Whitepaper: Field Apparel

Greenfields Exploration Ltd

April 2019

EXECUTIVE SUMMARY

This whitepaper sets out the research into the apparel requirements for Greenfields Exploration Ltd's Frontier project in eastern Greenland. The Frontier licences cover a very large area within which there is alpine terrain and an Arctic Desert climate. Exploration activity in 2019 is expected to primarily involve foot traverses during the summer months (most likely August). The level of physical activity and location of operations means that the field personnel are at risk of exposure to cold, and moisture either through precipitation, perspiration, or immersion. As moisture management is a major consideration in apparel in such terranes and climates, it is determined that the traditional three-layer approach to cold weather management is sub-optimal. Instead, this whitepaper identifies that the military approach of emphasising speed of drying over absolute waterproofing is appropriate for Frontier field personnel. The military Protective Combat Uniform system involves seven levels of garments that can be variously combined to meet the climatic challenges. Importantly, the system doesn't consider materials such as Gore-Tex to be adequately breathable and places more emphasis on the drying ability of soft-shell levels. Furthermore, materials like Gore-Tex often include chemicals that are deleterious to the environment and potentially the wearer's health. Alternatives to conventional membranes are discussed. The whitepaper identifies which fabric materials may be suitable for inclusion, and exclusion from personnel apparel. It also identifies that where practicable, personal-rescue responders be included in the garments, and that ethical assurance systems be used in the procurement process.

Greenfields Exploration Ltd
ABN: 50 619 328 442

Contact details & Registered address
Level 14, 197 St Georges Terrace
Perth WA 6000
P: 08 6270 6318
E: basecamp@gexpl.com

Online
Gexpl.com
linkedin.com/company/Greenfields-exploration-ltd/
facebook.com/gexpl/
Twitter: GreenfieldsExpl

FRONTIER PROJECT

Commissioning & Reporting Entity

Greenfields Exploration Ltd ('GEL'), 14/197 St Georges Terrace, Perth, Western Australia, 6000. ABN50 619 328 442.

Author:

Jonathan Bell (lead author), Managing Director of Greenfields Exploration Ltd

MSc Mineral Economics, BSc Applied Geology, RG146 Accredited[1], Member of the Australian Institute of Geoscientists[2] (MAIG, #3116), Graduate of the Australian Institute of Company Directors[3] (GAICD), Associate of the Resources and Energy Law Association, Affiliate of the Stockbrokers Association of Australia (AfSAFAA)

Reviewers:

Crowdsourced via LinkedIn between 26 February 2019 and 26 March 2019. The organic search resulted in 1,334 impressions, 720 clicks, a 55.02% engagement rate, and a 53.97% click-through rate. GEL considers the LinkedIn statistics to be statistically significant, and as such, a reasonable basis to consider the findings presented in this whitepaper to be reliable.

Consent & Warranty:

GEL prepared this whitepaper and gave its consent to use this document for release into the public domain. GEL warrants that it disclosed all relevant material, and to the best of its knowledge the information provided is accurate and true. GEL has not provided any information that has is confidential and not to be disclosed. GEL made reasonable efforts to verify the accuracy and relevance of the available data within what may be reasonably expected of a whitepaper. GEL endeavoured to ensure that opinions provided in this whitepaper have reasonable grounds and to ensure that the whitepaper is not misleading or deceptive.

Document information:

Reporting standard/s	Nil.
Report date:	8 April 2019
Effective date	8 April 2019
Status:	Published
File:	Whitepaper_Apparel_FINAL_190408

[1] http://asic.gov.au/regulatory-resources/find-a-document/regulatory-guides/rg-146-licensing-training-of-financial-product-advisers/
[2] https://www.aig.org.au/
[3] http://aicd.companydirectors.com.au/

Contents

EXECUTIVE SUMMARY 2
1 INTRODUCTION 5
1.1 Purpose 5
1.2 Scope 5
1.3 Context 5
1.4 Reliance on Other Experts 9
1.5 Information Sources 9
1.6 Site Visit 9
1.7 Report Costs and Relationships 9
1.8 Effective Date 9
2 RISK SCENARIOS 9
3 OPERATIONAL REQUIREMENTS 11
4 PRINCIPLES OF COLD WEATHER APPAREL 11
5 MATERIALS 14
5.1 Cotton 14
5.2 Nylon 15
5.3 Polyester 15
5.4 Down 15
5.5 Wool 15
5.6 Breathable Fabric Membranes 16
6 FINDINGS 17
7 RECOMMENDATIONS 18
8 REFERENCES 20
9 APPENDIX 1 25

Tables

Figure 1: Frontier's location 6
Figure 2: Annual daylight at Ittoqqortoormiit 7
Figure 3: Average monthly temperature and precipitation at Ittoqqortoormiit 7
Figure 4: Average monthly UV index at Ittoqqortoormiit 8
Figure 5: Stauning Alps in mid-August, 2018 8
Figure 6: Gauss Halvø in late August, 2018 8
Figure 7: Cold weather risk 10
Figure 8: Apparel of the PCU levels 13
Figure 9: PCU situational recommendations 13
Figure 10: PFC and bioaccumulation 17

Figures

Figure 1: Frontier's location 6
Figure 2: Annual daylight at Ittoqqortoormiit 7
Figure 3: Average monthly temperature and precipitation at Ittoqqortoormiit 7
Figure 4: Average monthly UV index at Ittoqqortoormiit 8
Figure 5: Stauning Alps in mid-August, 2018 8
Figure 6: Gauss Halvø in late August, 2018 8
Figure 7: Cold weather risk 10
Figure 8: Apparel of the PCU levels 13
Figure 9: PCU situational recommendations 13
Figure 10: PFC and bioaccumulation 17

1 INTRODUCTION

1.1 Purpose

Field personnel operating in the Frontier project may be subject to variable weather conditions that have the potential to be a major risk to health and safety. While operating away from camp, the personnel need to have adequate clothing to help reduce the risk of climatic exposure. Based on Greenfield Exploration Limited (GEL)'s observations during the 2018 field program, the apparel between individuals was highly variable. While GEL encountered no apparel issues during the 2018 field program, there is a risk that persons may bring inappropriate clothes to the Frontier and be at risk. Consequently, there is a need to establish minimum dress requirements, if not company supply of approved clothing. This whitepaper represents the first step in managing that risk by providing a reference point for policy and procedure documents for the 2019 exploration program.

1.2 Scope

This whitepaper examines the appropriateness of apparel potentially worn by people working in the Frontier project, Greenland. The paper identifies the risks and requirements of field apparel, presents for consideration, and GEL's findings. The scope does not include peripheral apparel such as footwear, headwear, handwear, and bags; however, the principles may be applicable. The intent is for this whitepaper is to provide the main reference point for GEL's apparel policy and procedure.

1.3 Context

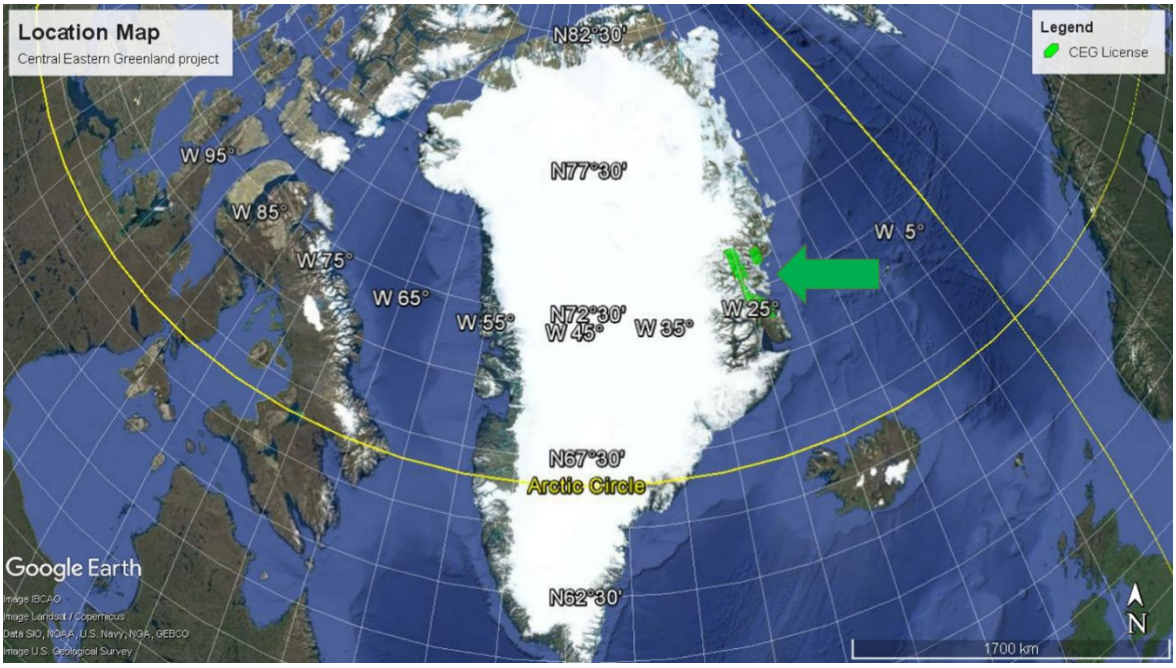
GEL is in a joint-venture option ('JVO') agreement with Independence Group NL ('IGO'). The JVO concerns the exploration project known as 'Frontier', which is located in northeastern Greenland. The exploration field programs typically occur in August and involve physical activity. Much of the field work is usually conducted below the snow-line.

Frontier sits just inside the High Arctic in the Sermersooq municipality of eastern Greenland and spans approximately 300 km between 71.25°N and 74.25°N, and 130 km between 26°W and 21°W (Figure 1) (1; 2; 3; 4; 5; 6). Frontier covers 14,988km^2 but due to the excise of fjords, is officially recorded as 12,975 km^2 (Figure 1) (1; 2; 3; 4; 5; 6). GEL calculates that this area is approximately equivalent to the size of 5% of Norway or New Zealand, 10% of England, 90% of Northern Ireland; or about five times the size of Hong Kong and eighteen times larger than Singapore. The majority of Frontier is within the boundaries of the North East Greenland National Park, which covers about 972,000 km^2 (7) (~45% of Greenland) and has an Arctic Desert climate and ice-cap (7). The physiography of Frontier is dominated by two major northwest-southeast systems, the King Oscar and Kaiser Franz Joseph fjords (8). The coastal areas are of moderate relief, ranging from sea level to around 500 m above sea level ('ASL'); and the inland area is of high relief (the Stauning Alps), with elevations ranging up to 2000 m ASL (8). The highest peaks in the Frontier region are Berzelius Bjerg with a topographic prominence of 1,535 m, Svedenborg Bjerg at 1,730 m, and Blaskbjerg at 1,575 m (9).

The nearest township to Frontier is Ittoqqortoormiit (70°31 N, 22°00' W) which is about 100 km south-southeast of the project's boundary. Ittoqqortoormiit has a population of approximately 450 (10) but no significant infrastructure or services. There are no civilian settlements to the north of Ittoqqortoormiit, and the next nearest township in Greenland is Tasiilaq some 850 km to the south. Iceland's capital city, Reykjavik, at 710 km is closer to Ittoqqortoomiit than Tasiilaq (11). The local township is commonly described as one of the most isolated settlements on Earth (12) and has an economy dominated by subsistence hunting (7). Military dog-sled patrols (13; 14), research stations (15), and weather stations (16) (~20 to 30 people) (7) exist to the north of Frontier.

Public air access to Frontier is possible via Nerlerit Inaat Airport (17) (previously known as Constable Point). With permission from the Danish authorities, it is possible to fly to the Mestersvig airstrip[4] (18) located with the southern portion of the licence area. The 1.8 km long Mestersvig runway (19) can accommodate heavy lift aeroplanes like the Lockheed C-130 Hercules (8), which require a length of at least 1.5 km (20). Several airstrips in the Frontier region can support the nimble and common de Havilland Canada DHC-6 Twin Otter aeroplanes (21).

Figure 1: Frontier's location

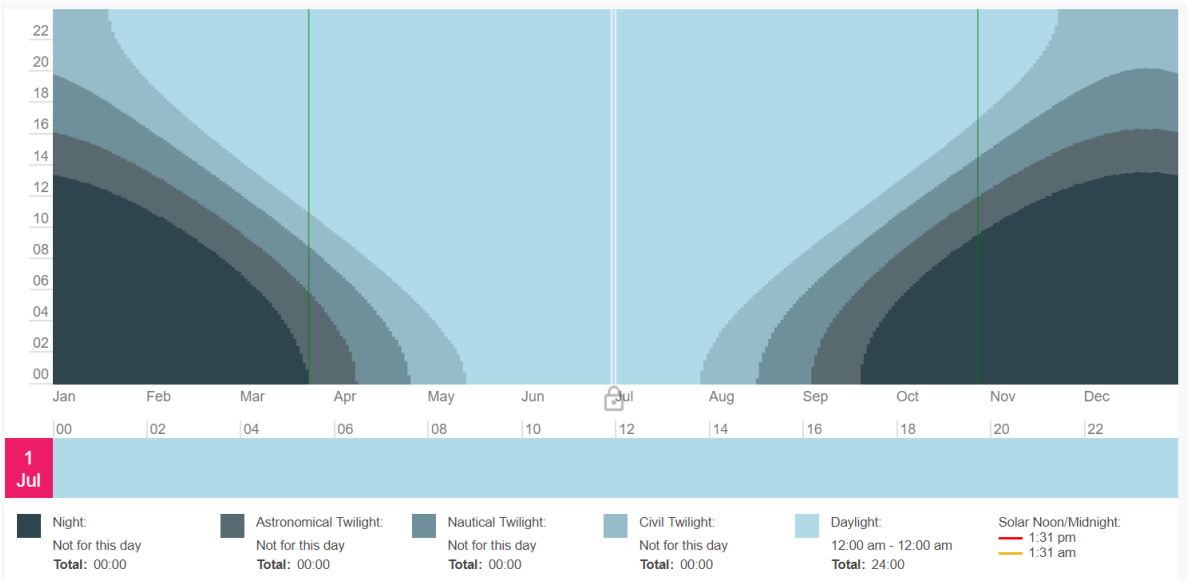


Source: Generated by GEL in Google Earth using shapefiles supplied by the Government of Greenland

Frontier lies just inside the demarcation of the High Arctic (22), and the Atlantic Ocean moderates its climate (23). At such latitudes, daylight is a significant environmental factor. At Ittoqqortoormiit, there is 24-hour light from around mid-May through to the end of July (24)(Figure 2). The driest month is June, with about an average of 12.4 mm of precipitation (25), July is the warmest with average temperatures ranging from 3° to 7°C (25)(Figure 3). For context, the July average for Perth Australia is 93.1 mm of rain and a temperature range of 8 to 18°C. The highest average monthly ultra-violet light ('UV') index reading at Ittoqqortoormiit is 3, which occurs between May and July (Figure 4) (26). A UV Index reading of 3 is the same as the annual low in Perth, in June and July, and a quarter of Perth's peak in December and January (27).

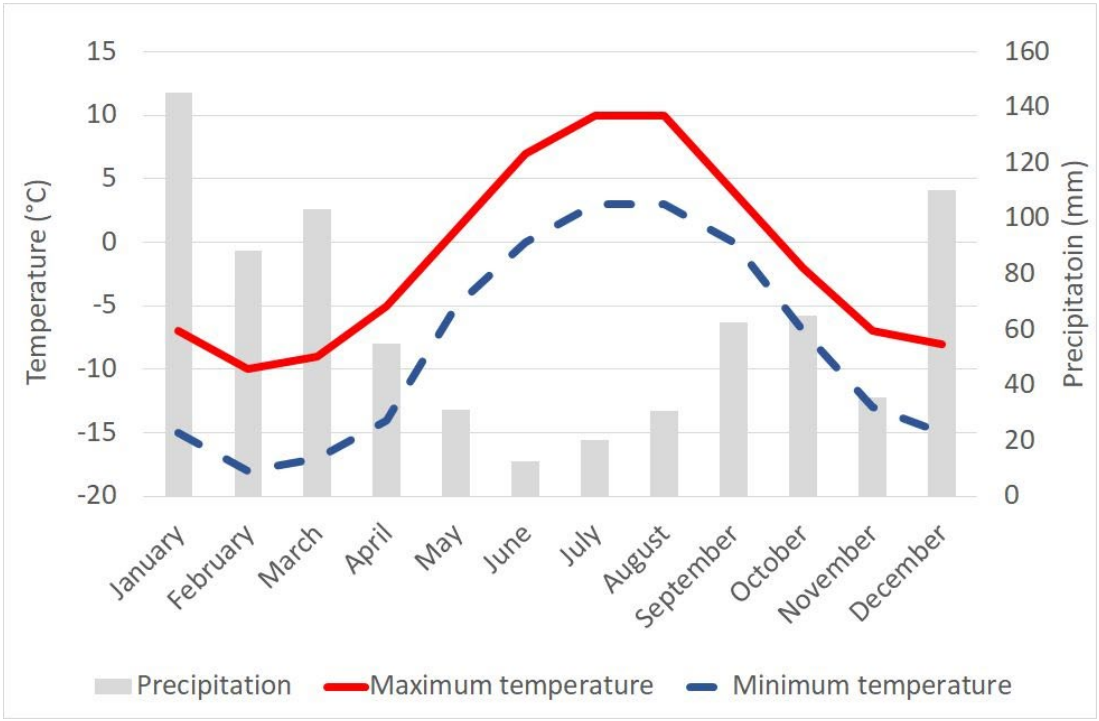
[4] Located at 2°14'7.78"N and 23°55'6.95"W

Figure 2: Annual daylight at Ittoqqortoormiit



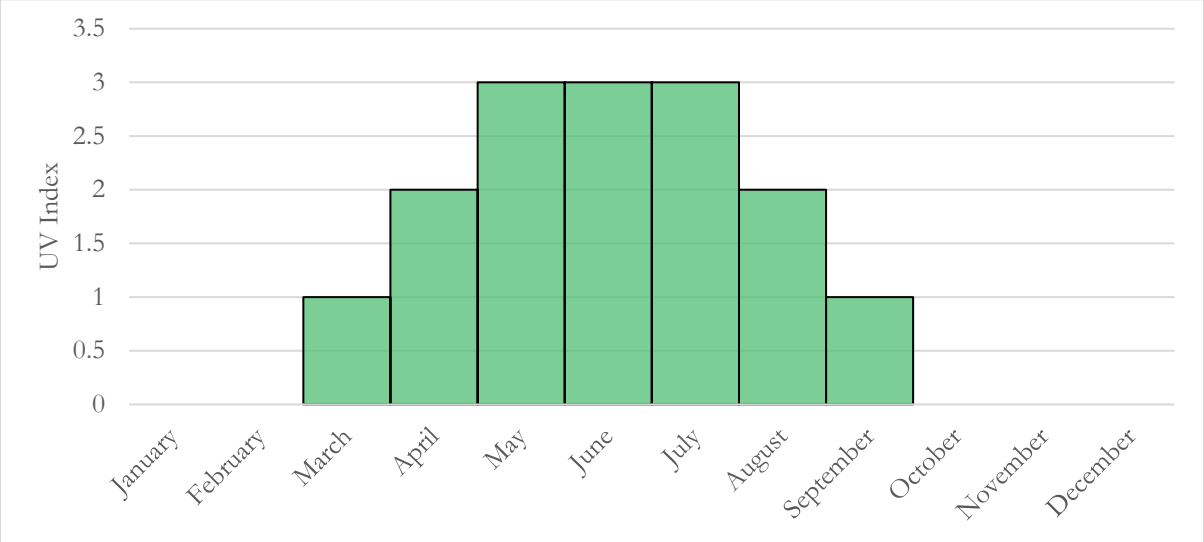
Source: Timeanddate.com (24)

Figure 3: Average monthly temperature and precipitation at Ittoqqortoormiit



Source: Timeanddate.com (25)

Figure 4: Average monthly UV index at Ittoqqortoormiit



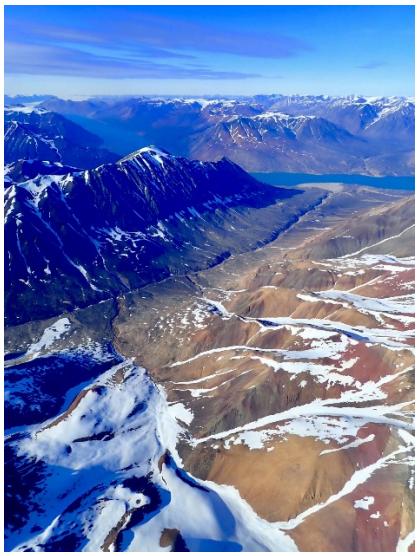
Source: weather-atlas.com (26)

For a more thorough overview of Frontier and its technical qualities, refer to the Technical Assessment Report dated 29 April 2018. Photos of the more topographically and climatically extreme parts of the Frontier are shown in Figure 5 and Figure 6.

Figure 5: Stauning Alps in mid-August, 2018

Perspective: Looking approximately south-southeast

Figure 6: Gauss Halvø in late August, 2018



Perspective: Looking approximately north-northeast

1.4 Reliance on Other Experts

GEL has not relied on third parties in preparing this whitepaper. However, the whitepaper is based entirely on third-party reports and data, much of which is available in the public domain. Where possible, GEL uses peer-reviewed documents as the primary sources of information. GEL made this document freely available online to maximise the benefit of independent peer review via the 'wisdom of the crowd'.

1.5 Information Sources

In preparing this whitepaper, GEL undertook a review of information available in the public domain, as well as proprietary information. GEL confirms that:

- full, accurate, and true disclosure of all material information in its possession has been made available;
- the available information or lack thereof does not compromise the integrity and accuracy of the conclusion and recommendation; and
- the whitepaper does not contain commercially sensitive or confidential information.

A list containing the citations is presented at the end of this whitepaper.

1.6 Site Visit

GEL and IGO carried out an exploration program at the Frontier between 13 and 30 August 2018. The personnel involved in this site visit were Jonathan Bell (GEL), Ahmad Saleem (GEL), and three IGO employees. Polar Logistics Group AS also had between two and four person's on-site during this time, and BlueWest Helicopters Greenland Aps typically had one pilot on site during the field program.

1.7 Report Costs and Relationships

The cost of this whitepaper is not contingent on its conclusions or success of Frontier as it was internally generated and paid for by GEL and was not subject to a third-party commercial contract. The principal author of this whitepaper, Mr Jonathan Bell, is the managing director of GEL and at the time of writing, the majority shareholder.

1.8 Effective Date

The Effective Date of this advanced whitepaper is 26 February 2019. The outcomes of this whitepaper reflect the prevailing conditions and circumstances that are relevant as at the Effective Date. GEL cautions the reader that new information could result in a change in the merit of the findings and recommendation. GEL advises the reader to make an investigation as to whether there are any changes after the Effective Date that may materially affect the risk.

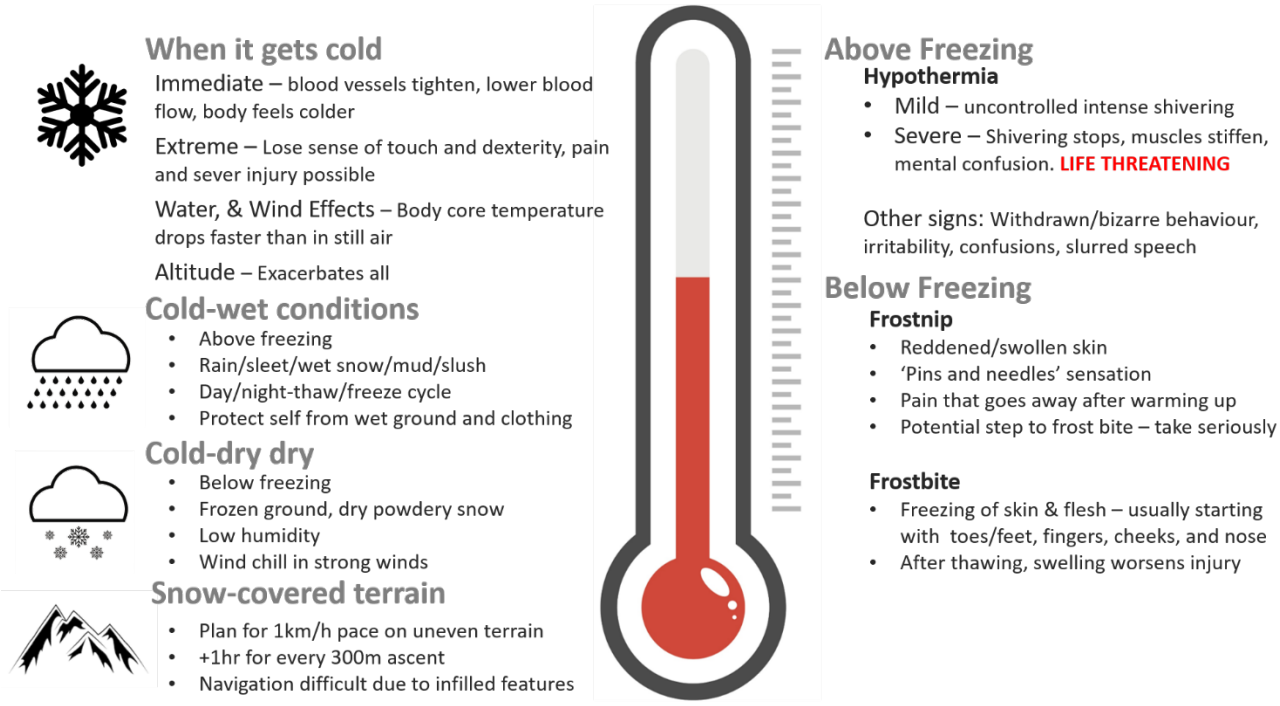
2 RISK SCENARIOS

As the Frontier is in the High Arctic, and in alpine terrane, the plausible risk scenarios that concern apparel include:

- rapid fall in apparent temperature with a significant lapse in time before extraction is possible;
- team members become wet, either through precipitation or falling into water bodies (still or flowing);
- emergencies where helicopter extraction is not possible for many hours/days and team members need to be able to sustain long enough to reach shelter or be extracted; and
- exposure to dangerous, sudden and intense katabatic winds known as Piteraq (28). For simplicity, a Piteraq can be thought of like an avalanche of cold air collapsing from the Greenland ice-sheet.

In these scenarios the predominant risks relating to apparel range from hypothermia through to frostbite due to temperature, wind chill, and moisture (Figure 7). Hypothermia is a condition where the core temperature of the body drops below the level required to maintain vital organs functioning (~35°C) (29). Hypothermia can occur in temperatures well above freezing (30). This may be due to the presence of water, which conducts heat away from the body 25 times more than air (31). Water may be present due to perspiration, precipitation or immersion. Figure 7 provides an overview of the effects of hypothermia and some of the conditions under which it may occur. Hypothermia may also be a consequence of underlying physiological vulnerabilities (29), and the use of alcohol and psychoactive substances also contribute to hypothermia mortality (29). Frostbite is also a plausible risk; however, it may have a lower level of probability in the context of the expected work programs in the Frontier project.

Figure 7: Cold weather risk



Source: Greenfields, based on Kwikpoint (32)

These thermal risks may occur through different mechanisms (33), including:

- **Evaporative** heat loss is due to moisture evaporating from the body, which causes a rapid cooling effect, sometimes referred to as 'flash off';

- **Convective** heat loss is the result of cold air moving over the surface of a body, like wind, sometimes resulting from the bellowing of baggy clothes;
- **Conductive** heat loss comes from direct contact where heat transfers from the warmer object (a person) to a cold object (e.g. a rock sat upon);
- **Radiant** heat loss is caused by infrared release, such as when the sun sets; and
- **Combination of evaporative and convective** heat loss experienced by breathing in extremely cold air, which circulates inside the body before being exhaled, facilitating evaporative heat loss (33).

While there are other risks faced by personnel at Frontier, by and large, apparel does little to mitigate the most serious ones. Consequently, this whitepaper focuses on addressing thermal risk.

3 OPERATIONAL REQUIREMENTS

As the Frontier is an early-stage exploration project, its team members may be required to traverse for several hours a day across difficult terrane. This physical activity in remote locations means that equipment and apparel need to be robust and reliable while providing enough freedom of movement to avoid introducing other risk scenarios[5]. Furthermore, traverses may require significant physical exertion and the apparel must be able to handle perspiration, that if not allowed to dissipate, may increase the chance of hypothermia. Consequently, **durability, flexibility, water resistance, breathability and moisture-wicking** are key metrics identified for assessing appropriate field apparel. **Visibility** is also a key metric, particularly when working in high-contrast environments (e.g. shadow of mountains) and when working around helicopters. However, as visibility can be addressed by peripheral apparel (e.g. high-visibility vests), it is not discussed in this whitepaper. Similarly, footwear, gloves and other peripheral items are outside of the scope of this green-paper. As the maximum UV Index for Ittoqqortoomiit (south of the Frontier) is 3, and in August 2, there are no apparel requirements that are out of the ordinary for mineral exploration activity.

4 PRINCIPLES OF COLD WEATHER APPAREL

As the weather conditions in the Frontier may be highly variable both day-to-day, and site-to-site, the apparel used by team members **must be adaptable**. The driving principle to manage climate variability is layering of clothes, with each layer having a different function. Notionally:

- Base layers serve to wick away moisture from the skin;
- Mid layers act as insulating layers; and
- Outer layers provide protection (typically from environmental moisture rather than perspiration) (34).

By using a layering system, it is possible to rapidly adapt the clothing through removal or opening of various layers (35). This means that the clothing can adapt to unexpected warmth or cold. By contrast, a single- or two-layer system where the outer layer acts as both heavy insulation and protection (think of a thick, heavy jacket), may not provide good adaptability.

While the natural inclination is to have layers that are highly water resistant, mountaineering and Arctic/Antarctic expedition experience suggest that **rapid drying is more important than staying dry** (33; 36; 37). The rationale is that it is almost impossible to stay perfectly dry due to sweat or external moisture sources (36). As sweat is inevitable in fieldwork, the emphasis is on the ability

[5] For example, highly restrictive clothing that may lead to falls or similar incidents.

to dry as fast as possible (36). It is on this basis and its experience of operating in Afghanistan that the United States military bases its Protective Combat Uniform ('PCU') which uses **levels rather than layers**. During summer, Frontier explorers share similarities with the operational requirements of military personnel operating in Afghanistan, namely remoteness, cold, elevation and rapidly changeable climate. As the military considerations are relatively free of the influence of manufacturer marketing and other commercial interests, GEL considers it the most objective approach to managing cold climate apparel. The levels of the PCU are:

- ***Level 1***: Next-to-skin garments, though Level 1A and Level 2 garments can also fill this role (33). These thin layers wick moisture away from the body and add insulation (38).
- ***Level 2***: Next-to-skin, mid-weight pullover and long pants in fleece, that wick moisture away from the skin, pushing it outward (33).
- ***Level 3***: A very warm and quick drying heavyweight fleece jacket. This layer adds warmth by adding space between layers and trapping air (38). However, it's generally not ideal in action situations due to the amount of warmth it retains, which can result in overheating when the user is in motion and generating a lot of heat (33).
- ***Level 4***: A soft, thin, windproof 'wind-shirt' which is intended for use inside the system, though it can be worn as an outer layer (38). Generally, it's worn under other layers and helps retain heat. While very compact and can compressed into a cargo pocket, it is less durable than the Level 5 soft shell garments and not meant for high abrasion situations (33).
- ***Level 5***: A soft-shell[6] fabric jacket and pants that are highly stretchable, windproof, water repellent and breathable. Level-5 is the key component of the PCU system (33).
- ***Level 6***: A water-proof hard-shell[7] jacket and pant for wearing over light load carriage. Level 6 garments are breathable, though less so than Level 5 and are sized to go over the Level 5 garments (33). Level 6 is only used during heavy rain or wet snow because even though they are made of waterproof breathable membranes, they trap moisture from the inside (38). The principle of this PCU system is to transport moisture to the outside, and that is why the use of this shell is limited (38).
- ***Level 7***: For extreme conditions, it comprises a high-loft jacket, vest and pants, to be worn atop the other PCU components. Level 7 garments are water resistant and breathable (33).

Figure 8 shows the components of each of the PCU levels, and Figure 9 shows the conditions under which each level may combine for an optimal level of preparedness. While snow is possible on mountain peaks within the Frontier, during the likely field season the sea-level temperatures are unlikely to go below -17°C (0°F). Consequently, level 7 garments are likely to be excessive for the envisioned situation, unless the work is likely to be stationary for long periods at temperatures between 0°C and -17°C. Also, as the PCU system uses long-sleeve and long-legged levels, GEL considers the system to inherently provide enough protection from UV exposure[8].

[6] A soft-shell is designed for mobility and comfort while moving around (94). A common feature among soft-shells is their breathability (94). As soft-shells can be worn either on their own or as an insulating layer for skiing and snowboarding, breathability is of key importance because not only does it help regulate body temperature and prevents overheating, it also helps wick moisture away (94). This results in a dry and moisture-free jacket, which is ideal (94). The majority of soft-shells are water-resistant by having a water-repellent shell (94). Weather-wise, soft-shells are best suited for dry and mild temperatures (94).

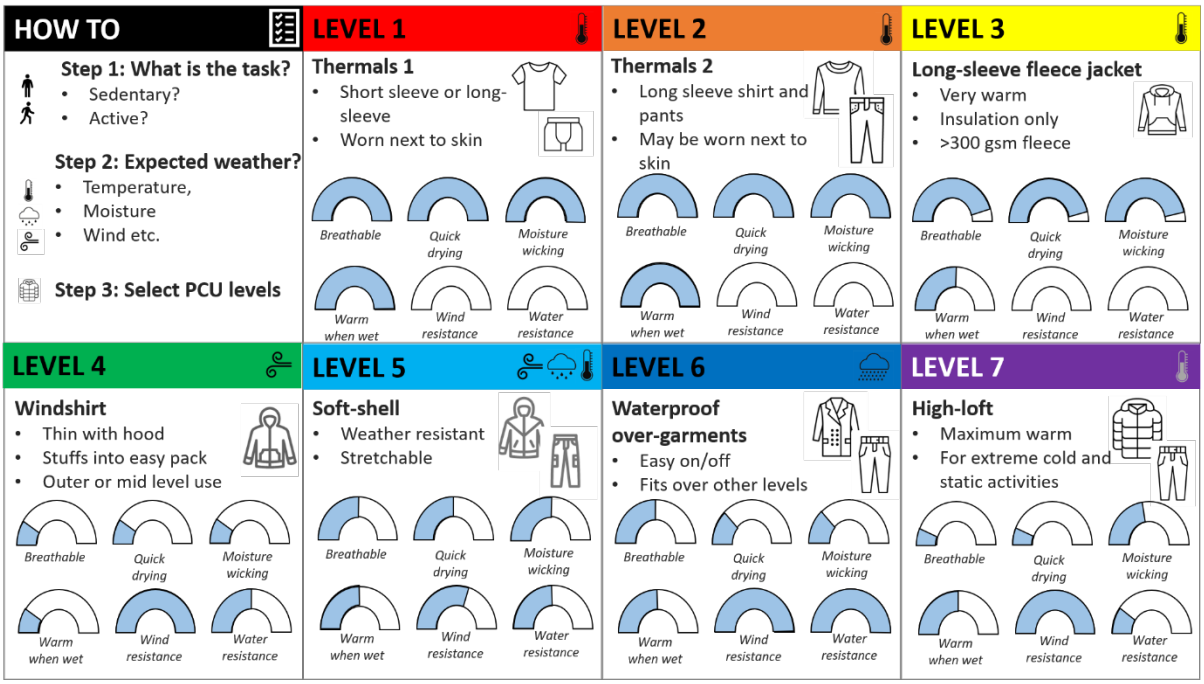
[7] A hard-shell is very waterproof layer that isn't very flexible or stretchy (94). Hard-shells come with a hood and their main may include a windproof outer shell that makes these jackets suitable for rainy weather. Hard-shells may come without insulation, which makes them very light weight and packable (94).

[8] Although hats and sunscreen should still be used.

Contact details & Registered address
Level 14, 197 St Georges Terrace
Perth WA 6000
P: 08 6270 6318
E: basecamp@gexpl.com

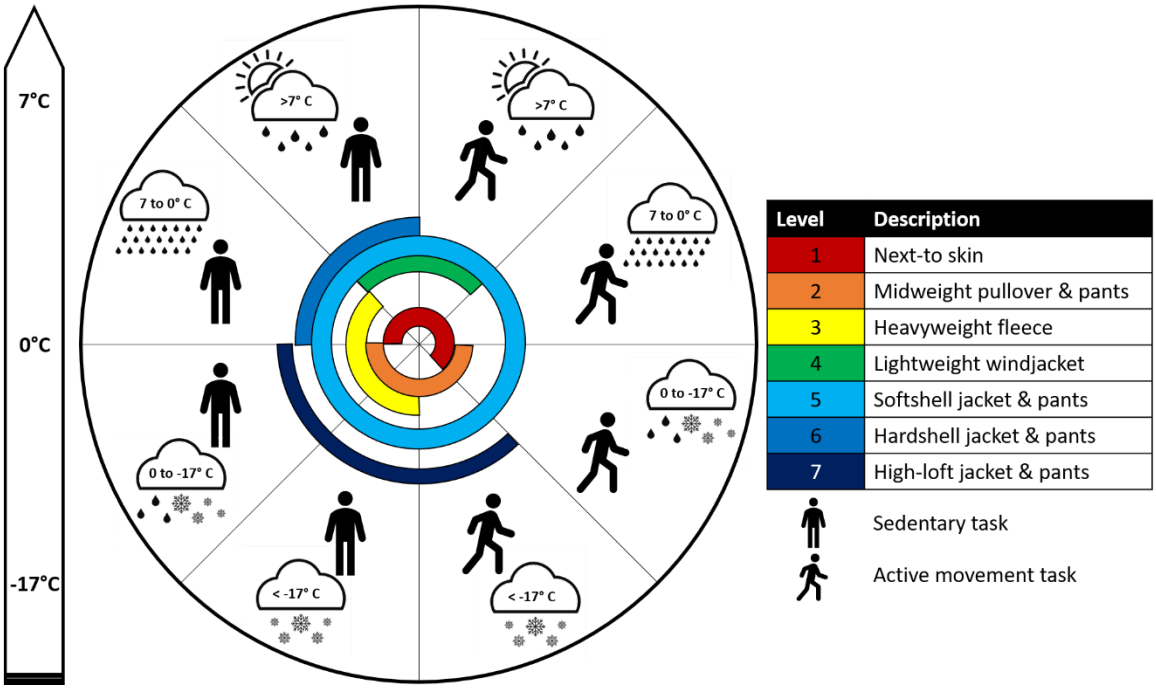
Online
Gexpl.com
linkedin.com/company/Greenfields-exploration-ltd/
facebook.com/gexpl/
Twitter: GreenfieldsExpl

Figure 8: Apparel of the PCU levels



Source: Greenfields, modified from Kwikpoint (32)
Disclaimer: The 'fuel gauges' are purely indicative and must not be interpreted as literal

Figure 9: PCU situational recommendations



Source: Greenfields, based on Kwikpoint (32)

Levels 5 and 6 require water-resistance and water-proofing. These are defined terms, the qualities of which are shown in Table 1. The water-proofing ratings are generally determined by a test that involves placing fabric at the base of a static, 1-inch diameter vertical column (39), although there is inconsistency in the size of the tube or the temperature at which the tests are performed (40). The column is filled with water, and the water's height in millimetres when leakage begins becomes the waterproof rating (39). A piece of fabric that can withstand 20,000 mm of water pressure will have a rating of 20,000 mm (39). A rating above 10,000 mm is required before fabric can be

deemed to be waterproof (41). While fabrics have waterproof ratings, the construction of a garment can greatly affect the performance in the field (42).

Table 1: Waterproof ratings

Waterproof Rating (mm)	Water Resistance Provided	Conditions
0-5,000 mm	No resistance to some resistance to moisture.	Light rain, dry snow, no pressure.
6,000-10,000 mm	Rainproof and waterproof under light pressure.	Light rain, average snow, light pressure.
11,000-15,000 mm	Rainproof and waterproof except under high pressure.	Moderate rain, average snow, light pressure.
16,000-20,000 mm	Rainproof and waterproof under high pressure.	Heavy rain, wet snow, some pressure.
>20,000 mm	Rainproof and waterproof under very high pressure.	Heavy rain, wet snow, high pressure.

Source: EVO 2018 (41)

Absolute waterproof (>40,000 mm (43)) is possible, through impermeable coatings such as rubber. However, absolute waterproofing is not desirable as it also traps in moisture and heat, that in turn can increase the risk of hypothermia (44). Consequently, it is important that a garment is also breathable (44). Breathability can be achieved through design (flaps, vents etc.), and through using breathable materials (45). The amount of material breathability needed depends on the activity undertaken. Based on an analogy borrowed from skiing as an activity, the amount of breathability required is (41):

- 5,000 to 8,000 grams ('g') of water vapour in 24 hours - For a mild activity where there are regular breaks (46);
- 10,000 to 15,000 g - If the day trip involves medium-intensity activity that may include a light pack (46); and
- >20,000 g - For a high-intensity activity or carrying a heavy pack (46).

The caveat to the points above is that individual fitness also needs to be considered. That determines mild, medium and high-intensity will vary from individual to individual, and the amount of perspiration produced will reflect the level of fitness (47) and physique (48).

Relative to waterproof ratings, breathability test results can vary significantly (41). This variance is due to differences in temperature, humidity, pressure and the type of test (29). Furthermore, there is no standardisation between manufacturers, and the type of test they use is rarely disclosed (41). Consequently, breathability ratings between manufacturers must be treated with caution, although it may be reasonable to compare garments produced by the same manufacturer (41).

5 MATERIALS

5.1 Cotton

Cotton is highly durable and comfortable (49). When cotton gets wet, it ceases to insulate all the air pockets in the fabric fill up with water (50). Following the deaths of several hikers in the early 1960s, a series of experiments conducted by the National Institute for Medical Research discovered that the 'thermal stress' responsible for each of the deaths was a result of inadequate clothing (51). Although the victims had been wearing an ample amount of clothing, their demise

Contact details & Registered address
Level 14, 197 St Georges Terrace
Perth WA 6000
P: 08 6270 6318
E: basecamp@gexpl.com

Online
Gexpl.com
linkedin.com/company/Greenfields-exploration-ltd/
facebook.com/gexpl/
Twitter: GreenfieldsExpl

was expedited by its form: jeans (denim is a form of cotton), cotton t-shirts, cotton underwear, and sweaters made of a wool-cotton blend. The subsequent experiments found cotton garments to have a **low thermal value when exposed to wet and windy conditions** (31; 52). It is for these reasons that there is a saying that "*cotton kills*" (50).

5.2 Nylon

Nylon (also known as polyamide) absorbs very little moisture overall, and it is also quite durable to abrasions and damage from oils and several other chemicals (53). Nylon fibres are soft and flexible and were originally made as an alternative to silk (53). However, nylon is not very insulating, which makes it unsuitable to wearing in cold climates, unless the garment is made of mixed layers (53). When nylon gets wet, it will remain so for some time, thereby increasing the risk of hypothermia (53; 31).

5.3 Polyester

Polyester is hydrophobic, which means that these fabrics 'hate' water and will not absorb it (54) (53). Polyester does not get soaked *per se*. Instead, polyester allows moisture to move through the fabric (6). This makes wicking of perspiration easy, and it also helps with insulation as it does not draw excess temperature from the body to dry (6). Polyester is stretch-resistant, meaning that it won't lose its shape with time(6). Polyester also shows an anti-pilling effect. Pilling is what happens when fabric fibres roll up and form small balls on the surface and affect its cosmetic appearance but do not affect its performance or durability (6). However, polyester is not oil resistant and is oleophilic and can hold onto odour even after laundering (6). Fleece is an example of polyester. Fleece is renowned for the speed at which it dries.

5.4 Down

Avian down filled garments are unbeatable in dry, cold climates as they have the best warmth-to-weight ratio and are highly compressible (55). Down garments also offer tremendous durability, and when cared for properly can retain their loft (the ability to fluff up) for decades. The weakness of down is moisture - when it gets wet avian down clumps together and loses its ability to trap body heat (55). The moisture can occur from the outside (snow, rain) or the inside (perspiration), and once down gets wet it is usually very slow to dry.

Synthetic down filled garments are usually made of thin polyester fibres and provide warmth like avian down, but importantly, retain heat more effectively when wet (55). However, synthetic down is not as compressible as avian down and can be less durable (55). Furthermore, synthetic down does not have quite as good warmth-to-weight ratio as avian down, but they can perform better in damp conditions (55).

5.5 Wool

Wool is naturally antimicrobial and thus offers excellent odour control (56). In general, wool provides better breathability than polyester (56). However, mid-layer garments with high-quality polyester fleece may have better breathability than heavy/thick wool garments as it is more porous (56). Wool is soft to the touch and typically doesn't itch, but this depends on the quality of wool which is measured by the diameter of the fibres (56): the smaller the diameter, the softer the fabric. High-quality wool clothing is made of fibres less than 18.5 microns in diameter (56). Durability is the weakness of wool clothing and is not suited to use in high-intensity activities such as running (56). Wool absorbs more moisture than polyester (33% vs 0.4%), so it is heavier when soaked by sweat or precipitation – which also means it may be slower to dry (56; 57). However, wool clothing doesn't feel as clammy against the skin as wet clothing made of other materials (56).

5.6 Breathable Fabric Membranes

Breathable fabric membranes ('BFM') are microporous and durable materials that have very low rates of moisture-absorption (58). The most commonly known BFM brand is Gore-Tex, which is often used in more expensive 'high-end' garments and as such is often considered to be high-tech. However, BFM/Gore-Tex has been used in apparel since 1975 (59) and as such, is not 'new tech'. In the case of Gore-Tex, it has a membrane comprised of over 9 billion pores per square inch, which is what helps it remain breathable and capable of wicking moisture away from the body (58). There are typically three important aspects of BFM garments, being a membrane, a laminate and a fabric technology (58). It is a laminate due to being bonded between the outer and inner linings, creating a single layer where all three elements work as one (58). BFM is a useful technology because it fulfils different requirements for different products by using its waterproof and highly breathable qualities (58). BFMs like Gore-Tex can have waterproof ratings that start at 28,000 mm[9] and can withstand heavy rain (58). However, most BFMs rely on a durable water repellent ('DWR') treatment to minimise water contact that helps further waterproof the fabric (58). Coatings tend to degrade over time to light abrasions, dirt, and even body oils degrade the DWR (60) which is problematic as:

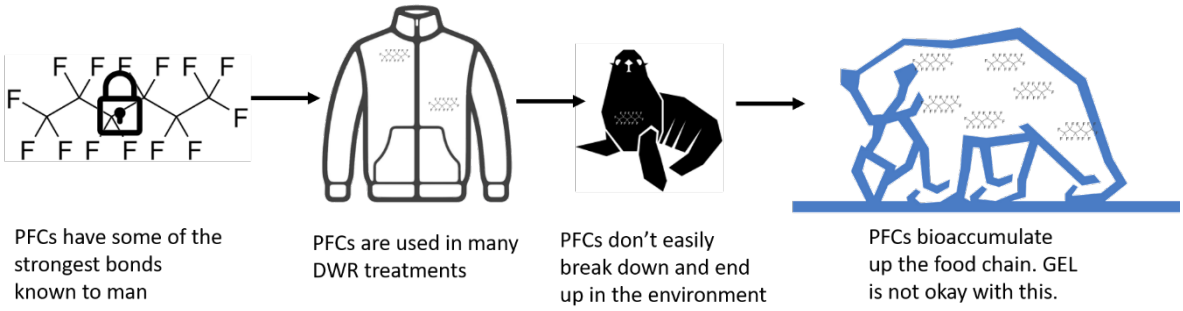
- the apparel becomes more vulnerable in bad weather, and may place the wearer at risk of overheating due to the clogging of pores from the water (58);
- when the BFM pores are saturated, moisture will fail to evaporate (33);
- if the shell gets cold and moisture inside freezes, bonding the insulation layer to the shell, this prohibits the movement of vapour and moisture towards the outside of the system (33); and
- if the user is not in motion and is losing heat, rather than generating heat, the rate of moisture transfer will lower, significantly reducing efficient transfer (33).

For the above reasons, the United State military's **PCU uses BFM sparingly** (33). While BFM is still a component of the PCU system, its use is minimised to specific conditions (33) in which there is significantly more moisture outside the system than inside the system, such as restricting its use to level 5.

The majority of BFM require regular DWR maintenance to keep up its ability to protect against the weather (58). DWR treatments also **harm the environment, as well as its potential negative impact on the human body** (58). This negative impact is due to the common use of Perfluorinated compounds ('PFC') in many DWR treatments (58) (61). PFCs are prevalent in DWR as they have strong and stable chemical bonds. However, this same quality makes them environmentally persistent and bio-accumulative (62)(Figure 10). Despite the isolation, polar bears and seals in East Greenland are contaminated with PCFs that largely derive from global sources (63). For such reasons, many of the major outdoor apparel manufacturers and retailers (64) are moving towards eliminating the use of traditional long-chain PFCs. In some instances, long-chain PFCs are being replaced by short-chain PFCs; however, this is not regulated, and do not have any harmonised classification (65). The molecular structure between the short-chain and long-chain PFCs is so similar that short-chain PFCs also may be persistent, bioaccumulative and toxic (65). While long- and short-chain PFC alternatives are becoming increasingly available for DWR applications, by and large, they are not as durable as the chemicals that they replace (66).

[9] Note that for garments to be labelled as waterproof they must have a rating above 10,000 mm. However, during research into this paper, it was identified that commonly used Australian garments with ratings below 10,000 mm are labelled as waterproof.

Figure 10: PFC and bioaccumulation



Inspired by: Colombia 2016 (67) image adapted by GEL

An alternative fabric technology to traditional BFM involves the elimination for the need for a DWR layer. Construction processes that heat bond layers together without leaving gaps are one means of achieving a high level of waterproofing, without the need for a DWR (58). Such processes may have less aesthetically pleasing qualities, such as the look of a rubber drybag (58). However such processes do not undermine the waterproofing and breathability, and importantly cannot become saturated despite long periods of exposure to rain (58). One line of garments with such technology has a waterproof rating of 20,000 mm^3, which well above the definition of waterproof (10,000 mm^3) [10] (58). However, while breathability is not undermined, it is not as good as traditional BFM garments and may be heavier (58). To compensate for the breathability and heating characteristics relative to traditional BFMs, garments tend to have by additional pit zips to help with venting (58). While the PFC-free aspect is an important consideration given the potential environmental and health implications, the DWR-free aspect is significant in the ease of determining if a garment's waterproofing has degraded.

6 FINDINGS

Under no circumstance may cotton be worn while working in the Frontier. Avoid wearing garments that are labelled as corduroy, denim, flannel, or duck. These are all made with cotton. Also, do not use cotton-polyester blends. Furthermore, other cellulosic fibres with similar qualities to cotton must not be used (e.g. lyocell, linen, bamboo, ramie and viscose rayon (68)).

Avian down should not be used at Frontier. While avian down is very warm, it does not perform well when wet. Synthetic down is better than avian down. However, it appears to be inferior to polyester fleece when it comes to the speed of drying. Consequently, polyester fleece, as recommended in PCU Level 3, should be considered over down apparel.

Due to its poor thermal regulation when wet, and the impracticality of remaining dry, nylon may also pose a thermal risk to the wearer, albeit at a lower level than cotton. Nylon may be acceptable where it is used to augment (ruggedise) parts of apparel, or where it is used in conjunction with other materials that offset its low thermal value when wet. It is noted that most commercially available Level 5 pants are constructed of nylon. Level 6 hard-shells are an exception for use, as this level only needs to be waterproof and insulation is not its primary purpose.

Polyester is a material that may be used extensively through all levels of apparel. The main drawback of this material is that it may hold onto odours, which may be discomforting for other

[10] Note that for garments to be labelled as waterproof they must have a rating above 10,000 mm. However, during research into this paper, it was identified that commonly used Australian garments with ratings below 10,000 mm are labelled as waterproof. Specifically, the Rainbird Workwear brand that is often sold in safety and workwear stores.

team members on extended field trips at the Frontier. GEL also considers materials with similar qualities to polyester, such as polypropylene, as suitable for use in the Frontier.

Wool is also an acceptable material for use at the Frontier. Its ability to minimise body odours makes it suited to Level 1 and 2 garments. For insulation in Level 3, wool may be acceptable but is not recommended for heavy garments where wool's ability to retain moisture may become a risk (e.g. in the case of immersion). Consequently, a poly-wool blend may be suited to use in these mid-levels.

For levels that require water-resistance or water-proofing, it is determined that PFC-based DWRs are not suitable for use at the Frontier. The environmental and health implications of PFCs, and the inability to easily inspect the performance of a DWR make these fabric technologies problematic. This finding applies to both long-chain and short-chain PFCs. It is identified that there are alternative construction methods to traditional BFM that alleviate the shortcomings of DWRs.

An ancillary finding is that consideration be given to garment related search and rescue devices such as the RECCO Avalanche System. RECCO is a two-part system (69) where a sensor can be used to detect a reflector underneath snow. The system is analogous to submarine sonar where the detector sends a signal that bounces off the chip and is received by the detector (70). The RECCO detector has a range of up to 120 meters through the air, 20 meters through dry snow, 10 meters in wet snow, and 8 inches in water (70). The reflector is permanently attached, requires no training and no batteries to function. A RECCO reflector weighs around 4 to 22 grams (71) and may be sown into a garment or attached by other means. Some garments may come with inbuilt RECCO Reflectors. However, as RECCO may be implemented through after-market adjustments, this may not be a key item when selecting a garment.

A second ancillary finding is that there are certification systems that align with Greenfields' ethos to be as environmentally (and socially) responsible as possible. The Bluesign system that certifies that harmful substances are not present in the supply chain, and that production is carried out in a safe manner (72). Systems such as Bluesign may simplify the process of procuring ethically sourced apparel.

7 RECOMMENDATIONS

It is recommended that the PCU system is implemented for all field personnel at Frontier. This military derived system is field tested and originated out of variable/cold climate environments that may be analogous to that experienced at Frontier. By adopting this system, risks associated marketing hype and misconceptions may be minimised. Furthermore, the PCU system is designed to account for one of the identified risks, immersion – an aspect that is poorly addressed by the traditional three-layer approach to cold-weather apparel.

For Frontier, field apparel should be meet all the levels up to 6. Level 7 is likely to be excessive given the climate and conditions that may be encountered during the summer months. Should field programs start earlier in spring or extend into autumn, the need for Level 7 apparel must be investigated. Similarly, if extended fieldwork is expected to occur above the snow-line, the need for Level 7 must be re-assessed.

Where possible, PFC DWR treatments must be avoided. This chemical exposure may have a negative long-term impact on the wearer's health and as such, non-shedding water-resistance or waterproofing should take priority in product selection.

Sourcing items of apparel should be preferentially done via large brands. The advantage of larger brands is that they may have a greater diversity of cuts and cater to both men and women's forms. A poor fit can significantly downgrade the effectiveness of field apparel and increase the thermal risk to the wearer. A preliminary review of commercial offerings suggests that no one-stop manufacturer meets all of GEL's PCU needs. Table 2 in Appendix 1 presents potential items that may meet the Frontier PCU requirements. It is important to emphasise that the identified garments have not been endorsed but are presented for procurement guidance. It is recommended that where possible, Bluesign certified apparel is selected. It is also recommended that RECCO reflectors be incorporated into the field kit of each person working in the Frontier.

8 REFERENCES

1. **Naalakkersuisut MLSA.** *Exploration licence with exclusive exploration rights for Greenfields Exploration Pty Ltd for the area Gauss Halvø in East Greenland.* Nuuk : Mineral Licence and Safety Authority, 2017. Licence No. 2018/03.

2. —. *Exploration licence with exclusive exploration rights for Greenfields Exploration Pty Ltd for the area Scott Bjerg in East Greenland.* Nuuk : Mineral Licence and Safety Authority, 2017. Licence No. 2018/19.

3. —. *Exploration licence with exclusive exploration rights for Greenfields Exploration Pty Ltd for the area Stauning Alper in East Greenland.* Nuuk : Mineral Licence and Safety Authority, 2017. Licence No. 2018/02.

4. —. *Exploration licence with exclusive exploration rights for Greenfields Exploration Pty Ltd for the area Strindberg Land in East Greenland.* Nuuk : Mineral Licence and Safety Authority, 2017. Licence No. 2018/01.

5. —. *Exploration licence with exclusive exploration rights for Greenfields Exploration Pty Ltd for the area Wegener Halvø in East Greenland.* Nuuk : Mineral Licence and Safety Authority, 2017. Licence No. 2018/05.

6. —. *Exploration licence with exclusive exploration rights for Greenfields Exploration for the area Hesteskoen in East Greenland.* Nuuk : Mineral Licence and Safety Authority, 2017. Licence No. 2018/04.

7. *Ittoqqortoormiit and the National Park of Greenland: a community's option for tourism development.* **Tommasini, Daniela.** 3: 237-239, Roskilde : The Polar Record, 2013, Vol. 49. 1475-3057.

8. **Thomassen, Bjørn, Rink, Matilde and Stelter, Sebastian.** *Technical Report on Mineral Exploration 2013, Jameson Land and Liverpool Land, Central East Greenland.* London : Avannaa Exploration Ltd, 2014. Statutory report.

9. **Wikipedia.** List of mountain peaks of Greenland. *Wikipedia the free encyclopedia.* [Online] Wikimedia Foundation, 2018. [Cited: 2 March 2018.] https://en.wikipedia.org/wiki/List_of_mountain_peaks_of_Greenland.

10. **Visit Greenland.** Visit Greenland. [Online] 2017. [Cited: 17 February 2018.] https://visitgreenland.com/destinations/ittoqqortoormiit/.

11. **Timeanddate.com.** Distance. *TimeandDate.* [Online] Time and Date AS, 2018a. [Cited: 19 February 2018.] https://www.timeanddate.com/worldclock/distances.html?n=705.

12. **Insider.** Travel. *Insider.* [Online] Insider Inc, 2017. [Cited: 19 February 2018.] http://www.thisisinsider.com/worlds-most-isolated-remote-places-2017-10#ittoqqortoormiit-greenland-7.

13. *Greenland as a self-governing sub-national territory in international relations: past, current and future perspectives.* **Ackrén, Maria and Jakobsen, Uffe.** 4: 404-412., s.l. : The Polar Record, 2015, Vol. 51. 14753057.

14. **Higgins, Anthony K.** *Exploration history and place names of northern East Greenland.* Copenhagen : Geological Survey of Denmark and Greenland, 2010.

15. *Foreword: Synthesis of the Greenland Ecosystem Monitoring program.* **Christensen, Torben R, et al.** 1:1-2, s.l. : Ambio, 2017, Vol. 46. 0044-7447.

16. **Wikipedia.** Northeast Greenland National Park. *Wikipedia.* [Online] Wikimedia Foundation Inc, 22 January 2019. [Cited: 25 January 2019.] https://en.wikipedia.org/wiki/Northeast_Greenland_National_Park.

17. **Nerlerit Inaat Airport.** ***ISSAAFIQ - The Arctic Gateway.*** **[Online] ISSAAFIQ, 3 April 2015. [Cited: 19 February 2018.] https://www.isaaffik.org/users/nerlerit-inaat-airport.**

18. Bernstein, Stefan. ***Personal communication.*** **Copenhagen, 25 April 2017.**

19. SkyVector. Mestersvig Airport. ***SkyVector Aeronautical Charts.*** **[Online] SkyVector, 2019. [Cited: 25 January 2019.] https://skyvector.com/airport/BGMV/Mestersvig-Airport.**

20. Cassidy, Joseph F. Military Traffic Management Command Transportation Engineering Agency. [Online] 1 June 2001. [Cited: 25 January 2019.] http://www.dtic.mil/dtic/tr/fulltext/u2/a391744.pdf.

21. Thomassen, Bjørn. ***Technical Report on Mineral Exploration in the Eleonore Bay Supergroup, Central East Greenland.*** **London : Avannaa Exploration Ltd, 2012. Statutory report.**

22. NanuTravel. Home. ***Nanutravel.com.*** **[Online] Nanu Travel, 2018. [Cited: 20 February 2018.] http://www.nanutravel.dk/.**

23. Naalakkersuisut. Exploration Projects. ***Govmin.*** **[Online] Government of Greenland, 2018. [Cited: 24 February 2018.] https://www.govmin.gl/minerals/geology-of-greenland/exploration-projects.**

24. TimeandDate. Ittoqqortoormiit, Greenland — Sunrise, Sunset, and Daylength, February 2018. ***Timeanddate.com.*** **[Online] Time and Date AS, 2018. [Cited: 20 February 2018.] https://www.timeanddate.com/sun/greenland/ittoqqortoormiit.**

25. —. Annual Weather Averages in Ittoqqortoormiit. ***Timeanddate.com.*** **[Online] Time and Date AS, 2018. [Cited: 20 February 2018.] https://www.timeanddate.com/weather/greenland/ittoqqortoormiit/climate.**

26. Weather Atlas. Ittoqqortoormiit. [Online] Weather Atlas, 2019. [Cited: 31 January 2019.] https://www.weather-atlas.com/en/greenland/ittoqqortoormiit-weather-january#uv_index.

27. WeatherAtlas. Perth. [Online] Weather Atlas, 2019. [Cited: 31 January 2019.] https://www.weather-atlas.com/en/australia/perth-climate#uv_index.

28. Katabatic winds and piteraq storms: observations from the Greenland ice sheet. ***GEUS Bulletin 31.*** **[Online] Jun 2014. [Cited: 20 February 2018.] http://www.geus.dk/publications/bull/nr31/nr31_p83-86.pdf.**

29. ***Hypothemia as a cause of death in British Columbia, 1998-2012: a descriptive assessment.*** **Stares, Joanne and Kosatsky, Tom. 4:325-358, s.l. : CMAJ Open, 2015, Vol. 3. 2291-0026.**

30. Rettner, Rachael. Can a Person Freeze to Death. [Online] Live Science, 2. [Cited: 6 November 2018.] https://www.livescience.com/6008-person-freeze-death.html.

31. MOC. Why Cotton Kills: Discovering the Dark Side to this Fluffy Fabric. [Online] My Open Country, 2018. [Cited: 2 November 2018.] https://myopencountry.com/hiking-camping-tips-guides/clothing/why-cotton-kills/.

32. Kwikpoint. [Online] Kwikpoint Visual Language Publications, 2013. [Cited: 2 November 2018.] https://www.kwikpoint.com/wp-content/uploads/2013/01/PCU_FR_00110_PRESSsm.jpg.

33. ITS. The PCU Protective Combat Uniform: A Buyer's Guide and Clothing System History. ***Imminent Threat Solutions.*** **[Online] 30 August 2016. [Cited: 2 November 2018.] https://www.itstactical.com/gearcom/apparel/comprehensive-guide-protective-combat-uniform/.**

34. EscapeTrekking. Cold Climate Technical Layering. *Escape Trekking Adventures.* [Online] Escape Trekking Adventures, 2019. [Cited: 25 January 2019.] https://www.escapetrekkingadventures.com.au/cold-climate-technical-layering/.

35. Neverman, Laurie. The 4 Layers of Cold Weather Clothing Everyone Should Know. *Common Sense Home.* [Online] Common Sense Home, 2019. [Cited: 25 January 2019.] https://commonsensehome.com/best-cold-weather-clothing/.

36. Kirkpatrick, Andy. Waterproof Truths. *Andy-Kirkpatrick.* [Online] 9 November 2008. [Cited: 11 February 2019.] https://andy-kirkpatrick.com/articles/view/the_truth_about_breathable_waterproofs.

37. Fiennes, Sir Ranulph. An Evening with Sir Ranulph Fiennes - The Worlsd's Greatest Explorer. Crown Theatre, Perth : British Broadcasting Corporation, 29 March 2019.

38. Quiñonez, Juan Pablo. This is how Special Operations Forces layer clothes for 40°F to -50°F. [Online] Survival Skills Guide, 2018. [Cited: 7 November 2018q.] http://survivalskills.guide/this-is-how-special-operations-forces-layer-clothes-for-40f-to-50f/.

39. TSG. What is waterproof? *Backcountry.com.* [Online] TSG Consumer Partners, 2018. [Cited: 5 November 2018.] https://www.backcountry.com/sc/what-is-waterproof.

40. Waterproof rating: How is Waterproof and breathability measured? [Online] Melbourne Snowboard Centre, 2019. [Cited: 25 January 2019.] https://www.melbournesnowboard.com.au/pages/waterproof-ratings.

41. EVO. Waterproof Ratings & Breathability Guide. [Online] Evolucion Innovations Inc., 2018. [Cited: 5 November 2018.] https://www.evo.com/guides/outerwear-waterproof-ratings-and-breathability.

42. Slater, Dan. A Basic Guide to Understanding Waterproof/Breathable Membranes. [Online] Trek & Trave, 2 March 2018. [Cited: 6 November 2018.] https://www.trekandtravel.com.au/blogs/trek-travel-events-and-blog/understanding-waterproof-breathable-membrane-ratings.

43. What is Waterproof? *BackCountry.* [Online] 2019. [Cited: 25 January 2019.] https://www.backcountry.com/sc/what-is-waterproof.

44. MedilinePlus. How to prevent frostbite and hypothermia. *MedlinePlus.* [Online] National Institute of Health, 3 August 2018. [Cited: 25 January 2019.] https://medlineplus.gov/ency/patientinstructions/000866.htm.

45. OutdoorsFather. Waterproof Clothing Basic. *Outdoors Father.* [Online] 3 May 2015. [Cited: 25 January 2019.] http://www.outdoorsfather.com/2015/05/waterproof-clothing-basics/.

46. Hasan, Ariful, et al. An Overview of Waterproof Breathable Fabrics . *Textile Learner.* [Online] 2019. [Cited: 25 January 2019.] http://textilelearner.blogspot.com/2013/05/an-overview-of-waterproof-breathable.html.

47. Smith, Paige. Your fitness level may determine how much you sweat. *Healthy Living.* [Online] 24 August 2018. [Cited: 25 January 2019.] https://www.huffingtonpost.com.au/entry/sweating-fitness-level_us_5924cdb4e4b0650cc01ff4ff.

48. *Variations in body morphology explain sex differences in thermoeffector function during compensable heat stress.* Notley, Joonhee Park, et al. 5:545-562, s.l. : Experimental Physiology, 24 February 2017, Vol. 102. 0958-0670.

49. Cottonique. 6 Reasons why you should wear cotton made clothing. [Online] Cotton Incorporated, 2018. [Cited: 25 January 2019.] https://www.cottoninc.com/quality-products/fabrics/durability/.

50. THA. Cotton Kills. [Online] Trail Hiking Australia, 2018. [Cited: 2 November 2018.] https://www.trailhiking.com.au/cotton-kills/.

51. *Clothing Insulation and Accidental Hypothermia in Youth.* Pugh, L G C. 1281-1286, London : Nature, 1966, Vol. 209.

52. *Steady-state thermal comfort properties of fabrics incorporated with microencapsulated phase change materials.* Alay, Sennur, Alkan, Cemil and Göde, Fethiye. 7:757-765, s.l. : The Journal of the Textile Institute, 2014, Vol. 103. 0040-5000.

53. Norway Geographical. Polymide (Nylon) vs Polyester: Differences and Comparison. [Online] Norway Geographic, 14 July 2018. [Cited: 2 November 2018.] http://norwaygeographical.com/polyamide-nylon-vs-polyester/.

54. *Effect of Charge and Hydrophobicity on Adsorption of Modified Starches on Polyester.* Samu, R, Moulee, A and Kumar, V G. 220:260-268, Mumbai : Journal of Colloid and Interface Science, 2018, Vol. 15.

55. EVO. How to Choose Insulated Garments. [Online] Evolucion Innovations Inc, 2018. [Cited: 5 November 2018.] https://www.evo.com/guides/how-to-choose-insulated-garments.

56. BestHiking. Polyester vs. Merino Wool: Which material is better for sportswear? [Online] Best Hiking, 18 September 2018. [Cited: 2 November 2018.] https://besthiking.net/polyester-vs-merino-wool/.

57. Blaz. Experiment: Does Polyester Really Dry Faster Than Merino Wool? *Best Hiking.* [Online] Best Hiking, 26 September 2018. [Cited: 8 April 2019.] https://besthiking.net/does-polyester-dry-faster-than-merino-wool/.

58. Norway Geographical. OutDry vs Gore-Tex Technology: Which one is Better? [Online] Norway Geographic, 7 July 2018. [Cited: 2 November 2018.] http://norwaygeographical.com/outdry-vs-gore-tex-technology/.

59. Cunneff, Tom. How the 93-year-old matriarch of Columbia Sportswear fled the Nazis and later built a $2B empire. *CNBC.* [Online] NBCUniversal News Group, 30 August November. [Cited: 7 November 2018.] https://www.cnbc.com/2017/08/30/columbia-sportswear-matriarch-fled-nazis-built-billion-dollar-empire.html.

60. Columbia. Preview: OutDry Extreme. [Online] Columbia Sportswear Company. [Cited: 4 November 2018.] https://blog.columbia.com/outdry_extreme/.

61. NIEHS. Perfluorinated Chemicals (PFCs). [Online] July 2016. [Cited: 2 November 2018.] https://www.niehs.nih.gov/health/materials/perflourinated_chemicals_508.pdf.

62. *Toxicology of perfluorinated compounds.* Stahl, Thorsten, Mattern, Daniela and Brunn, Hubertus. 1:1-52, s.l. : Environmental Sciences Europe, 2011, Vol. 23.

63. *Trends of perfluorochemicals in Greenland ringed seals and polar bears: Indications of shifts to decreasing trends.* Rigét, F, et al. 8: 1607-1614, s.l. : Chemosphere, 2013, Vol. 93. 00456535.

64. H&M. Approved alternatives to perfluorinated compounds (PFC). *H&M Group.* [Online] 2013. [Cited: 28 January 2019.] http://sustainability.hm.com/content/dam/hm/about/documents/masterlanguage/CSR/Others/Approved%20alternatived%20to%20PFC%20version%205.pdf.

65. Levi Strauss & Co. Case Study on Phase out of Short-Chain C6 Perfluorinated Chemicals (PFCs) from Apparel. [Online] May 2016. [Cited: 25 January 2019.]

http://www.levistrauss.com/wp-content/uploads/2016/05/160311_Case-Story_Levi-Strauss_May252016final1.pdf.

66. So, Adrienne. Great Waterproof Gear That'll Keep you PFC-Free this Autumn. *Wired.* [Online] Condé Nast, 27 September 206. [Cited: 28 January 2019.] https://www.wired.com/2016/09/pfc-free-outdoors-gear/.

67. Columbia. [Online] 20 June 2016. [Cited: 2 November 2018.] https://blog.columbia.com/preview-outdry-extreme-eco/.

68. Wiki. Lyocell. [Online] Wikipedia, 3 October 2018. [Cited: 4 November 2018.] https://en.wikipedia.org/wiki/Lyocell.

69. RECCO. The RECCO System. [Online] RECCO, 2018. [Cited: 10 November 2018.] http://www.recco.com/the-recco-system.

70. Achelis, Steve. RECCO Avalanche System. [Online] Avalanche Beacon Reviews, 2018. [Cited: 10 November 2018.] https://beaconreviews.com/recco.php.

71. SnowSafe. Recco Reflector. [Online] Snow Safe UK, 2018. [Cited: 10 November 2018.] https://www.snowsafe.co.uk/product/recco-reflector/.

72. Bluesign. Home. [Online] Bluesign Technologies AG, 2018. [Cited: 6 November 2018.] https://www.bluesign.com/.

73. Marmot. EVODry. [Online] Marmot Mountain LLC, 2018. [Cited: 2 November 2018.] https://www.marmot.com/evodry/EVODry-landing.html.

74. Gear Patrol. The Best Rain Jackets of 2018. [Online] Gear Patrol, 5 April 2018. [Cited: 4 November 2018.] https://gearpatrol.com/2018/04/05/best-rain-jackets/.

75. Icebreaker. [Online] VF Corporation, 2018. [Cited: 5 November 2018.] https://au.icebreaker.com/en/mens-baselayers?prefn1=fabricWeight&prefn2=phClass&prefv1=200%20-%20220%20Lightweight&prefv2=Long%20Sleeve%20Tops%7CBottoms.

76. Mammut. [Online] Mammut Sports Group AG, 2018. [Cited: 6 November 2018.] https://www.mammut.com/p/1022-00210-00205/aconcagua-ml-tights-men/.

77. —. Alvra. [Online] Mammut Sports Group AG, 2018. [Cited: 6 November 2018.] https://www.mammut.com/p/1014-00260-4585/alvra-ml-pull-men/.

78. Lundhags. Quilt Crew. [Online] LUNDHAGS SKOMAKARNA AB, 2019. [Cited: 11 February 2019.] https://www.lundhags.se/en/products/clothing/midlayer/midlayer-tops/quilt-crew?variant=26299/(color)/604.

79. Icebreaker. Men' 旅 Tabi Realfleece Sweat Crewe. [Online] VF Corporation, 2018. [Cited: 6 November 2018.] https://au.icebreaker.com/en/mens-layering-midlayers/-tabi-realfleece-sweat-crewe/104253.html?dwvar_104253_color=001.

80. —. Men's 旅 Tabi Realfleece Sweat Pant. [Online] VF Corporation, 2018. [Cited: 6 November 2018.] https://au.icebreaker.com/en/mens-pants-leggings/-tabi-realfleece-sweat-pant/104231.html?dwvar_104231_color=001.

81. Mammut. Arctic. [Online] Mammut Sports Group AG, 2018. [Cited: 6 November 2018.] https://www.mammut.com/p/1014-10394-00162/arctic-ml-jacket-men/.

82. North Face. Campshire Pullover hoodie. [Online] The North Face Inc, 2018. [Cited: 5 November 2018.] https://thenorthface.com.au/product/men-s-campshire-pullover-hoodie#NF0A33QV6HJ.

83. Mountain Hardwear. Hatcher Full Zip Hoody. [Online] Columbia Sportswear, 2018. [Cited: 5 November 2018.] https://www.mountainhardwear.com/mens-hatcher-full-zip-hoody-1824651.html?cgid=mens-tops-fleece&dwvar_1824651_variationColor=010#start=2.

84. Wild Things. Windshirt. [Online] Wild Things LLC, 2018. [Cited: 5 November 2018.] https://www.wildthingsgear.com/products/windshirt-wt-1-1?variant=1625681795.

85. Bergans. Fløyen jacket. *Bergans of Norway.* [Online] Bergans Retail AS, 2018. [Cited: 7 November 2018.] https://www.bergans.com/catalog/clothing-men/jackets-men/softshell-jackets-men/Fl%C3%B8yen-Jacket.

86. —. Stranda Insulated Hybrid Jacket. *Bergans of Norway.* [Online] Bergans Retail AS, 2018. [Cited: 10 November 2018.] https://www.bergans.com/catalog/clothing-men/jackets-men/insulatedshell-jackets-men/Stranda-Insulated-Hybrid-Jacket.

87. Mammut. Aenergy. [Online] Mammut, 2018. [Cited: 6 November 2018.] https://www.mammut.com/p/1011-00061-3473/ultimate-v-so-hooded-jacket-men/.

88. —. Ultimate Eisfeld. [Online] Mammut Sports Group AG, 2018. [Cited: 6 November 2018.] https://www.mammut.com/p/1010-24720-5924/ultimate-eisfeld-so-hooded-jacket-men/.

89. Stranda Insualted Pants. *Bergans of Norway.* [Online] Bergans Retail AS, 2018. [Cited: 10 November 2018.] https://www.bergans.com/catalog/clothing-men/pants-men/insulatedshell-pants-men/Stranda-Insulated-Pants?color=Dark+Navy+%2f+Dark+Fogblue.

90. Mammut. Courmayeur. [Online] Mammut Sports Group AG, 2018. [Cited: 6 November 2018.] https://www.mammut.com/p/1020-05215-0001/courmayeur-so-pants-men/.

91. Bergans. Osatind Pants. *Bergans of Norway.* [Online] Bergans Retail AS, 2018. [Cited: 7 November 2018.] https://www.bergans.com/catalog/clothing-men/pants-men/softshell-pants-men/Osatind-Pants.

92. Fjällräven. VÄRMLAND ECO-SHELL TROUSERS M. [Online] Fjällräven AB, 2018. [Cited: 6 November 2018.] https://www.fjallraven.com/shop/fjallraven-varmland-eco-shell-trousers-m-F90590-dark-olive/?sku=7323450269104.

93. Columbia. Outdry Ex Eco jacket. [Online] Columbia Sportswear Company, 2018. [Cited: 6 November 2018.] https://www.columbia.com/mens-outdry-ex-eco-jacket-1714271.html.

94. —. Men's OutDry Ex Stretch Pant. [Online] Columbia Sportswear Company, 2018. [Cited: 6 November 2018.] https://www.columbia.com/mens-outdry-ex-stretch-pant-1781051.html?cgid=men-pantsShorts-rainShell&dwvar_1781051_variationColor=010#start=0.

95. Backcountry. All About Fleece Jackets. [Online] Backcountry, 2018. [Cited: 5 November 2018.] https://www.backcountry.com/explore/all-about-fleece-jackets.

96. Norway Geographical. Hardshell vs Softshell Jackets: What's the Difference? Which One to Choose? [Online] Norway Geographical, 9 June 2018. [Cited: 2 November 2018.] http://norwaygeographical.com/hardshell-vs-softshell-jackets/.

9 APPENDIX 1

As PFC based DWRs are used extensively in traditional BFM that are found in level 6 garments, some of the identified alternatives are:

- OutDry is strongly recommended for a Level 6 garment, which serves exclusively as a waterproof layer. A major factor in forming this recommendation is that it is not easy to determine the level of waterproofness of Gore-Tex as the DWR degrades. From a management perspective, it is much easier to identify tear or other defects in OutDry

garments and as such, manage the risk of non-performance in the field. As PFC-based DWR may negatively impact the long-term health of the wearer, such garments should not be used. Furthermore, the PFCs bioaccumulate and are not aligned with GEL's corporate philosophy. PFC-free DWR garments may still be considered for Levels 2-5 where water resistance is a nicety, rather than waterproofness being a necessity.

- An acceptable Level 6 alternative to traditional Gore-Tex products may be the Marmot EVODry Collection (73). Marmot uses PFC-free DWR that bonds at a molecular level, which gives it permanence. This is important as it means that DWR does not deteriorate and should not require re-application (74). However, this is a relatively new product and not as well understood as the OutDry alternative.
- An acceptable Level 5 replacement to conventional DWR treatments may be the PFC offering from Fjällräven. Like most DWR treatments it degrades with use, and its degradation cannot be readily identified without soaking. Consequently, the Fjällräven is recommended for use as a water repellent (not waterproofing) agent on Level 5 garments.

The garments identified in Table 2 are intended as guidance for a procurement process. The identified garments are not endorsed by GEL, nor are there manufacturers. An apparel procurement process must involve a high level of independent due-diligence and not rely on Table 2.

Table 2: Garments possibly suited to CPU Levels

Level	Examples
1 - Moisture wicking next to skin	Icebreaker lightweight base-layers, predominantly made of wool (75) Icebreaker midweight base-layers, predominantly made of wool (75) Mammut Aconcagua Bluesign (pants only) (76)
2 - Mid-weight pullover and long pants	Mammut Alvra pullover Bluesign (77) Lundhags Quilt Crew (78) Icebreaker Tabi Realfleece sweat crewe (79) Icebreaker Tabi Realfleece sweat pants (80)
3 – Heavy weight[11] fleece	Mammut Arctic Bluesign unknown g/m (81) Northface Campshire 330g/m polyester (82) Mountain Hardware 420 g/m bonded wool-poly-nylon (83)
4 – Wind-shirt	Wild Things silicon encapsulated wind-shirt (84) Bergans Fløyen Bluesign (85)
5 - Highly stretchable, windproof, water repellent and breathable soft-shell	Top – Bergans Stranda Bluesign RECCO (86) Top – Mammut Ultimate V Bluesign (87) Top – Mammut Ultimate Eisfeld (88) Pants - Top – Bergans Stranda Bluesign RECCO (89) Pants – Mammut Courmayeur Bluesign (90) Pants – Bergans Brekketind Bluesign (91) Pants – Fjällräven Varmland EcoShell (92)
6 – Wind and waterproof hard-shell	Top – Colombia OutDry Ex Eco Bluesign jacket (93) Bottoms – Columbia OutDry Ex stretch pant (94)
7 – High-loft jacket, vest and pant	N/A

Note: The table above is for indicative purposes only. The reader must perform their own research and satisfy themselves that the garments meet the intended purpose.

[11] Heavy-weight, as defined by Polartec, is more than 300 g (23)

Contact details & Registered address
Level 14, 197 St Georges Terrace
Perth WA 6000
P: 08 6270 6318
E: basecamp@gexpl.com

Online
Gexpl.com
linkedin.com/company/Greenfields-exploration-ltd/
facebook.com/gexpl/
Twitter: GreenfieldsExpl