LONG PLAIN MINE

PROPOSED SURFACE WATER AND GROUNDWATER MONITORING INFRASTRUCTURE AND TESTING

For

GRANGE RESOURCES TASMANIA

Job No.	1839_G
Doc No.	3549
Date:	March 2013
Prepared by:	Alexis Valenza

Mining One Pty Ltd
Level 9, 50 Market Street
Melbourne VIC 3000
Ph: 03 9600 3588
Fax: 03 9600 3944

FINAL REPORT

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1 INTRODUCTION

The Long Plains Prospect is located approximately 10km by road south of the Savage River Mine and concentrator, and is owned by Grange Resources Tasmania (GRT).

The Long Plains magnetite deposit was first investigated during the late 1950's, and was identified as having mineralisation outcropping near surface. The Exploration Licence, EL30/2003, comprises an area of 38 km^2 which encompasses the entirety of the Long Plains magnetic anomaly and provides continuous leasehold with the Savage River Mine Lease.

A ground magnetic survey was conducted in 2011 and a diamond drilling exploration program completed in May 2012 to evaluate the ore potential. As part of the mine planning, GRT is currently in the process of drilling additional holes for geotechnical and groundwater testing.

GRT is also seeking technical support to investigate the hydrological and hydrogeological setting of Long Plains and is keen to combine the planned geotechnical drilling and testing with the acquisition of groundwater data (packer testing, falling head testing, water quality sampling and water level measurement), which is required for the preparation of the environmental work plan.

The scope of this brief is to provide technical guidance for the definition of a monitoring program aiming to provide baseline data for the development of the environmental work plan (Stage 1).

The Stage 1 scope covered by Mining One is the following:

- Site visit by a Mining One Hydrogeologist aiming to define the proposed monitoring network in collaboration with GRT staff;
- Review of all GRT data relevant to the key issues; and
- Design of a suitable monitoring infrastructure together with specification for hydrogeological testing at the site.

At completion of Stage 1, decision will be made by GRT as to how much further support may be needed for the hydraulic testing at the site or any further improvement in the monitoring program (Stage 2).

2 PROPOSED INFRASTRUCTURE

As part of the Long Plain Mine development project the characterisation of the groundwater system is required to assist geotechnical stability analysis and groundwater seepage considerations for mining operations. The development of the environmental work plan is also required involving the implementation of a dedicated environmental monitoring program.

To enable these characterisations to be completed a program of piezometer installation consisting primarily of vibrating wire piezometers (VWP) and open standpipe piezometers (OP) has been developed. Surface water flow monitoring infrastructure is also described in this document.

2.1 Vibrating Wire Piezometers

Drilling of drillholes is currently being completed at the site as part of the exploration program. Selected holes will be fitted with VWPs and occasionally standpipe piezometers. The drillholes will be completed by conventional drill rig. This drilling method produces a 4 inch diameter hole into which the VWPs will be installed either as a single- or multiple-level installation. All drillholes will be extended beyond the static water table and VWPs installed at a selected level within the water column to allow measurement of a range of water levels consistent with the analytical requirements of the project.

The coordinates of the exploration holes to be fitted with VWP are shown in Table 2-1

Table 2-1: VWP Coordinates

Borehole ID	Easting UTM	Northing UTM	Elevation AHD
LP1103	5394660.11	348459.91	227.50
LPDD1204	5394944.11	348304.45	259.22
LPDD1205	5395259.99	348194.82	240.68
CZ pad 1312	5396160.00	348090.00	262.53
Site 1212	5396390.69	348081.88	240.00
Site 1310	5396676.70	348081.84	270.00
LPDD1228	5397078.50	347988.84	263.66
Bowry Creek	5397476.00	347763.00	168.00
Site 1304	5397050.07	347772.31	261.39
Site 1306	5396931.50	347795.28	276.33

Figure A-2 showing the location of the VWP boreholes is attached in Appendix A.

2.2 Open Standpipe Piezometers

In order to provide baseline data for the development of the environmental work plan, a series of control bores will be drilled on the mine lease, outside of the proposed pit boundary.

Due to access restriction, the drillholes will be completed by helicopter mounted drill rig. This drilling method produces a 4 inch diameter hole into which the standpipe piezometers will be installed at a selected level within the water column to allow measurement of a range of groundwater levels and enable groundwater sampling consistent with the analytical requirements of the project.

Draft coordinates of the environmental holes to be fitted with standpipe piezometers are shown in Table 2-1. Access restrictions that are currently under assessment may alter some locations shown below.

Table 2-2: OP Coordinates

Borehole ID	Easting UTM	Northing UTM
Env A	347712.62	5397371.59
Env B	348156.83	5397235.15
Env C	347515.12	5396849.93
Env D	348477.85	5396611.57
Env E	347885.30	5396215.92
Env F	348116.81	5395823.37
Env G	348155.93	5395060.17
Env H	348454.22	5394952.88
Env I	348669.98	5394349.21
Env A	347712.62	5397371.59

A map showing the location of the OP boreholes is attached in Appendix B.

2.3 Surface water flow monitoring

Surface water baseline data is currently collected at the site at several locations. It is proposed to install two flow monitoring units on the creeks draining the two catchments draining the extraction boundary.

Permanent automated monitoring will allow for the analysis of the rainfall / flow relationship and build baseline data to assess any impact of the planned operation on the stream flow variation.

A map showing the location of the proposed stream flow monitoring points is attached in Appendix C.

3 GROUNDWATER TESTING

As part of the project, the characterisation of the groundwater system is required to assist geotechnical stability analysis and groundwater seepage considerations for mining operations.

To enable these characterisations to be completed a program of packer testing and falling head testing (FHT) has been developed.

Packer testing will be conducted on existing exploration holes, prior to the installation of vibrating wires instruments. It is expected that around 5 to 7 tests will be conducted per each borehole.

Falling head tests will be conducted on shallow open piezometers prior to the installation of standpipes. One to two tests will be conducted per borehole.

A series of internal specifications were developed to allow for planning. A Packer testing specification is attached in Appendix D for material requirements to be identified.

4 CLOSURE

Mining One are pleased to provide this Stage 1 brief for the design of the installation of a groundwater and surface water monitoring infrastructure and to provide testing specifications to assist in characterising the groundwater system.

At the completion of Stage 1, a decision will be made by GRT as to how much further support may be needed for the implementation of the installation and testing program (Stage 2).

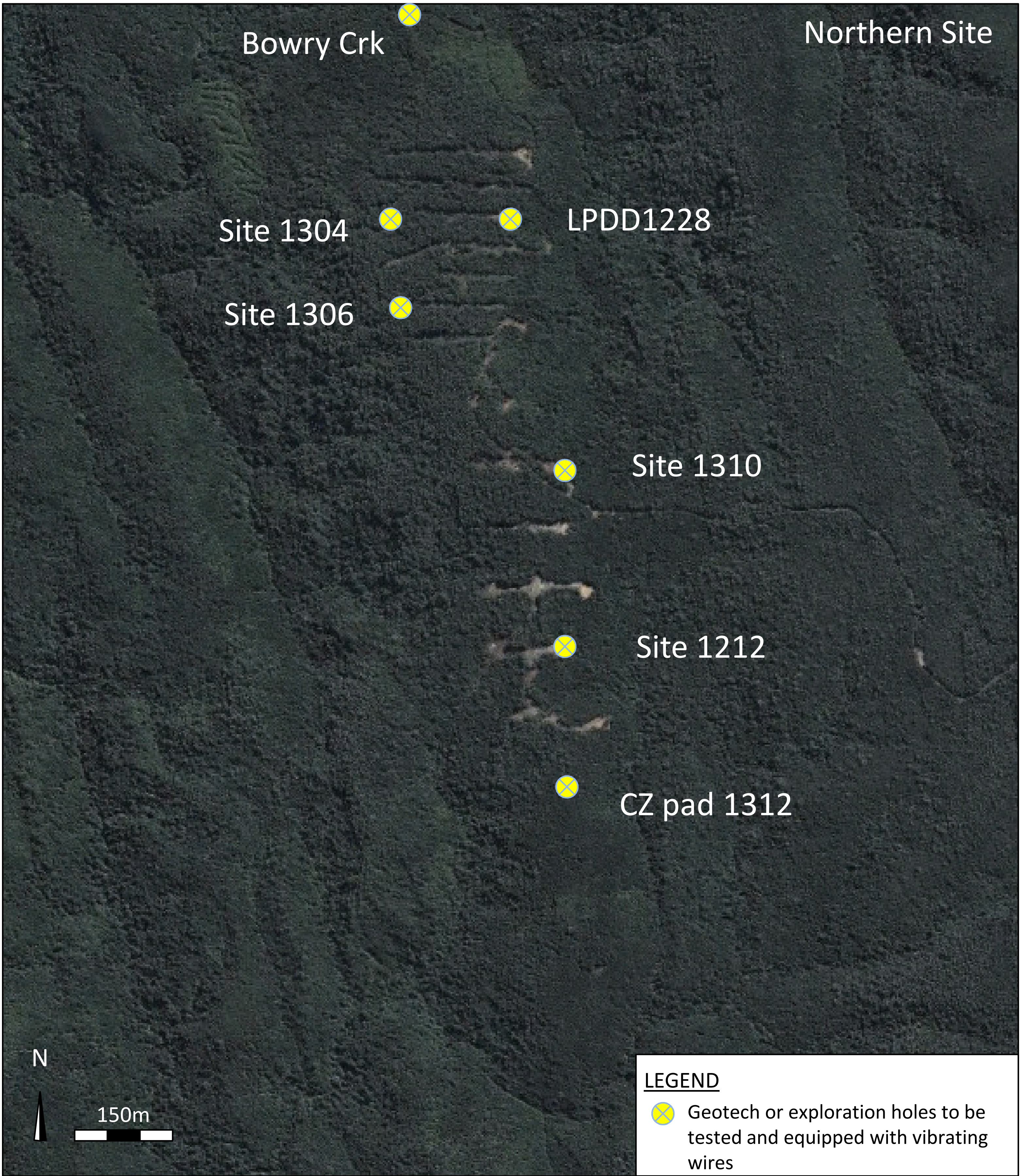
We look forward to discussing any further project requirements with you in order to provide you with assistance for assessments that might be required for Stage 2 for the hydraulic testing at the site, the analysis of the data and any modelling associated with the results or any further improvement in the monitoring program.

Yours sincerely

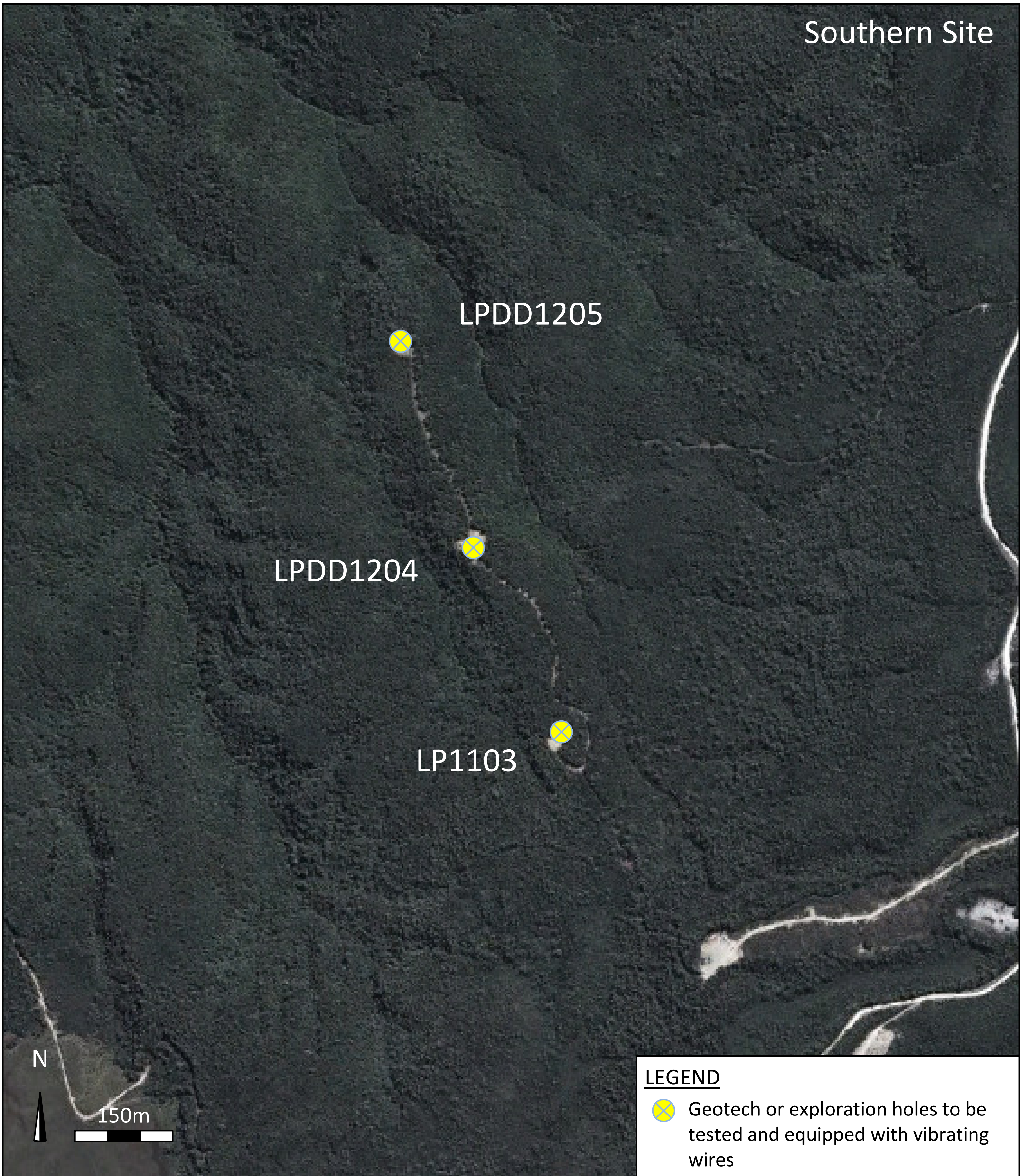
Alexis Valenza
Senior Hydrogeologist
Mining One Pty Ltd

Appendix A

Vibrating Wire Piezo Borehole Map



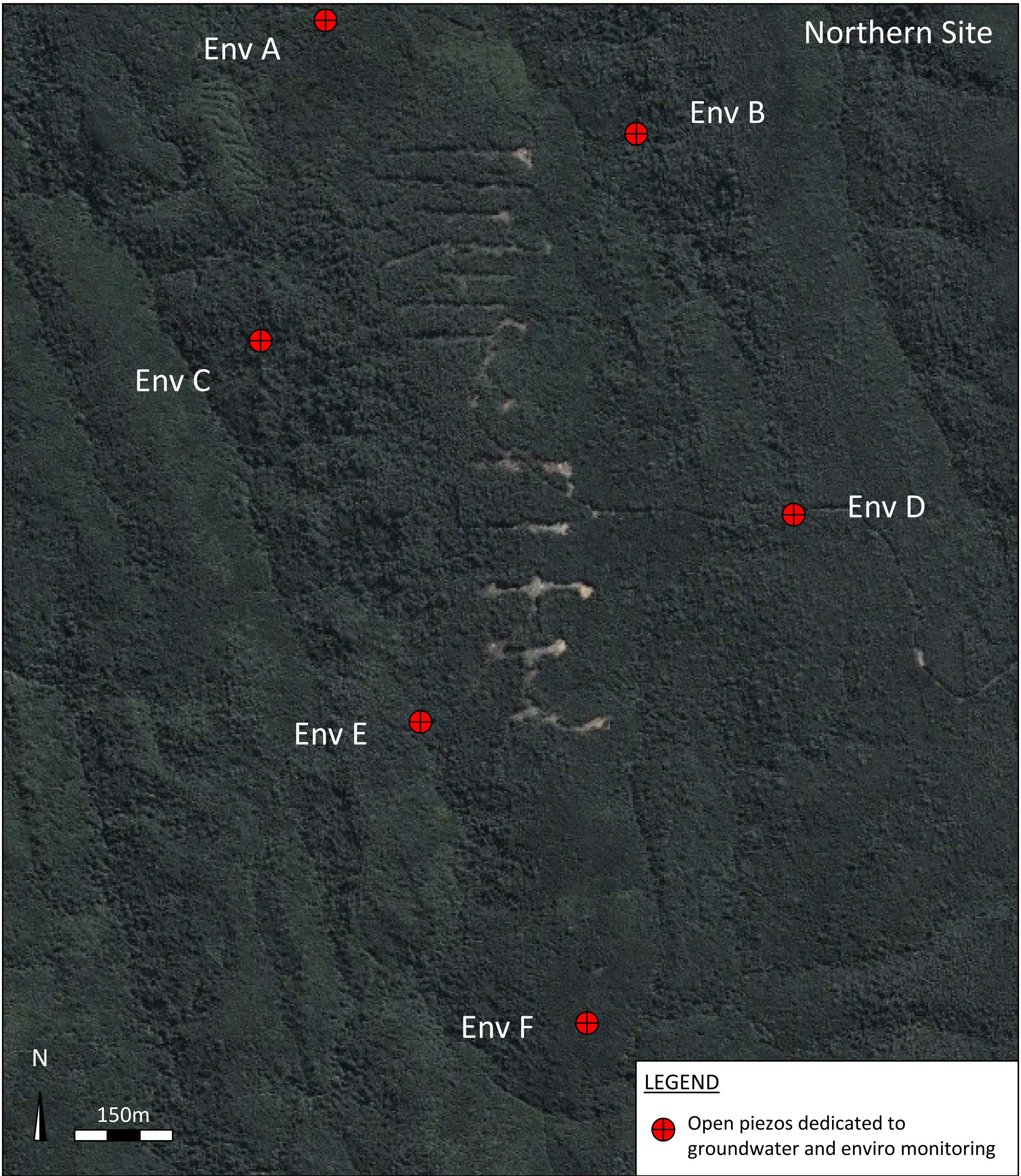
CLIENT GRANGE RESOURCES TASMANIA	mining one Consultants	Date 19/03/2013	Scale Not to Scale
PROJECT Long Plains Mine Proposed Groundwater Investigations Map	Mining One P/L	Job # : 1839_G	FIGURE A-1



CLIENT GRANGE RESOURCES TASMANIA	mining one Consultants	Date 19/03/2013	Scale Not to Scale
PROJECT Long Plains Mine Proposed Groundwater Investigations Map	Mining One P/L	Job # : 1839_G	FIGURE A-2

Appendix B

Open Piezo Borehole Map

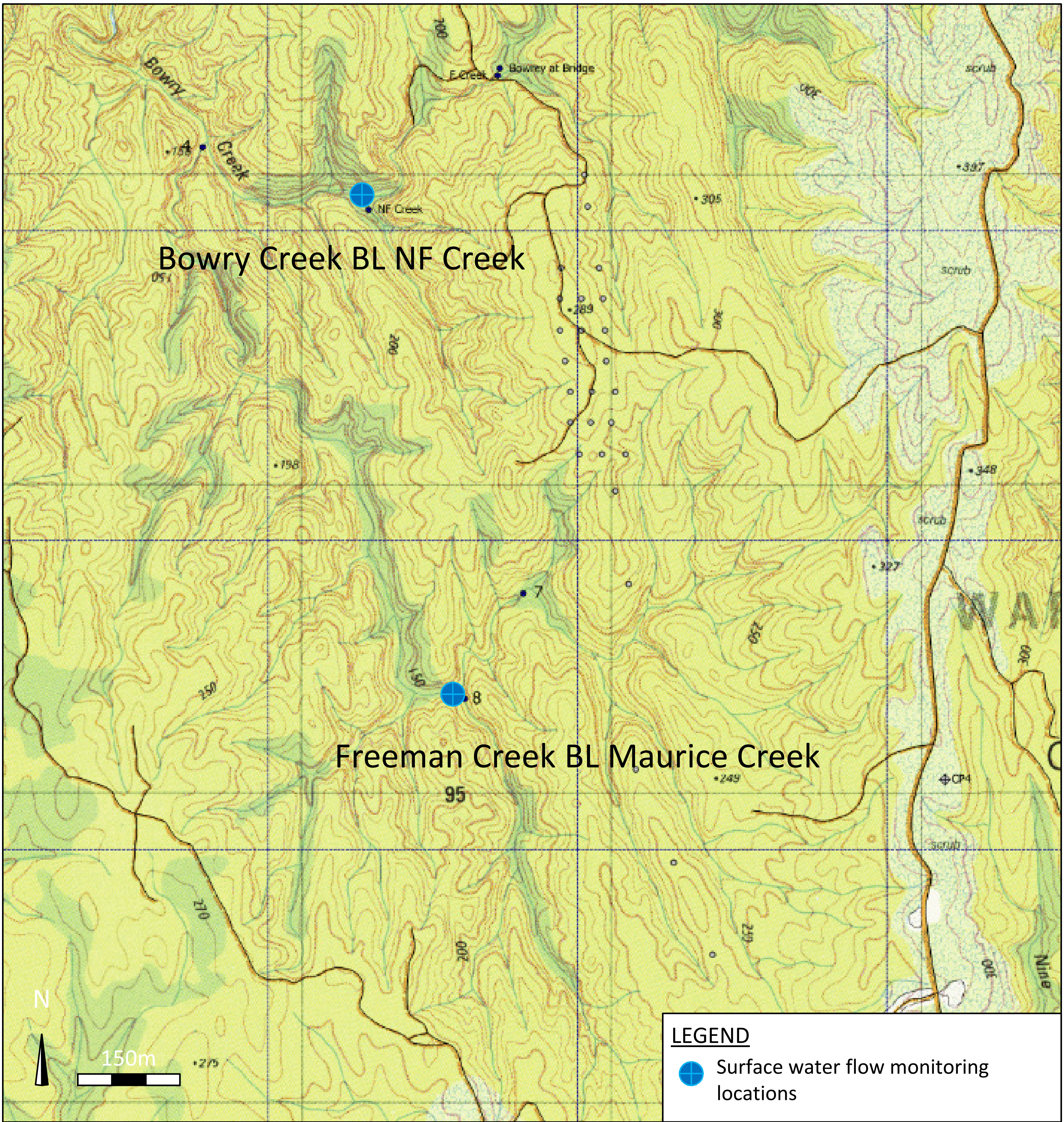


CLIENT GRANGE RESOURCES TASMANIA	mining one Consultants	Date 19/03/2013	Scale Not to Scale
PROJECT Long Plains Mine Proposed Groundwater Investigations Map	Mining One P/L	Job # : 1839_G	FIGURE B-1

CLIENT GRANGE RESOURCES TASMANIA	mining one Consultants	Date 19/03/2013	Scale Not to Scale
PROJECT Long Plains Mine Proposed Groundwater Investigations Map	Mining One P/L	Job # : 1839_G	FIGURE B-2

Appendix C

Stream Flow Monitoring Points



CLIENT GRANGE RESOURCES TASMANIA	mining one Consultants	Date 19/03/2013	Scale Not to Scale
PROJECT Long Plains Mine Proposed Groundwater Investigations Map	Mining One P/L	Job # : 1839_G	FIGURE C-1

mining one Consultants

Appendix D

Packer Testing Specifications

AGE DEVELOPMENTS PTY LTD
A.C.N. 009 188 989 A.B.N. 16 009 188 989
38 HARRIS ROAD, MALAGA
WESTERN AUSTRALIA 6090
TELEPHONE (08) 9209 2844
FACSIMILE (08) 9209 2820

8th September 2009

STANDARD OPERATING PROCEDURE FOR GAS INFLATED WIRELINE PACKERS

Preparation

Prior to running the packer system into the hole trial inflation should be performed on the surface. This has the dual function of checking the inflation system for leaks and also providing an opportunity to judge the required packer inflation times.

To perform trial inflation set up the inflation equipment as shown in the attached drawing as though inflating downhole. That is, connect the gas supply via a regulator to the inflation gauge assembly with a short length of hose; connect the packer via the full length of inflation tube and hose reel fly-lead to the inflation gauge assembly. The packer should be placed inside a test pipe (not supplied) with roughly the same I.D. as the expected downhole setting size.

I.E. 76mm ID for NQ packer equipment
96mm ID for HQ packer equipment
122mm ID for PQ packer equipment

For either nitrogen gas bottle or compressed air inflation the supply regulator should be set slightly higher than the required inflation pressure. All actual packer inflation should be controlled via the inflation gauge assembly. This assembly includes a 3-way valve which allows the supply pressure to be switched on or off (to the packer) and also allows the packer to be vented. The packer pressure is registered on the gauge only when the valve is in the off position and following a short stabilization period.

Ensuring the packer element is fully within the test pipe, inflate the packer until it just touches the pipe wall noting the inflation time and gauge pressure required. This may be done in stages as required but ensure that the approximate time and gauge pressure are noted for each stage.

Packer inflation may then be continued, again noting the time and gauge pressures used, to the maximum pressure required.

DO NOT EXCEED MAX. PACKER PRESSURE RATING FOR NOMINAL CORE HOLE DIAMETER

I.E. 1000psi (7000kPa) in 76mm ID for NQ packer equipment
1000psi (7000kPa) in 96mm ID for HQ packer equipment
1000psi (7000kPa) in 122mm ID for PQ packer equipment

Following wall contact, the packer pressure will increase at a much higher rate than during the earlier stage. Short inflation stages should therefore be used to bring the packer up to the required pressure - always allow sufficient time between each stage to ensure that actual packer pressure is being registered on the inflation gauge.

At full packer inflation pressure the system may be checked for leaks recognizing that some packer and tube creep will be evidenced by slight pressure decrease. To deflate the packer turn the 3-way valve to the vent position and wait till the packer fully deflates.

Trial inflations are recommended to be performed by each operator prior to running packer equipment downhole and whenever equipment or hole sizes are changed. The trial inflation provides valuable operator information regarding expected inflation mechanism and time when setting packers blind down the hole. Two of the most common problems noted by keeping good records of trial and downhole inflations are as follows:

1) Should inflation times, in open hole, be significantly longer at pressures equivalent to the trials in pipe this usually indicates the hole is washed out at the packer location.

2) If slight but gradual pressure loss is noted and no leaks can be found on surface, this may indicate that the packer is either expanding a weak formation or is extruding into a cavity.

Either of these problems may lead to over-expansion and subsequent bursting of inflatable packers.

Running and Operating Downhole

To run in, the packer system is set up as for trial inflation except that the inflation tube is not connected to the gauge assembly. The inflation tube should be securely taped to the top packer sub just below the wireline swivel connection ensuring water inlet holes are not covered.

On reaching setting depth the bit seating sub locates and suspends the packers as shown in the drawing. The inflation tube is connected to the gauge assembly and the packers may then be inflated using the procedures detailed above. Close attention should be paid to inflation data to avoid over-expansion of open hole packers.

To deflate the packers, turn the 3-way valve to the "vent" position and allow the packer pressure to vent. No attempt should be made to move the packers until the shut-in packer pressure indicates zero. The packers may then be moved and reinflated or tripped out as required.

Note that when either running the packer in hole or pulling it out extreme caution must be paid to ensure that the inflation tubing is run in/withdrawn at the same rate as the rig wireline. Failure to do so may lead to the inflation tube doubling over and subsequently damaging the tube or worse, jamming the downhole assembly in the rods.

Precautions

1. **UNDER NO CIRCUMSTANCES MAY OXYGEN GAS BE USED FOR PACKER INFLATION.**

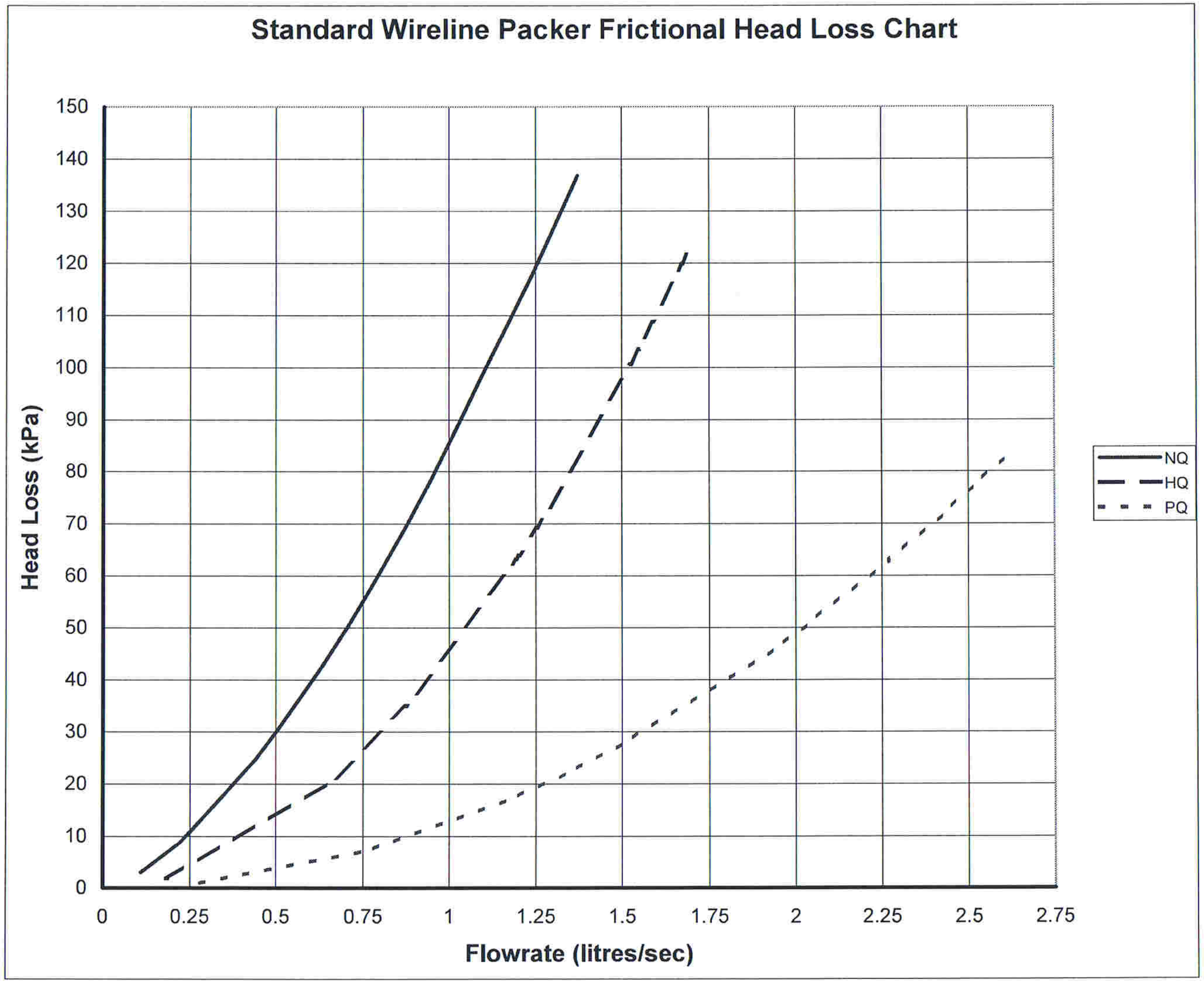
2. Inflation procedures use a significant quantity of compressed gas at high pressures thereby posing a risk of high energy explosion should a packer or associated component burst. Only personnel having appropriate training and experience with high pressure gas systems should operate these systems. Precautions to protect personnel and equipment against accidental burst of the packer element or associated component must be observed at all times. Such precautions should include:
    a. Keeping non-essential personnel clear.
    b. Ensuring any test pipe is directed away from all personnel and equipment. - A packer failing at high pressure may be ejected from the test pipe at high velocity.
    c. Complying with stated maximum working pressures of all equipment.

Hints and Tips

1. One problem often encountered is wrapping of the inflation tube around the wireline during running into the hole. Subsequent retrieval is difficult owing to entanglement of the wire and tube. One method successfully employed to counter this problem is to run the packer in to the test depth and then out of the hole prior to connecting the inflation hose - the packer inflation port should be capped off during this operation. This exercise seems to take the twist out of the wireline thereby reducing entanglement problems. If room allows, it is also helpfull to roll out the inflation tube and take out any twists prior to connecting it to the packer assembly.

2. Note that the standard flowmeter supplied is accurate to ±2% in the range 200 to 5000 litres per hour and accurate to ±5% from 50 to 200 litres per hour. At flow rates below this range the flowmeter's accuracy drops off rapidly.

IF ANY PROBLEMS OR FOR CLARIFICATIONS CALL ANDY GIACOMEL AT AGE DEVELOPMENTS PTY LTD ON PH: (08) 9209 2844 OR FAX: (08) 9209 2820


Standard Wireline Packer Frictional Head Loss Chart
Head Loss (kPa)
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
Flowrate (litres/sec)
0
0.25
0.5
0.75
1
1.25
1.5
1.75
2
2.25
2.5
2.75
NQ
HQ
PQ

® AGE DEVELOPMENTS PTY LTD
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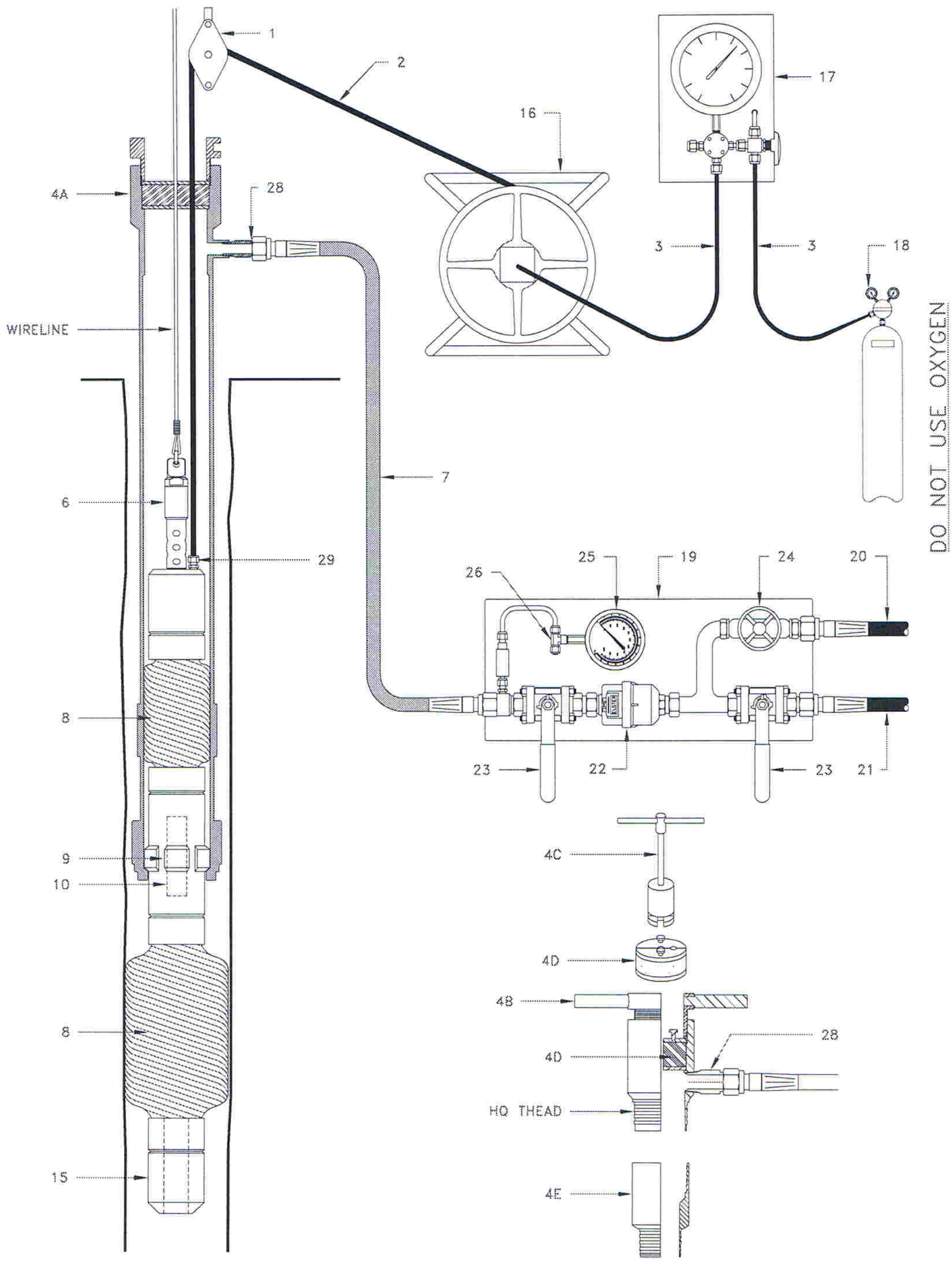
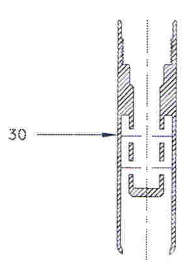
NQ WIRELINE SINGLE PACKER

NQ2-STD

S1021





DOWN HOLE EQUIPMENT

PART No	QTY.	DESCRIPTION
6	1	TOP SUB C/W SWIVEL
8	3	NQ PACKER
9	1	BIT SEATING SUB
10	1	INTERNAL SUB
15	1	END SUB (OPITIONAL)
29	3	INFLATION PORT FITTINGS
30	1	DIFFUSER (OPTIONAL)

HEADWORKS EQUIPMENT

4a	1	TIGHT HEAD (COMPLETE)
4b	1	HANDLE
4c	1	PULLING TOOL
4d	1	SEALING RUBBERS
4e	1	HQ-NQ CROSSOVER
28	1	HOSE ADAPTOR

SURFACE EQUIPMENT

1	1	SHEAVE
2	1	1/4" INFLATION TUBE
3	2	H.P. WHIP HOSE
7	1	1" WATER INJECTION HOSE
16	1	HOSE REEL
17	1	INFLATION SET
18	1	NITROGEN REGULATOR

FLOWMETER EQUIPMENT

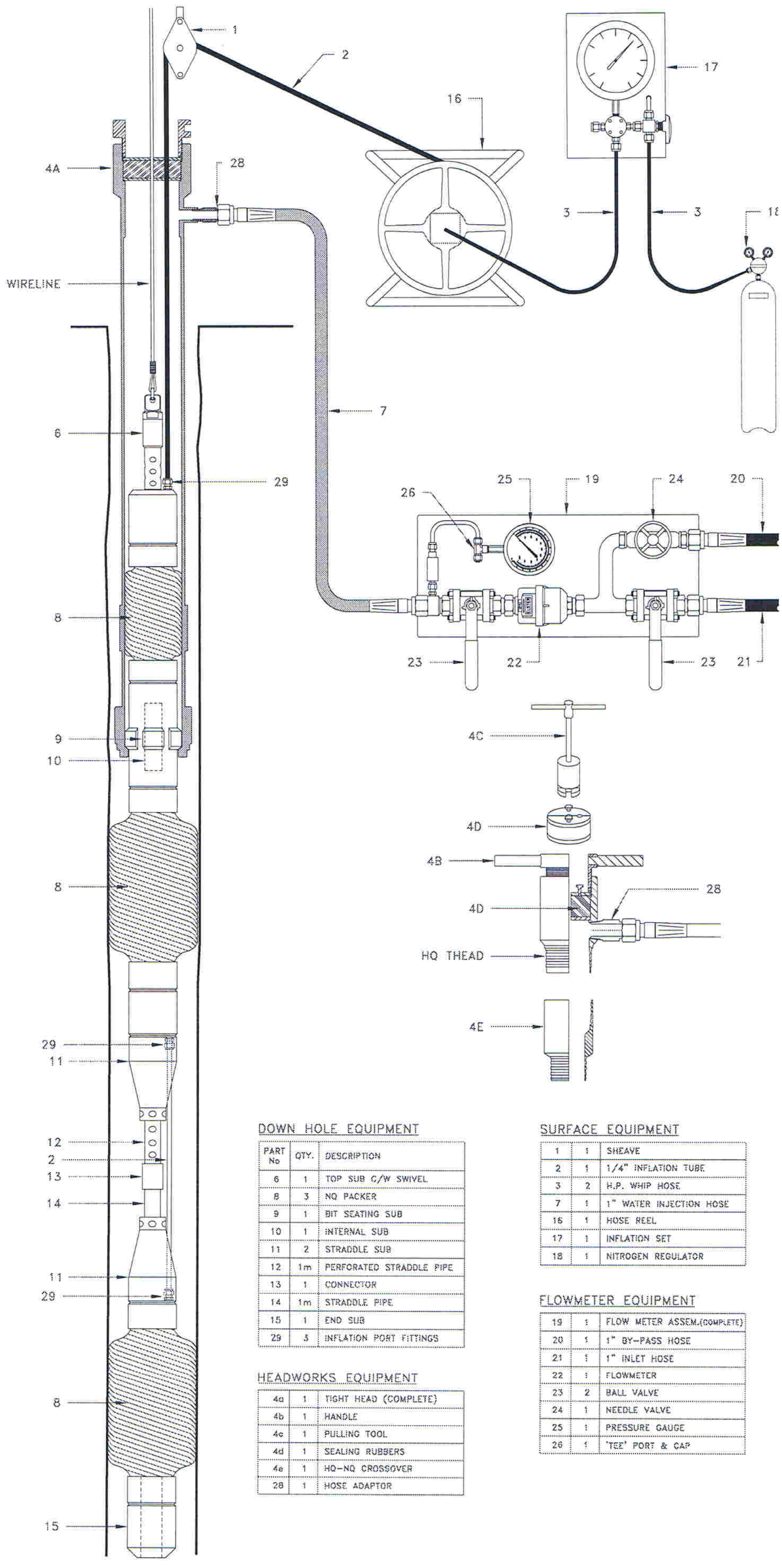
19	1	FLOW METER ASSEM.(COMPLETE)
20	1	1" BY-PASS HOSE
21	1	1" INLET HOSE
22	1	FLOWMETER
23	2	BALL VALVE
24	1	NEEDLE VALVE
25	1	PRESSURE GAUGE
26	1	'TEE' PORT & CAP

® AGE DEVELOPMENTS PTY LTD
38 HARRIS ROAD MALAGA WA 6090
PH 08 9209 2844 FAX 08 9209 2820

NQ WIRELINE STRADDLE PACKER

NQ1-STD

S1021



DOWN HOLE EQUIPMENT

PART No	QTY.	DESCRIPTION
6	1	TOP SUB C/W SWIVEL
8	3	NQ PACKER
9	1	BIT SEATING SUB
10	1	INTERNAL SUB
11	2	STRADDLE SUB
12	1m	PERFORATED STRADDLE PIPE
13	1	CONNECTOR
14	1m	STRADDLE PIPE
15	1	END SUB
29	3	INFLATION PORT FITTINGS

HEADWORKS EQUIPMENT

4a	1	TIGHT HEAD (COMPLETE)
4b	1	HANDLE
4c	1	PULLING TOOL
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26	1	'TEE' PORT & CAP

Adriano Giacomel, Managing Director, AGE Developments Pty Ltd
Clem Rowe, MIEAust CPEng, Engineering Director, AGE Developments Pty Ltd

INFLATABLE PACKER FUNDAMENTALS

SUMMARY: The basic construction details and operating characteristics of inflatable packers and inflatable packer based systems are presented and discussed in the light of general application requirements. Those criteria which are most relevant to the selection of packers are highlighted.

INTRODUCTION

Inflatable packers have been used in the oil industry for more than forty years. With the increasing availability of these packers designed specifically for economical use in other industries the areas of application have extended to include the water well, mineral, geotechnical and foundations drilling industries. Typical applications include:

- permeability testing,
- fracture testing;
- chemical injection;
- formation fluid sampling;
- casing/pile grouting;
- borehole plugging;
- downhole fishing tools

A drilling contractor's first introduction to inflatable packers is often when called upon to perform so called "packer tests" as part of a drilling program. In this case "packer test" is used as a generic term to cover a multitude of different downhole testing programs using inflatable packers. Usually when applied in a mineral drilling or investigation project the term means permeability testing using inflatable packers. In this case the packers are used to isolate a section of the hole to allow controlled pumping into this zone to enable the permeability of the formation to be determined. See Figures 3 and 4 for typical packer configurations used for testing.

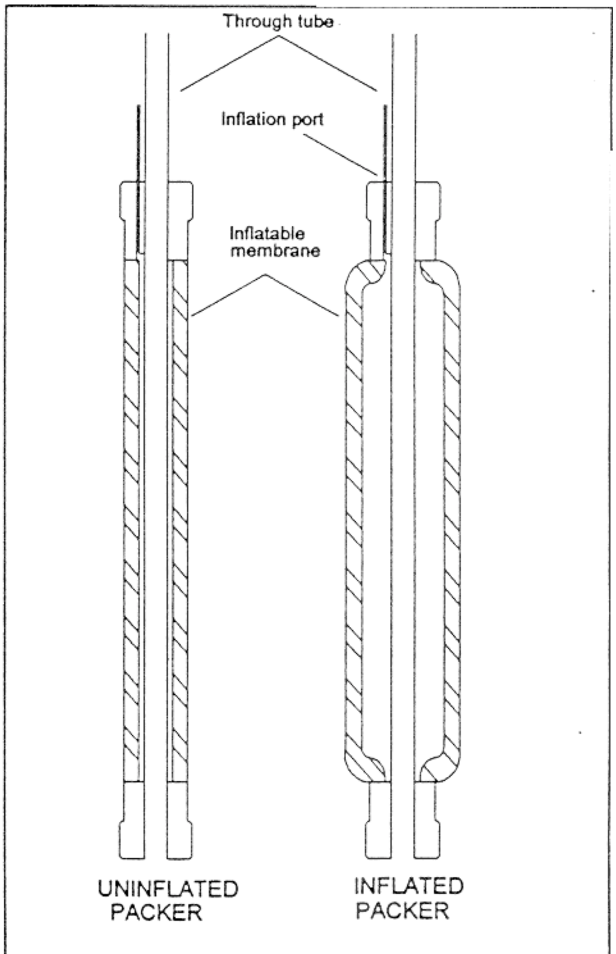

FIGURE 1 - Simple packer configuration

The term "packer testing" is also applied to fracture and so called stress testing, selective pump testing operations and on any particular project may be applied to any specific activity involving the use of inflatable packers.

Testing is by no means the sole or even the major use of inflatable packers. As indicated in the above list they also find application in a number of grouting procedures whether for foundations work, completions, casing repair operations, etc.
To gain a better understanding of the type of activity that may be addressed with packers and the advantages and limitations that may apply in any particular case it is helpful to understand the way in which inflatable packers work and the factors that effect their operation.
This paper is aimed at providing that basic knowledge and then showing how it is applied in several practical applications.

2.0 INFLATABLE PACKERS

An inflatable packer in the simplest form is a cylindrical, elastic membrane that is sealed at the ends and that when internally pressurized inflates radially. The radial inflation is used to seal and anchor the packer in place in the hole or pipe in which it is inserted.
In pratice, a packer looks like a short length of hose with steel end fittings and, usually, a central through pipe as illustrated in Fig. 1. The inflation medium is introduced between the central pipe and the inside of the membrane.
The membrane itself may be anything from a simple rubber tube to a fabric and wire reinforced rubber element to even a thin metal sheath. Obviously, the membrane type has a large bearing on the pressure rating for the complete packer and on the applications for which it is suitable.
A packer with an unreinforced rubber membrane will have a very low pressure rating, say 200-300 kPa. 'It will be relatively delicate, not capable of withstanding rough handling or even inflation in open hole where there is danger of cutting the membrane on sharp formations. A typical application would be for use in very shallow groundwater monitoring operations.
Similarly, packers manufactured with a metal sheath as the inflating membrane are for a limited range of very specialized applications. In this instance though we're looking at the opposite end of the pressure specturm to that addressed by the previous type. Typical applications are, very high temperature sealing systems, casing or pipe internal patches, etc.
For the main part, most inflatable packers used in the drilling industry employ fabric or wire reinforced rubber elements. These offer a broad range of operating characteristics which can be engineered to suit most applications.
Regardless of membrane type, all inflatable packers exhibit an unique characteristic with regard to their response to inflation pressure which is discussed in the following.

2.1 Packer Pressure Ratings

Inflation pressure rating is a decreasing

function of inflated diameter. That is, for any particular packer, the allowable inflation pressure at small expansion ratios will be lower than that at larger expansions ratios. (The expansion ratio is

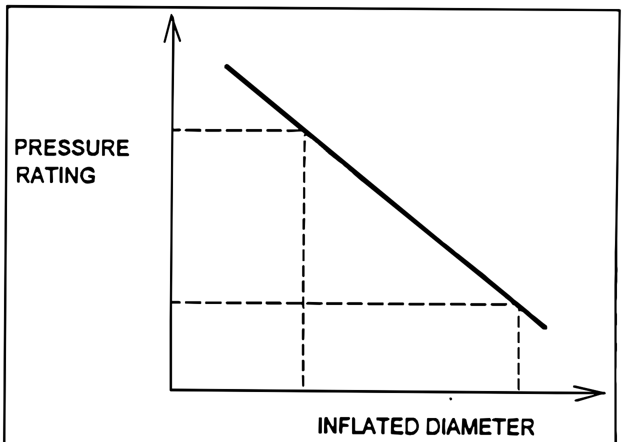

FIGURE 2 - Typical Pressure vs Diameter Chart
for Inflatable Packers

the inflated diameter divided by the uninflated diameter.) This relationship is illustrated in Figure 2.

Depending on the packer type and construction method the slope of rated pressure curve may be more or less severe.

With low expansion ratio packers this pressure/diameter characteristic is of minimal importance but since packers are now available with expansion ratios of up to 3:1 an appreciation of this aspect of packer pressure rating is essential.

As a general rule, if you run into a hole with only a small clearance your pressure rating when inflated to the hole diameter will be several times higher than if your packer has to expand an appreciable percentage of its uninflated diameter prior to reaching the wall.

The specification of inflatable packers for a particular job should make allowance for this characteristic. The consequence of not including such information in the specification is that you can end up paying a lot of money for something you don't really need.

For example, a "standard" oilfield packer to run on Y' API casing would typically be approx. 61/2" O.D. and be rated for 1000 psi when inflated in a 91/2" hole. To use such a packer for a shallow casing grouting job, e.g. 200m deep, 1W diameter with no restriction on run-in diameter, would be uneconomical since a low pressure packer, rated at 300psi and run-in at, say, W' O.D. would do the job equally well.

2.2 Differential Pressure Rating

A common misconception with inflatable packers is that the packer pressure rating indicates the packer's ability to support a differential pressure of this magnitude. A packer's pressure rating is the same as any other components' pressure rating. It's the pressure which the packer may safely support under the quoted conditions.

A packer's capacity to support a differential pressure, although related to the packer pressure rating is as much a function of the in-hole and support conditions.

The in-hole conditions, ie, fluid type, temperature, sealing surface type and condition, determine the frictional resistance to sliding which the inflated packer can generate. The support conditions, eg straddle configuration (two packers “straddling” a test zone), single packer run on pipe or wireline, etc., determine what contribution is required from the packer/hole friction.

The frictional component is best assessed by testing in conditions which as closely as possible mimic the worst of expected downhole conditions. Usually the support component may be readily calculated from the structural conditions.

2.3 Packer Types

Another unique characteristic of inflatable packers is related to the type of membrane end fixing employed. Two types are available, namely fixed end and moving end.

The fixed end type is the simplest kind of packer, with an unreinforced rubber element clamped at each end representing the simplest of all. Reinforced rubber or all metal membranes are also available in fixed end configurations. Regardless of membrane, the packer expands radially by axial stretching of the membrane.

Restricting attention to standard reinforced rubber elements, the fixed end packer offers low initial inflation pressures, moderate pressure capability, high expansion ratios and relatively simple construction. They are generally well suited to cased hole applications where packer over expansion into unconsolidated or washed out regions is not a consideration.

Moving end packers achieve radial expansion by allowing the packer element to shorten axially. Usually, one end is fixed and the other end slides on a central mandrel which doubles as the through pipe.

This type of packer typically has higher initial inflation and final pressure ratings. It is more suitable for open hole applications, particularly in soft or fractured formations.

The existence of mechanical seals at the sliding end presents a potential leak path, absent in the fixed end type. Also the fact of the moving end and subsequently the exposed sliding surface of the mandrel must be considered in the overall application. For example, for long term inflation, is the sliding surface subject to corrosion or in a grouting application, could grout set in the sliding region preventing the packer from returning to the deflated condition.

3 PACKER SYSTEMS

Many criteria concerned with the selection and use of inflatable packers relate to 'the total application system rather than just the packers themselves. Matters to be examined in this light include:

a) Geometrical constraints;.

b) Inflation fluid type;

c) Inflation method;

d) Deployment method;

e) Ancilliary operations.

3.1 Geometrical Constraints

This is perhaps the most basic of all criteria when assessing any downhole equipment. Will it fit in the hole? With inflatable packers, the question becomes "will it fit in the hole and inflate to seal at the required pressure”.

Due to the pressure/diameter relationship discussed previously the answer to this question may not always be obvious. The effect of hole size restrictions such as intermediate casings or no-go nipples and suchlike must also be considered.

Often an open hole is assumed to be in gauge and downhole components are sized accordingly. On the day it is discovered that

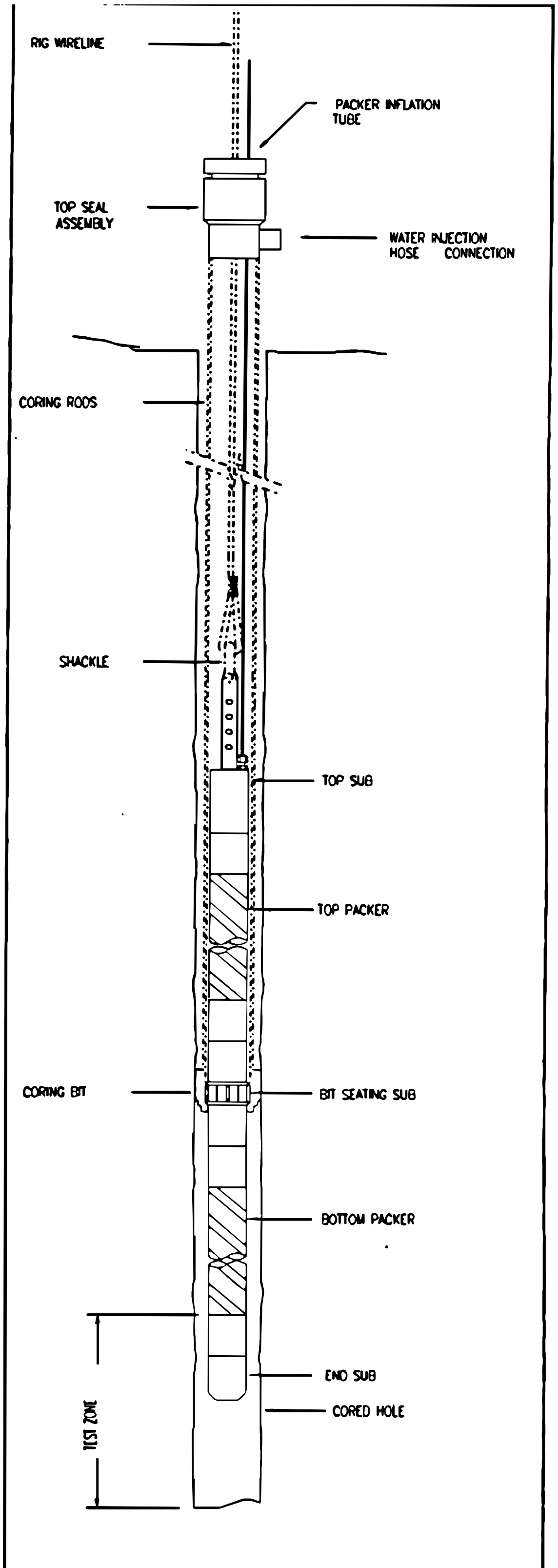

Figure 3 - Typical wireline system

the very zone where packers are to be set is washed out, thus making their use suspect or even impossible.

Where inflatable packers are to be used, careful attention must be paid in the planning stages to a realistic assessment of hole diameters and clearances.

3.2 Inflation Fluid

In general, packers may be inflated with. either a liquid or a gas. Oil, water, nitrogen gas and air are commonly used.

The choice of gas or liquid is often influenced by the packer's response to applied pressure. If inflated with a liquid, the packer inflation pressure will respond positively to any applied differential pressure owing to the essential incompressibility of the inflation volume.

This characteristic of liquid inflated packers is often made use of in grouting and fracturing applications to avoid initial high inflation pressures. As an example consider a fracturing job.

Two packers are inflated to isolate a test zone between them. The fracture pressure is expected to be around say, 20 MPa. In order to observe the fracturing process during fluid injection into the test zone, the last thing you want is for the packers to initiate fracture before you even start the test. To guard against this eventuality the packers would be inflated to only 10 MPa, say. As the test zone injection pressure increases, the packer pressure will increase in parallel so avoiding premature fracture.

In addition to this criteria the choice of inflation fluid should be carefully considered with respect to several other factors as follows:

- chemical compatibility with the packer materials;
- setting depth;
- hole conditions;
- the period for which the packers will remain inflated;
- availability.

3.2.1 Chemical compatibility

The question of chemical compatibility is an obvious one which more often becomes a problem where packers are used in an application other than that for which they were originally designed and purchased. The two most common pitfalls are inflation with oxygen gas which leads to explosive failure of the packer element and inflation of a natural rubber packer with a hydrocarbon liquid which leads to premature failure due to swelling and chemical attack.

3.2.2 Setting Depth

The influence of setting depth on choice of inflation fluid is not so obvious. It strictly relates more to the static pressure at the setting depth than to the actual depth and is best illustrated by considering an example.

Consider a packer located at 100 meters below the SWL. To initiate inflation with gas the 100 meter static head must first be overcome. So if the required inflation pressure is, say, 2000 kPa above static, the gas pressure required at surface is approximately 3000 kPa. This may be a problem if using a compressor for inflation.

In a more extreme case, if the setting depth were increased to 1000 metres below SWI, the required surface gas pressure becomes 12,000 kPa even though the actual packer inflation pressure is still only 2000 kPa. This sort of pressure requirement has consequences for the pressure ratings of both surface and downhole inflation equipment.

Use of a liquid, say water, as the inflation fluid in the above examples, reduces the maximum inflation system pressure rating to 2000 kPa in both cases by balancing the static head with an equal liquid head in the inflation system.

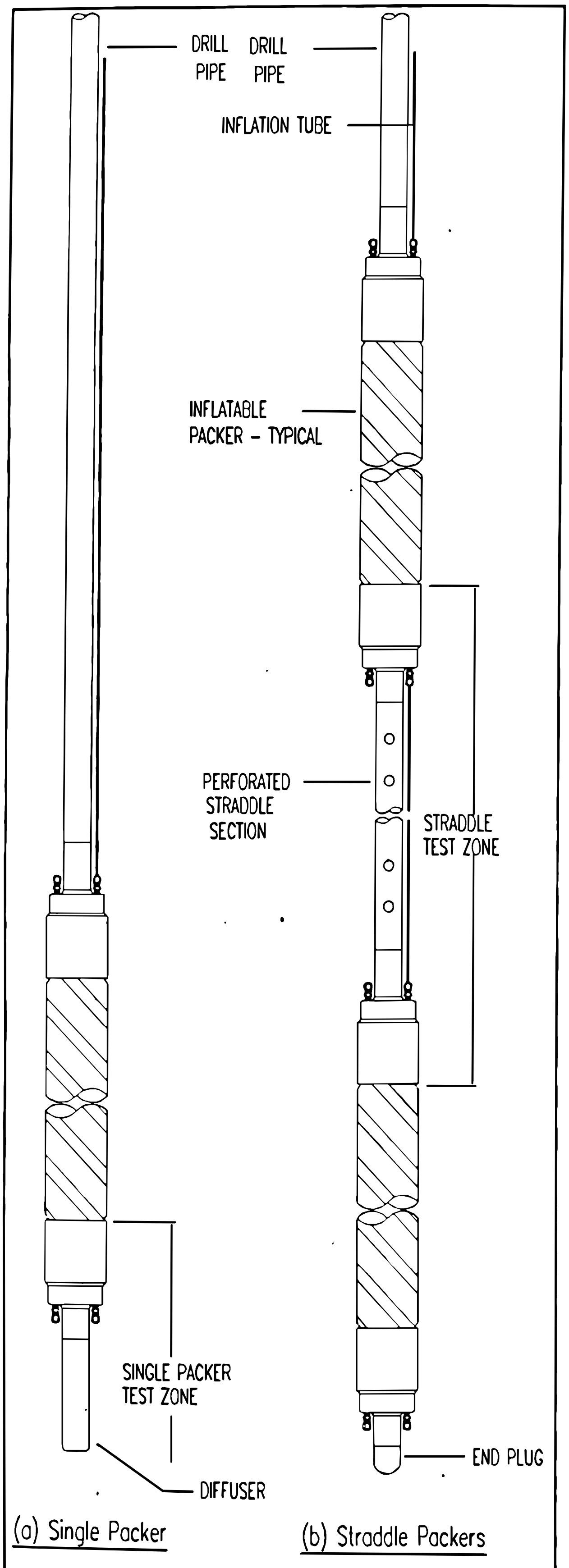

Figure 4 - Typical drill string deployed packer configurations

In some instances the static head due to a liquid inflation fluid can be a disadvantage. For example, if a packer is to be set in a hole where the SWL is, say 50 metres below surface, two problems may arise with liquid inflation.

First, the static head of the inflation fluid, if applied to the packer prior to reaching the setting depth may be sufficient to cause premature inflation. Secondly, for the packer to deflate it must be able to expel the inflation fluid via action of elastic rebound of the rubber. This action would be insufficient to eject the inflation fluid against a static head of 500 kPa.

A consequence of these two criteria is that additional equipment is required downhole to both protect against premature inflation and to allow dumping of inflation liquid downhole.

3.2.3 Hole conditions

The nature of the formation in which the packer is to be set influences packer inflation fluid selection.

A gas inflated packer can experience large volume changes without showing significant pressure variations at the surface owing to the compressibility of the gas. This situation is exacerbated where the packer volume is only a small percentage of the total inflation system volume e.g. in deep holes with larger inflation tubes..

As a consequence, a gas inflated packer may over expand and burst in a soft sand or clay formation without registering significant pressure drop (prior to burst) on surface instrumentation.

Another environmental condition to consider is the temperature. For example, water inflation is not a particularly attractive option if the downhole temperature exceeds 100°C owing to the danger of steam generation. At the opposite end of the spectrum, where very low surface temperatures are expected ie less than O°C, water is equally unsuitable.

3.2.4 Inflation period

The period of time for which the packer will remain inflated has a large bearing on the choice of gas or liquid as the inflation fluid. This is due to the gas permeability of the rubber membrane.

When inflated with gas over an extended period, the gas permeates the rubber membrane leading to a loss of inflation fluid and subsequently pressure. Rather than have an inflation monitoring program in place to keep topping up the losses, it is usually more convenient to use a liquid for inflation.

3.2.5 Availability

Often, the choice of inflation fluids boils down to whether to use a gas or a liquid with the particular type often being a matter of availability.

In remote locations, particularly where higher pressures are required, the only practical inflation fluid may be water. Even if this is not ideal, by consideration of the foregoing criteria, equipment or procedural allowances may be made to accommodate this situation.

3.3 Inflation Methods .

Two main inflation methods are available, namely, through the string or via an external tube.

The first of these uses the pipe string to which the packer is attached to inflate the. packer. Inflation pressure is retained by means of downhole valves of one sort or another. Many such systems are single set only. Resettable systems require a setting tool activated by either pipe string manipulation or drop or pump down plugs to inflate, deflate and allow resetting. It should be noted that this system of inflation does not readily permit gas inflation of the packers.

The external tube inflation system uses a small bore tubing run alongside the deployment pipe as a direct conduit to the inflatable packer. Such systems are naturally resettable and also allow continuous monitoring of packer inflation pressures during grouting or testing operations. On the minus side, the inflation tube is potentially subject to damage during installation and retrieval and, owing to the small tube diameter, inflation and deflation times may be excessive.

Each of these systems has advantages and disadvantages with the latter one generally being better suited for shallower applications where annular clearance is not a problem whereas the first system tends to suit deep applications with tight clearances and higher environmental stresses. This is reflected in that the through string inflation system is favoured by oilfield operators whereas water and geotechnical operators prefer the external tubing inflation system.

3.4 Deployment Method

The packer deployment methods in common use are via wireline, pipe or hose. The most common "wireline" method is illustrated in Figure 3. The wireline being in this case that usually used for core barrel retrieval on a wireline coring rig. Other wireline methods, both mechanical and electrical are also available though their use tends to be for specialized applications only.

The basic drill string deployment method with external tubing inflation is indicated in Figure 4. With few changes, this is also representative of hose deployment methods.

The deployment method dictates the packer connection detail. There is also some influence on inflation systems. For example, you usually can't have through string inflation if the packers are run on a wireline; through string inflation is also problematic for reusable packers deployed on hose owing to the limitations on downhole tool manipulation with the hose.

The required differential pressure capacity of the packer system may influence deployment method selection. For example, pipe weight may be required to hold a single packer (see Figure 4) down against an applied differential pressure.

Another criteria to be addressed in the choice of deployment methods is that of depth control. Packer applications often call for very precise depth control. In such circumstances hose or wireline deployment without rigorous external controls on depth measurement may be inappropriate.

3.5 Ancillary Operations

These criteria relate to how the packer interfaces with other elements in the application - both equipment and procedural consequences should be considered.

An example of this is where two or more packers are used on a single pipe string. Some procedures would require separate inflation and deflation of each of the packers. This requires each packer to have a through tube if using external inflation or separately operable valves for through string inflation.

Another example is where an annuluar grouting valve is to be used in conjunction with a casing packer to place grout in the annulus above the inflated packer. In this instance the activation and operating parameters of the grouting valve must be compatible with those of the packer. It may be that the operational requirements of the valve require a re- think of the type of packer, the inflation method, inflation fluid, etc. Say the valve is operated by shear off lugs activated by a pump down plug. If the packer is also operated by pump down plugs some interference may result.

4.0 CONCLUSIONS

There are a number of factors that effect the choice and operation of inflatable packers. These factors are generally well defined and relatively simple when approached in a logical manner.

When planning work involving the use of inflatable packers due consideration of these factors will lead to a better work program with equipment and procedures well suited to the application at hand.

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