	max 1:10

(D is the diameter at the defect being considered)

Definitions of the various terms are as follows :

SWEEP - The deviation of the pole from straightness, in a curve of large radius which occurs in:

(a) One direction in one plane (single sweep).
(b) Two directions in one plane (reverse sweep).
(c) Two planes (double sweep).
See Figs 1 - 3 NZS 3605 : 1977

SHORT CROOK - A short crook is a deflection from straightness affecting a maximum of 1.5m of the length, the parts on either side of the crook remaining straight.

CHECKS - Separations of fibres along the grain forming a fissure but not extending through the poles.

Safety Factor

It should be noted that all Hickson Electropoles proof tested in the above manner, are guaranteed to have a Factor of Safety of AT LEAST 1.54. This results from the testing being conducted at ANSI loadings compared to Design Wind Loadings via :

$$\frac{1}{1.16 * 0.71 * 0.79} = 1.54$$

The factor of 1.16 arises from the poles being tested wet rather than dry.

Engineers familiar with the previous ESA Codes may consider this FoS as somewhat low however it must be evaluated in terms of the reliability of the material. Concrete for example may have a FoS of 2 and due to its low variability could well have a 100% failure rate at 2.4 x Design Load. Alternatively, wooden Electropoles tested at 1.54 x Design Load are estimated (Walford 1989) to only have a 77% failure rate at 3 x Design Load - simply due to its wider variability.

A practical example of this could be in a Cyclone Bola situation with say forces of 3 x Design acting on the system, all steel and concrete poles could be assumed to break but only 70% of proof tested Electropoles.

- Tested to TLC
- Calculated strength = 1.54*TLC
- Designed to 1.54*TLC?

(TLC=Top load capacity)

Failure causes

- Rotten pole initiation
- Poles not strong enough

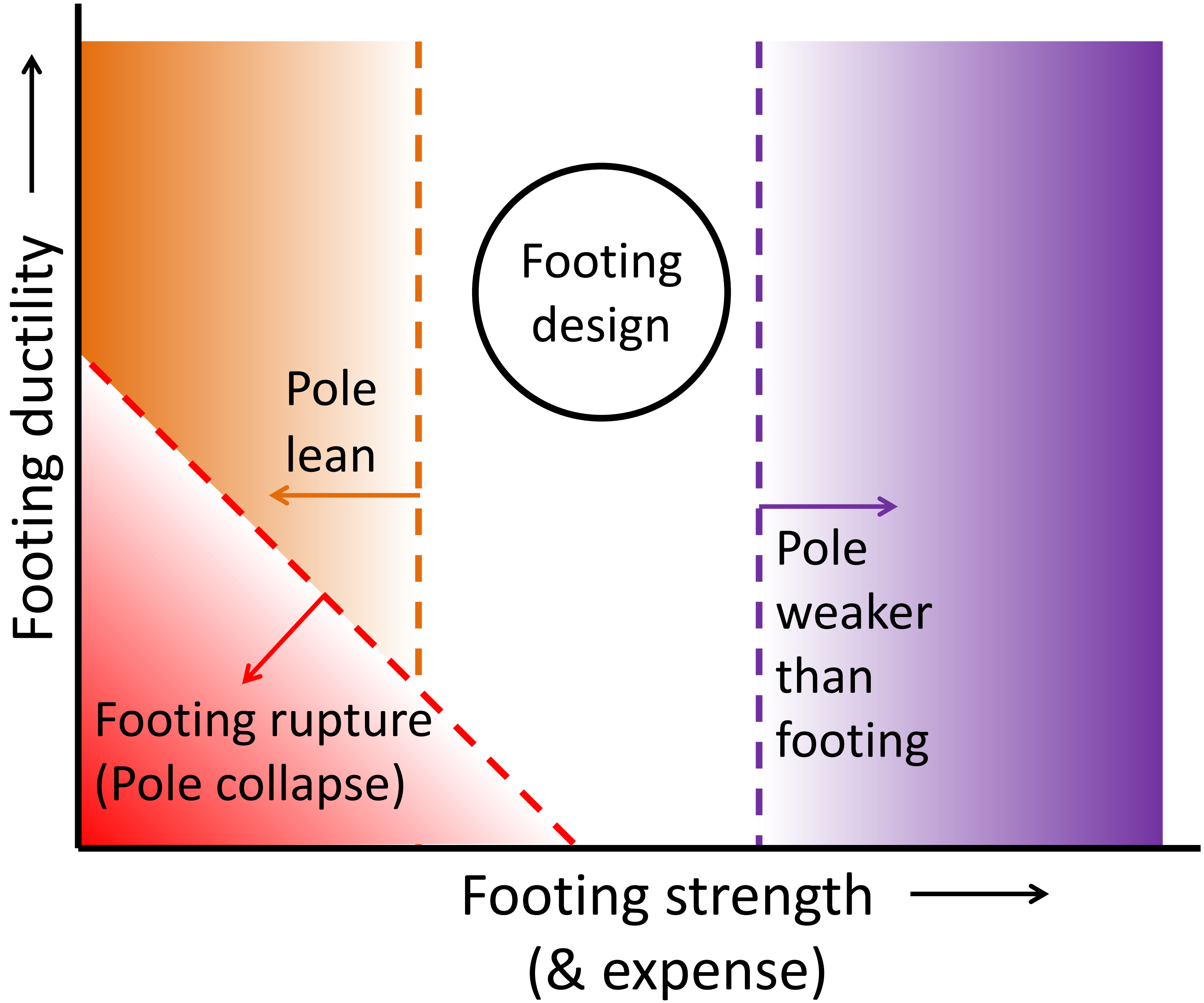
Failure causes

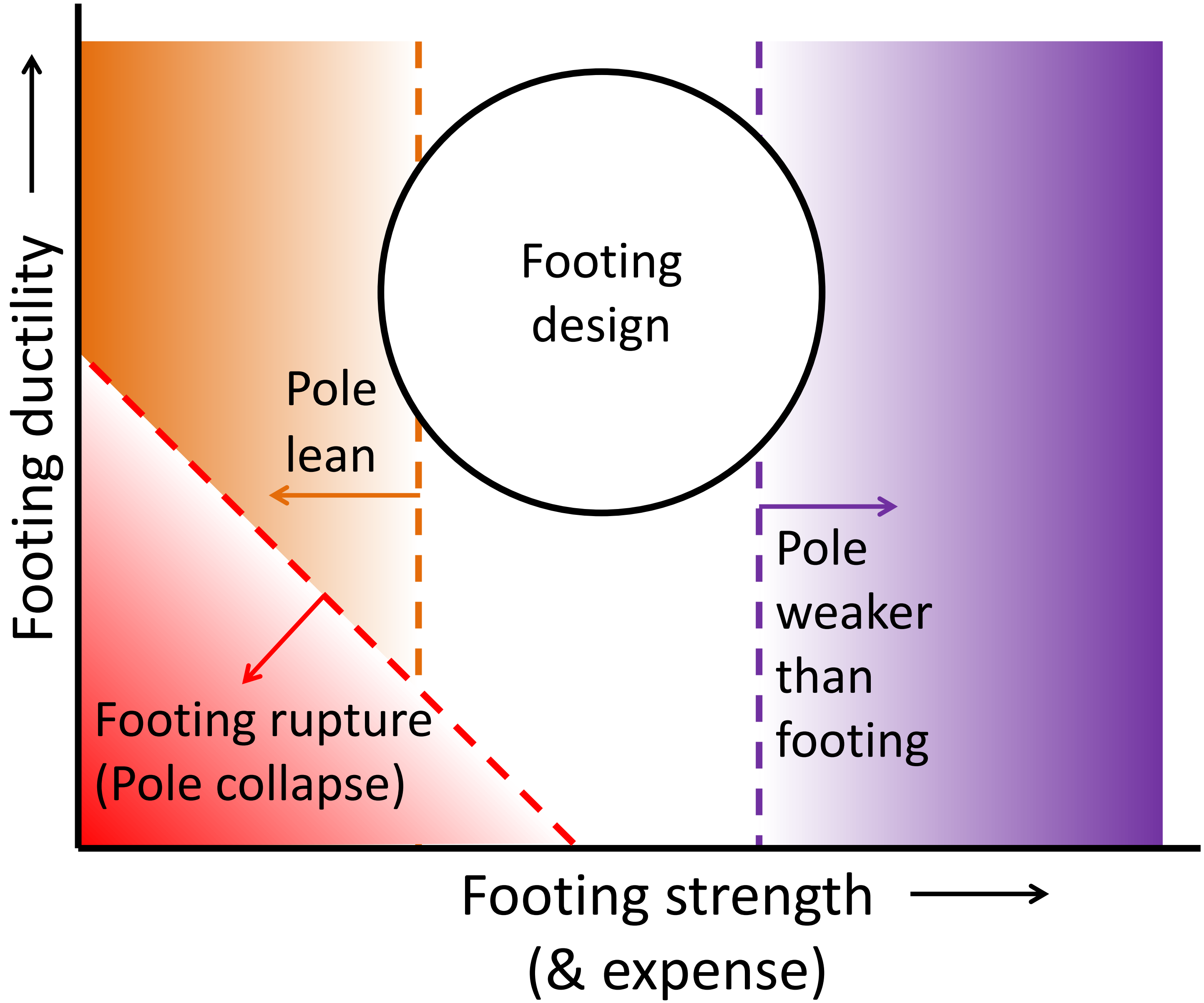
- Rotten pole initiation
- Poles not strong enough
- Footing failure?

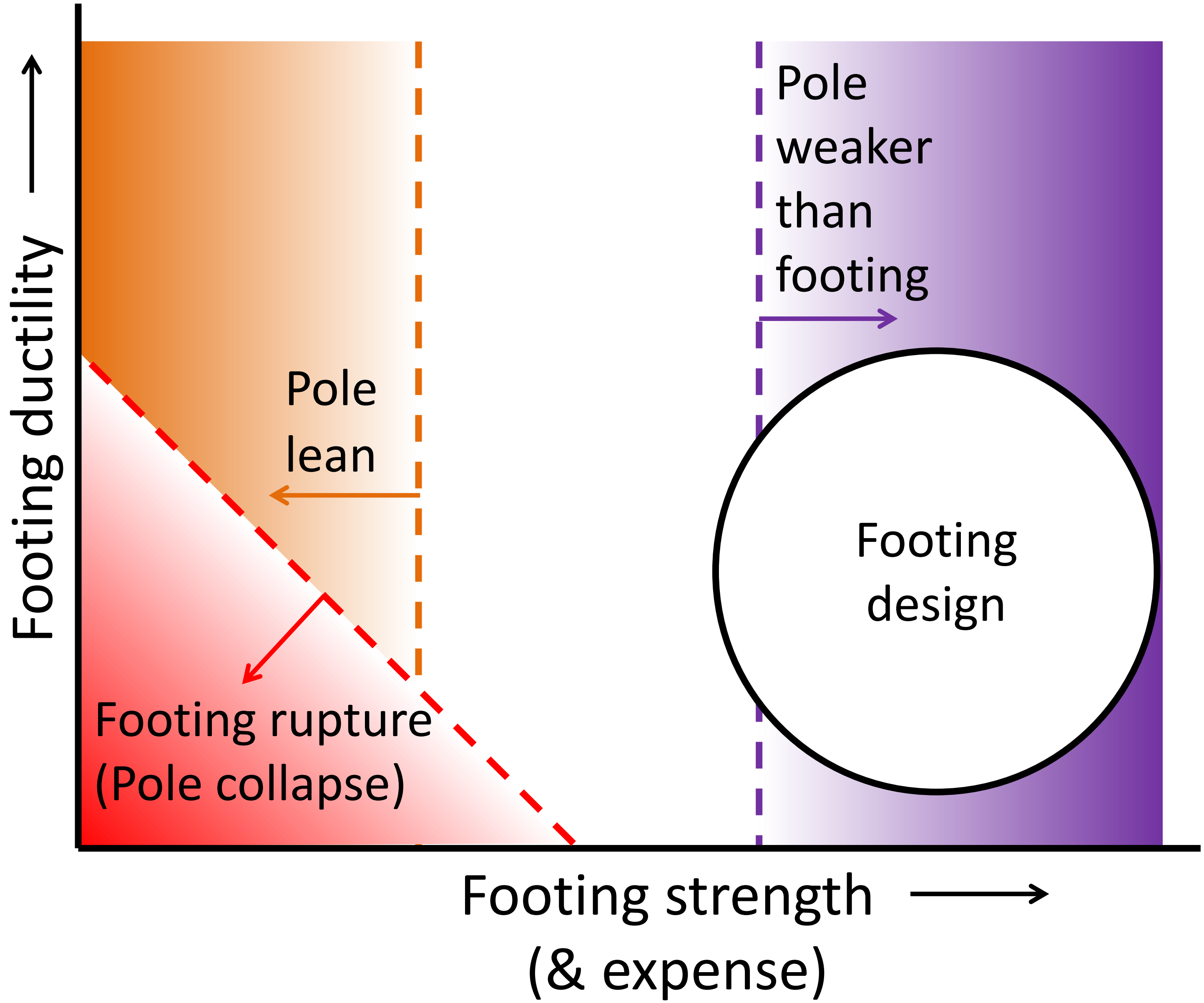
2. SITE No.'s 58 – 64 INCLUSIVE, PLUS 67, TO HAVE 1200mm MINIMUM DIA. & 3200mm DEEP POLE HOLES BACKFILLED AS PER SPECIFICATION.


Peninsula
80
80


20


Footing ductility
Footing design
Pole
lean
Pole
weaker
than
footing
Footing rupture
(Pole collapse)
Footing strength
(& expense)

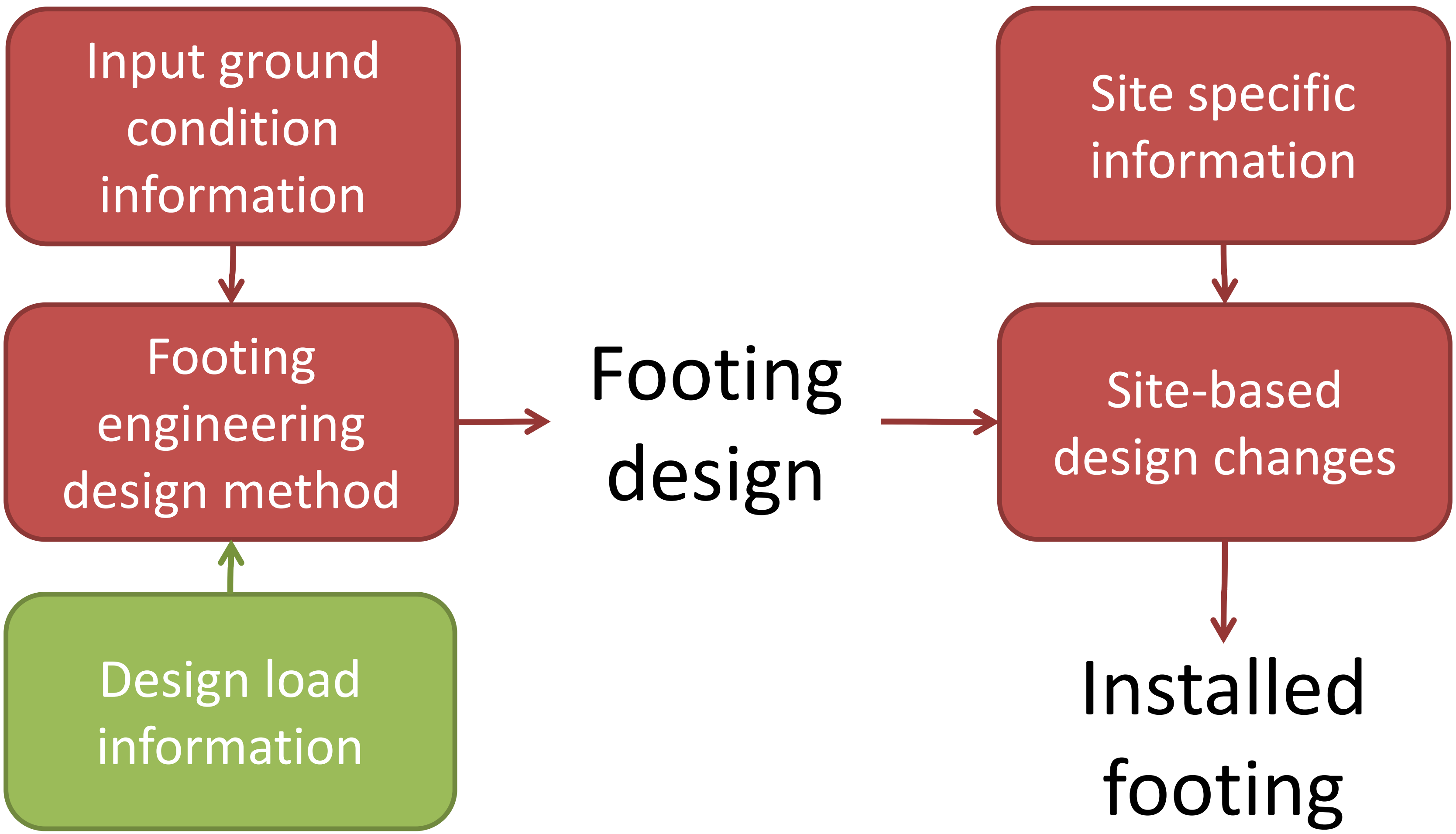

Footing design
Pole lean
Pole weaker than footing
Footing rupture (Pole collapse)
Footing ductility
Footing strength (& expense)


Footing ductility
Pole weaker than footing
Pole lean
Footing design
Footing rupture (Pole collapse)
Footing strength (& expense)

Proposed development of footing design method

To validate or develop a fit for purpose footing design method

Footing design elements



AS/NZS7000:2016 Appx L

Soil parameters

TABLE L1

TYPICAL PROPERTIES OF COHESIVE SOILS

Term	Unit weight (kN/m^3)	Shear strength, C_u (kPa) Undrained	Field guide to consistency
Very soft	16–19	0 to 10	Exudes between fingers when squeezed in hand
Soft	17–20	10 to 25	Can be moulded by light finger pressure
Firm	17.5–21	25 to 50	Can be moulded by strong finger pressure
Stiff	18–22	50 to 100	Cannot be moulded by fingers. Can be indented by thumb
Very stiff	21–22	100 to 200	Can be indented by thumb nail
Hard	20–23	≥200	Can be indented with difficulty by thumb nail

TABLE L2

TYPICAL PROPERTIES OF NON-COHESIVE SOILS

Soil type	Unit weight (kN/m^3)	Angle of friction, φ (degrees)
Loose gravel with sand content	16–19	28º–30º
Medium dense gravel with low sand content	18–20	30º–36º
Dense to very dense gravel with low sand content	19–21	36º–45º
Loose well graded sandy gravel	18–20	28º–30º
Medium dense clayey sandy gravel	19–21	30º–35º
Dense to very dense clayey sandy gravel	21–22	35º–40º
Loose, coarse to fine sand	17–22	28º–30º
Medium dense, coarse to fine sand	20–21	30º–35º
Dense to very dense, coarse to fine sand	21–22	35º–40º
Loose, fine and silty sand	15–17	20°–22º
Medium dense, fine and silty sand	17–19	25º–30º
Dense to very dense, fine and silty sand	19–21	35º–40º

AS/NZS4676

Soil parameters

I2 FOUNDATION PROPERTIES

I2.1 Bearing strength

I2.1.1 *Serviceability limit state*

Table I1 has been prepared using a simple broad classification of soil types, with bearing strengths based on degree of firmness or resistance to indentation. This can be readily assessed on site by the standard penetrometer test (AS 1289.F.3.2) at the appropriate depth. The boundaries between the classes are in fact quite arbitrary but correlate well with permissible bearing stress values quoted in the technical literature.

TABLE I1

BEARING STRENGTH OF SOILS AT THE SERVICEABILITY LIMIT STATE

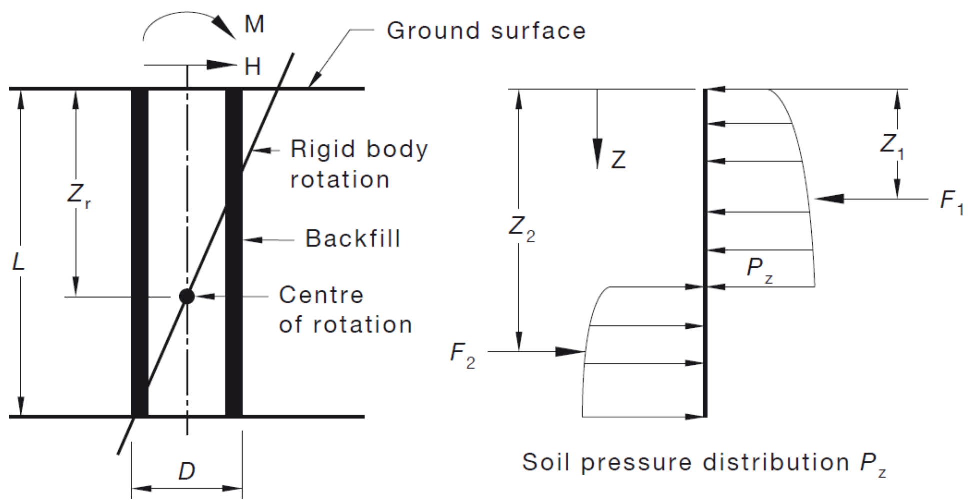
Class	Very soft	Soft	Firm	Very firm	Hard
Soil description	Silty clays and sands; loose dry sands	Wet clays; silty loams; wet or loose sands	Damp clays; sandy clays; damp sands	Dry clays; clayey sands; coarse sand s; compact sands	Gravels; dry clays
Strength (f_b) kPa	$f_b \leq 60$	$60 < f_b \leq 100$	$100 < f_b \leq 150$	$150 < f_b \leq 240$	$240 < f_b$

NOTE: The above values are based on foundation deformations of approximately 12 mm under serviceability loads on building structures. For poles supporting services that are sensitive to displacements at their supporting points (e.g. microwave antennas), this degree of deformation might be inappropriate. Therefore, suitable reduction of these values may be necessary. This may be achieved by increasing the embedment depth, or the footing diameter, or both, which will reduce the bearing pressures and, consequently, the deformations.

AS/NZS7000 Appx L

L3.3.1 *Brinch Hansen method*

The mathematical model of the pole/soil system is shown in Figure L1.



$$P_z = q_z K_q + c_u K_c \qquad \text{. . . L2}$$

where

q_z = vertical overburden pressure at depth $z = \gamma z$

γ = soil unit weight (see Tables L1 to L3)

c_u = soil shear strength (see Table L1)

K_q, K_c = factors that are a function of z/D and the soil angle of friction, ϕ (see Table L2)

AS/NZS7000:2016 Appx L

L3.2 Bored piers

The Brinch Hansen method presented here is considered to be appropriate to the dimensional range and characteristics of poles in transmission line structures. Alternative methods are given in SA HB 331.

The Brinch Hansen method does not provide an indication of pole rotation at the nominal failure load. However, ground line rotation when using Brinch Hansen is typically 2° for undrained conditions. For drained conditions the equation predicts overturning moments typically corresponding to 5° rotation.

Failure of the footing, that is when the rotation increases markedly for little increase in load, is typically associated with rotations of 5°. Accordingly, the calculated footing capacity in drained conditions should be appropriately factored down.

AS/NZS4676:2000

Varying embedment depth

$$D = \frac{3.6 H_R + \sqrt{12.96 H_R^2 + 16.2\, CM}}{2C} \qquad \ldots \text{I3.2(1)}$$

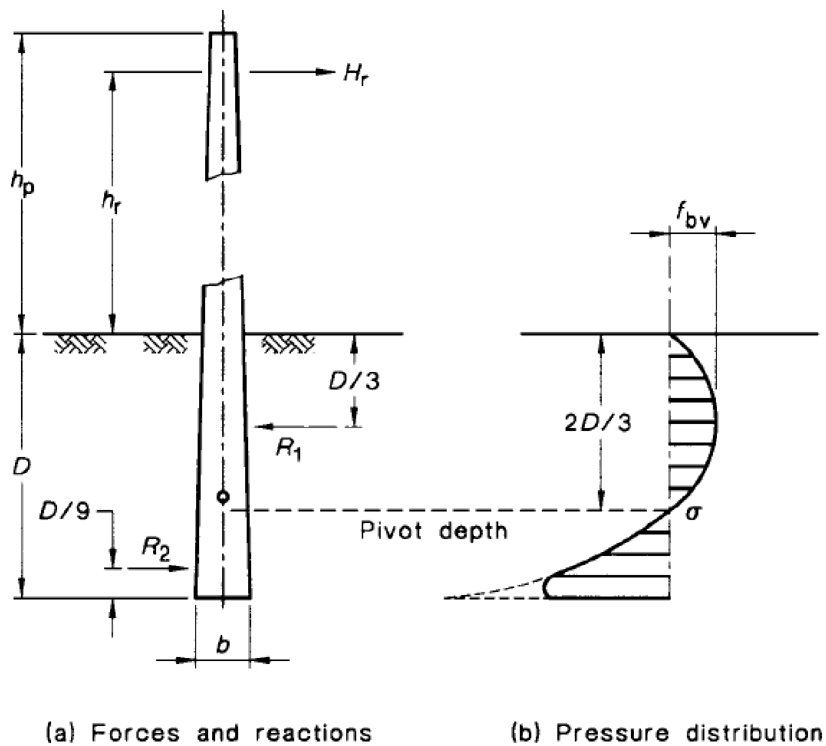


FIGURE I3.1 FORCES ON FOOTINGS AND FOUNDATIONS (VARIABLE EMBEDMENT)

AS/NZS4676:2000

Fixed embedment depth

Based on the above assumptions, the reaction force on upper bearer (R_{b1}) is given by—

$$R_{b1} = H_R\ (Kh_p + h_r - 0.1)/(kh_p - 0.4) \qquad \text{. . . I3.3(1)}$$

the reaction force on the lower bearer is given by

$$R_{b2} = R_{b1} - H_R \text{ ; and}$$

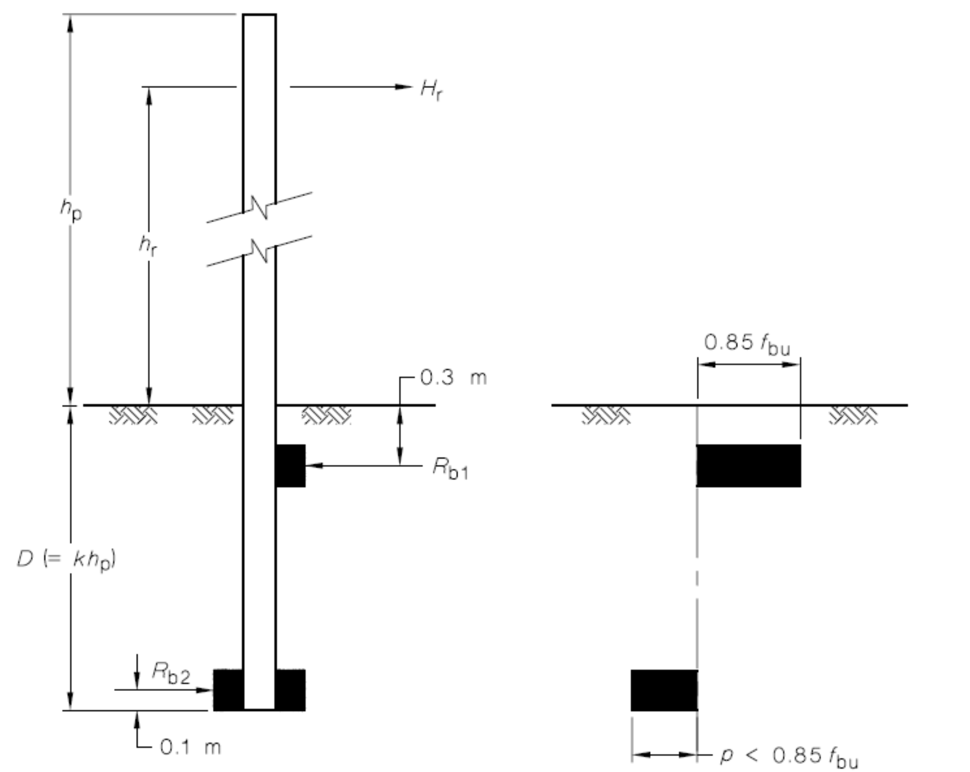


FIGURE I3.2 FORCES ON FOOTINGS AND FOUNDATIONS (FIXED EMBEDMENT)

HB 331:2012

9.4.6 *Site and geotechnical investigations*

It is recommended for all new overhead lines to conduct appropriate geotechnical and geological investigations, sufficient to ensure a safe, economical and practical design can be built.

The investigations should develop the characteristics of the soils, the water table and effect on construction and long term performance when loaded. Stability of the ground slopes also should be considered.

Investigations could involve:

(a) A walkover survey, general data of route, the surface soils, and identification of land stability issues and observable water Tables e.g. drains.

(b) Use of soil maps highlighting areas requiring specific investigations.

(c) Field investigations involving test pits to determine subsoil soil properties.

Any site investigations should include recommendations as to the design parameters and any further work required (e.g. proof loading, laboratory testing etc).

The suggested requirements for investigation are listed in Table 21.1.

TABLE 9.4

FOUNDATION INVESTIGATION REQUIREMENTS

Foundation Investigation Requirements	Line importance		
	Level I	Level II	Level III
Drive over route	✓	✓	✓
Walk over each site	✓	✓	✓
Test pits/scala penetrometer	—	✓	✓
Specific geotechnical advice required	—	—	✓

When investigation tests are required, there should be a minimum of 3 soil tests per soil type or 1 test per 5 km of line, whichever is the greater.

Site specific foundation investigations should be undertaken in the following circumstances when—

(i) the Line Importance is high; or

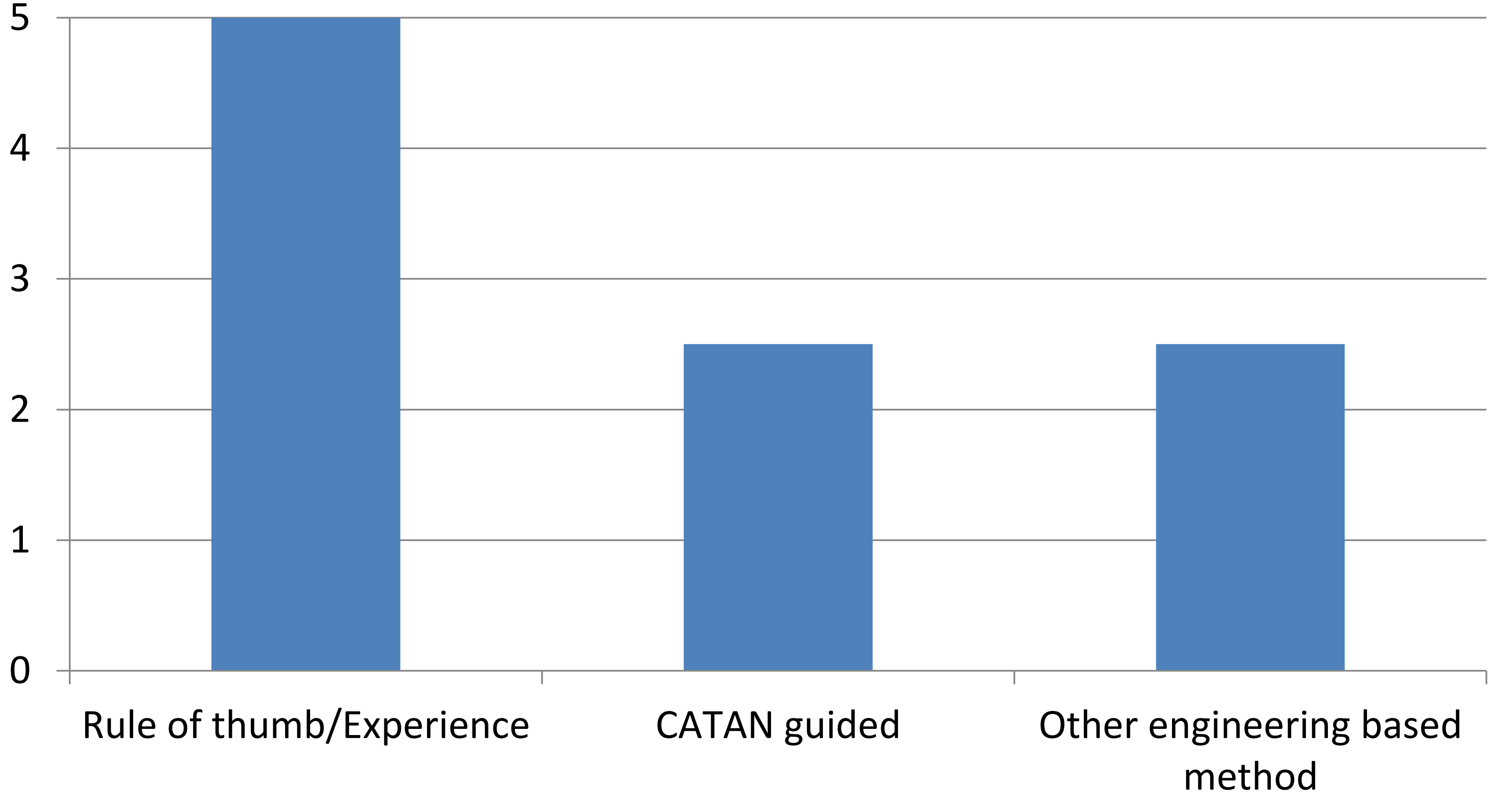
(ii) there are known foundation problems and a history of failures; or

(iii) there are land instability issues; or

(iv) poles are supporting aerial plant weighing more than 1000 kg.

The water table should be based on site investigations with allowance for seasonal fluctuations. If the water table has not specifically been determined, a level of 1 m below the ground surface could be used.

Footing design method in practice



Getting informed

- Install multiple poles with different footing designs
- Pull them to failure (where failure is defined the pole resisting 20% less than peak load)

Possible test permutations

- Testing could include any of the following variants:

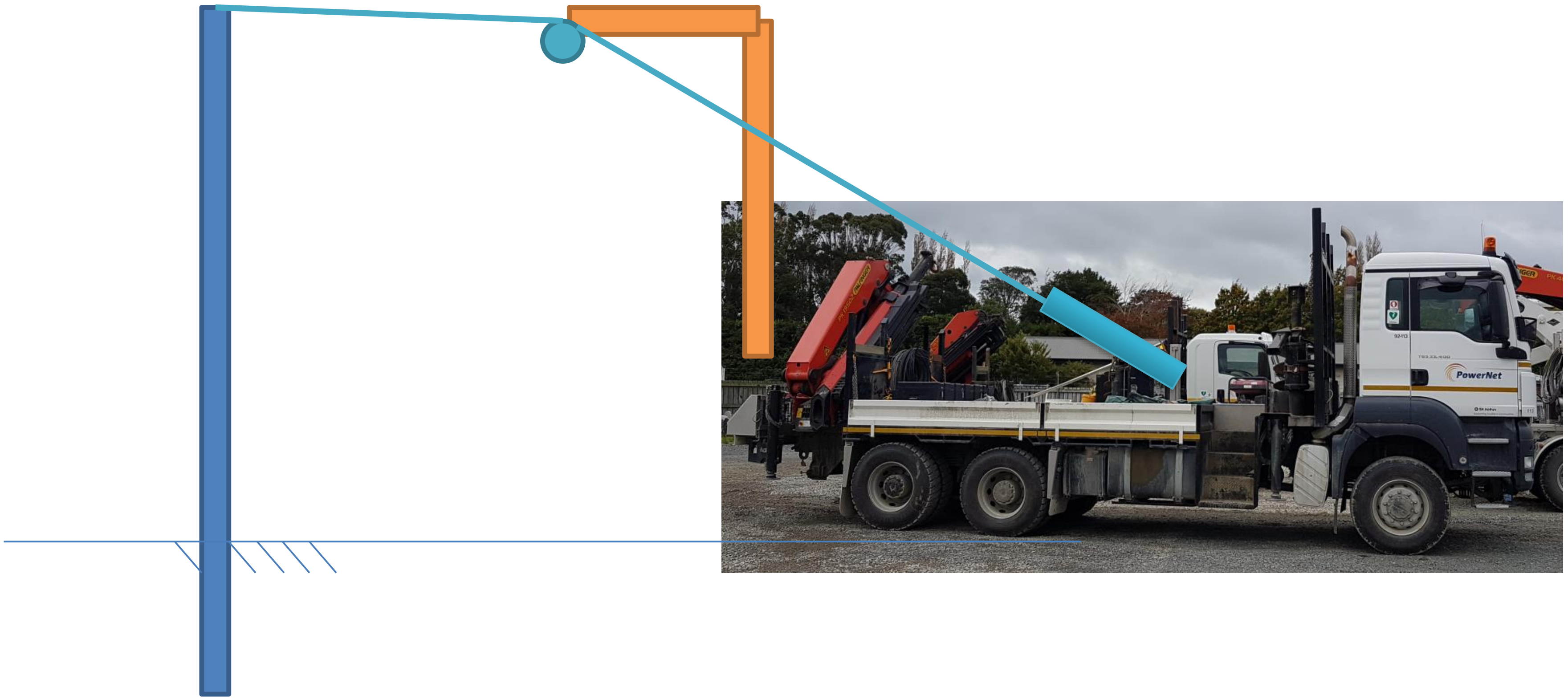
Location	Setup variant	Pole type	Hole	Embedment	Donut	Backfill	Breast block	Soil type
Site 1	Test 1	Busck B11.0	Augered	Standard	Yes	AP40	N/A	Site specific
Site 1	Test 2	Busck B11.0	Augered	Standard	Yes	AP40	N/A	Site specific - Saturated
Site 1	Test 3	Busck B11.0	Augered	Standard	Yes	Original	N/A	Site specific
Site 1	Test 4	Busck B11.0	Augered	Standard	Yes	AP40 (no compaction)	N/A	Site specific
Site 1	Test 5	Busck B11.0	Augered	Standard	Yes	AP40 cement stabilised	N/A	Site specific
Site 1	Test 6	Busck B11.0	Augered	Standard	Yes	Concrete	N/A	Site specific
Site 1	Test 7	Busck B11.0	Augered	Standard	No	AP40	N/A	Site specific
Site 1	Test 8	Busck B11.0	Augered	Standard	Yes	AP40	600mm	Site specific
Site 1	Test 9	Busck B11.0	Augered	Standard	Yes	AP40	900mm	Site specific
Site 1	Test 10	Busck B11.0	Augered	-0.8	Yes	AP40	N/A	Site specific
Site 1	Test 11	Busck B11.0	Augered	-0.4	Yes	AP40	N/A	Site specific
Site 1	Test 12	Busck B11.0	Augered	+0.4	Yes	AP40	N/A	Site specific
Site 1	Test 13	Busck B11.0	Augered	+0.8	Yes	AP40	N/A	Site specific
Site 1	Test 14	Double Busck B11.0	Augered	Standard	Yes	AP40	N/A	Site specific
Site 1	Test 15	Busck B9.5	Augered	Standard	Yes	AP40	N/A	Site specific
Site 1	Test 16	Busck B12.5	Augered	Standard	Yes	AP40	N/A	Site specific
Site 1	Test 17	Busck B12.4	Augered	Standard	Yes	AP40	N/A	Site specific
Site 1	Test 18	Hardwood 11m	Augered	Standard	Yes	AP40	N/A	Site specific

- It may be desirable to perform duplicate tests for each variant
- The total number of test variants and test sites will depend on the extent of industry support for the testing

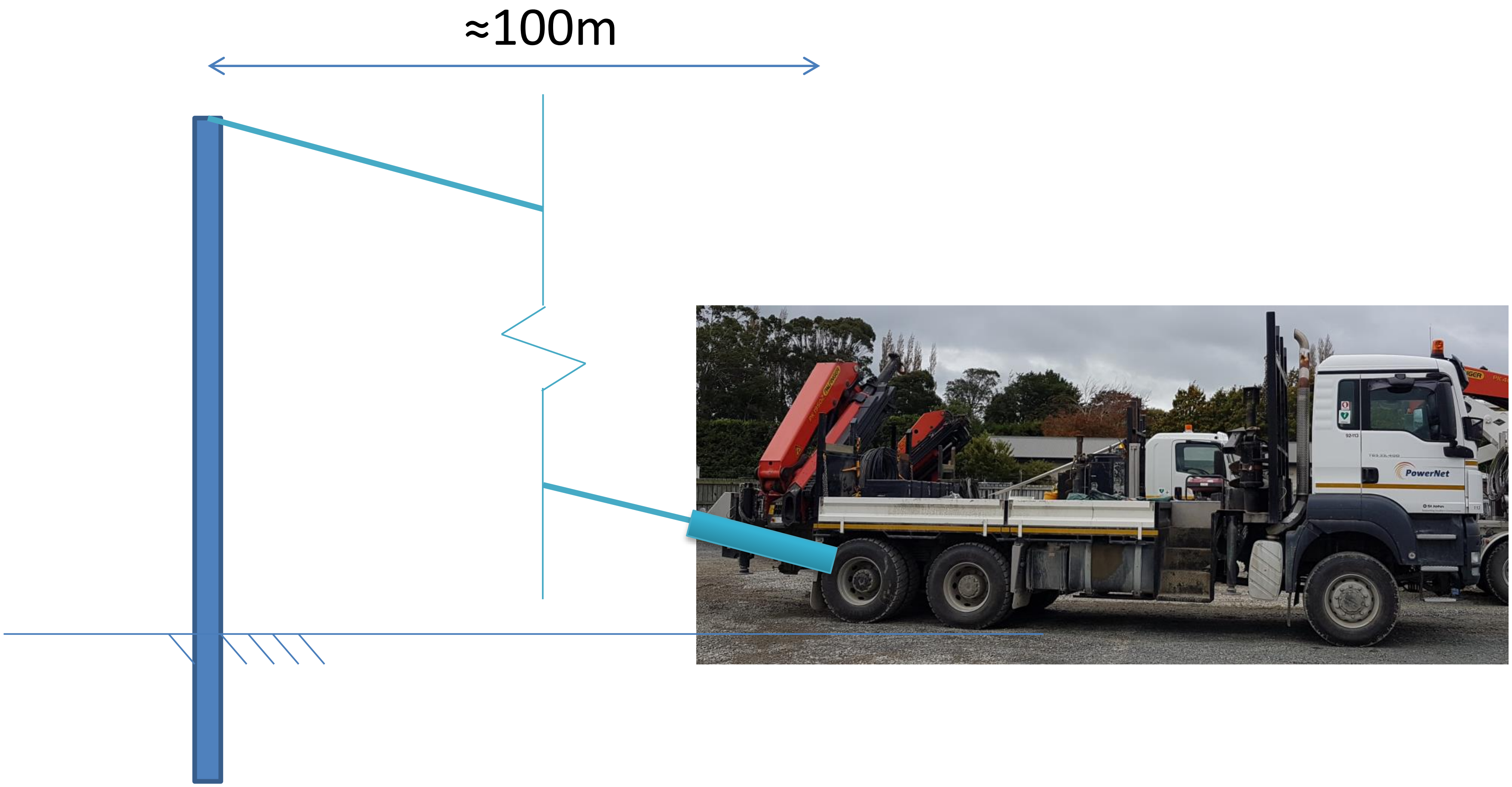
Multiple sites

- Representative sites
- Pool resources to support a site
- Establish a design method to last a generation, for the cost of a pole replacement in town

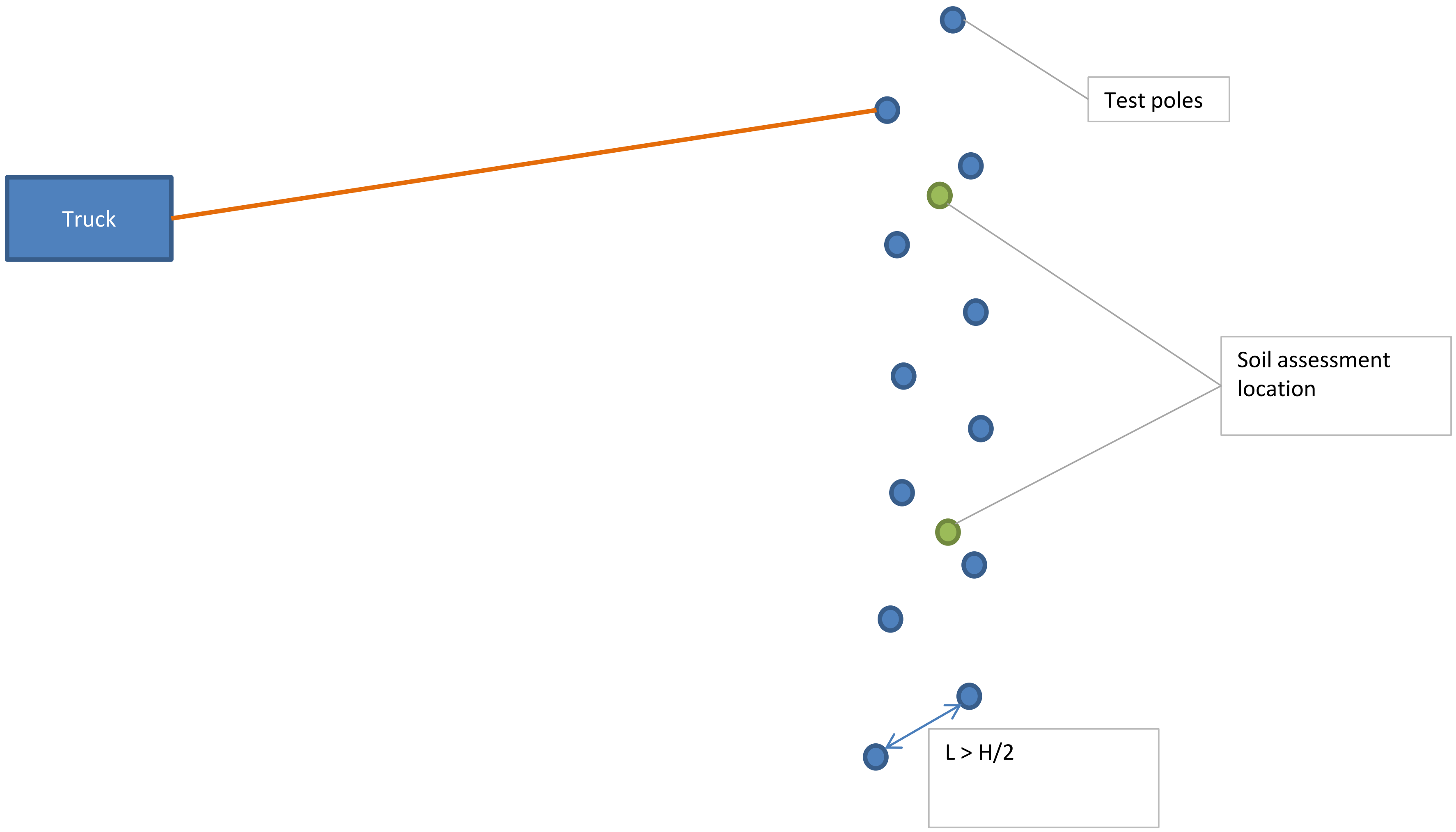
Test set-up - Option #1



Test set-up - Option #2

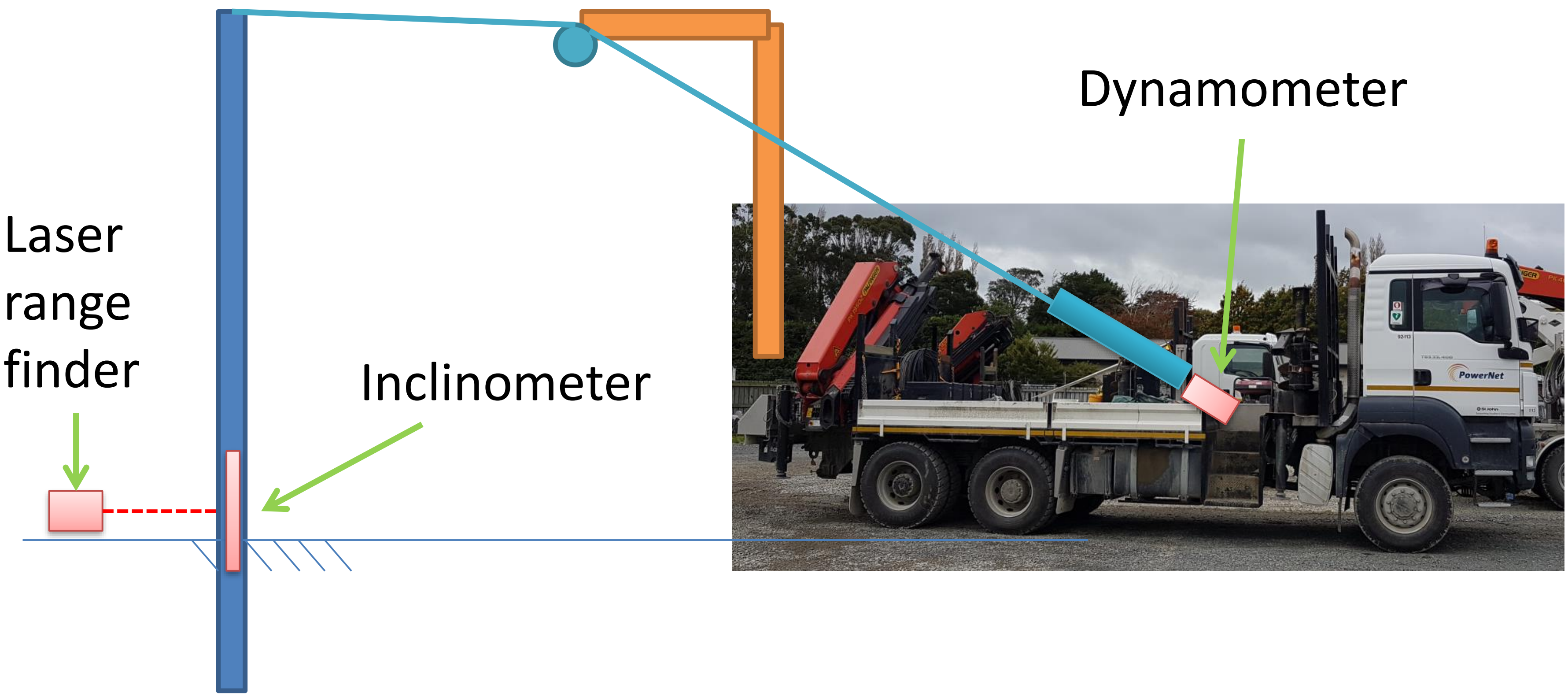


Test set-up – Plan view



Sensors

- Pole top load – Ground-line moment and shear
- Ground line displacement
- Ground line rotation



Geotechnical

- Scalar penetrometer (including torque measurement)
- Shear vein
- Hand auger
- Auger torque log (if possible)
- Geotechnical assessment (SPT)
- Geotechnical maps

(a focus on using tests which are cheap, simple and low cost)

Rough plan for next steps

- Identify project participants (contact: crathbone@powernet.co.nz, 021 515 910)
- Develop proposal
- Perform testing at first site
- Prepare feasibility report based on initial results
- Refine test programme (if applicable)
- Perform test at additional sites (number TBD)
- Prepare final report, including design recommendations