New generation swiftwater rope systems using Teufelberger TEC Reep and other accessories.

By Steve Glassey MEmergMgt CEM® ITRA-S3A/B/V-INS

Public Safety Institute, Wellington, New Zealand.

Abstract

The emergence of advanced fibre micro ropes in technical rescue is receiving considerable interest mainly by those in the rope rescue, mountaineering and tactical rope industries. Many of the examples found are in studies focusing on high angle applications and not in swiftwater environments. With minimal studies available on the use of advanced fibre micro ropes for swiftwater rescue, this study aimed to see whether or not there were advantages of using such ropes, specifically Teufelberger TEC REEP, along with the use of the VT prusik and the DMM Revolver in the water rescue context. A non-scientific trial using these new technologies was integrated into a scheduled swiftwater rescue technician course, including throw bag rescues, live bait rescues, boat on highline, strainer drill and zip lines. The results were that the combined use of these technologies significantly increased the efficiency and safety of swiftwater rope operations, with no significant limitations observed. Swiftwater rescue practitioners may also observe similar benefits in trialling new generation swiftwater rope systems including reduction in equipment required to be purchased and carried, increased strength in water rope rescue systems and ease of deployment through equipment space and weight savings.

Keywords

Swiftwater, Teufelberger, rescue, rope, UHMWPE.

Introduction

Not much has changed in swiftwater based rope rescue systems since the discipline was pioneered by legends such as Jim Segerstrom, Slim Ray, Charlie Wallbridge and others back in the 1970s.

The operating environment has always called for lightweight improvised solutions that could be quickly rigged using the bare necessities contained in a practitioner's personal floatation device – usually consisting of only a couple or Prusiks, a couple of karabiners and a webbing sling.

In the past for swiftwater, it was typical to have low-strength (often polypropylene) ropes for use in throwlines (MBS of 7-13kN is common). But then use larger and heavier static lifelines (typically a MBS of >20kN) for any significant rigging, such as boat on highline and zip lines as they provided a higher safety margin. But ask any swiftwater practitioner and you are likely to find that this mix and match was never an ideal solution and there was no one perfect rope for both throwlines and rescue rigging.

The swiftwater practitioner does not have the luxury of being able to carry a kaleidoscope of hardware and other accessories. This restriction makes it difficult to carry and rig rope rescue systems that are truly capable of rescue loads, until now.

Sixty years on from the introduction of kernmantle ropes, Teufelberger has developed TEC REEP a game changing rope that may well revolutionise how we approach swiftwater rescue.

Water Rescue Ropes

The author was originally introduced to Teufelberger RESC TECH by Craig Raskin who also provided advice on how to seal the cut ends with super glue. The RESC TECH was also a 8mm lightweight rescue rope, but it only came in tan/black/olive which made it somewhat counter-productive in a swiftwater environment where you need to easily spot throwlines – it would have been like having tactical mat black traffic cones. This lack of visibility appeared to be common across most of the 8mm Polyethylene/Aramid lightweight rescue ropes on the market, with the exception of Teufelberger TEC REEP which came in three colour options, including a yellow. In comparison to the RESC TECH cord, the TEC REEP also had the addition of XLF (polypropylene) in its sheath which is likely to improve its buoyancy in water.

TEC REEP is a 32 strand braided kernmantle rope that uses a Ultra High Molecular Weight Polyethylene (UHMWPE) core, covered with a Technora®/Dyneema®/XLF sheath. It floats in water and features low elongation, self-lubricating, good abrasion resistance, good grip and has a MBS of 30kN (Teufelberger,2020). See table 1 for characteristics of the fibres used to construct TEC REEP rope.

	Sheath Blend			Core
	Dyneema®	Technora®	XLF	UHMWPE
Denier Strength (daN/mm$^{2)}$	345	250	56	240
Specific Gravity (kg/cm$^{3)}$	0.97	1.45	0.91	0.97
Water Absorption (%)	0	3.0	0	0
Elongation (%)	3.5	3.5	20-25	3-4
Abrasion Resistance	Very Good	Very good	Sufficient	Very good
Melting Point (°C)	140	450	160	130-136
UV resistance	Good	Poor	Good	Good

Table 1: TEC REEP fibre characteristics (adapted from Robline,2020).

The TEC REEP UHMWPE core is 7-9 times stronger than steel (by weight) and is 15 times more abrasion resistant than carbon steel (Tong et. al.,2006). UHMWPE is used for a variety of applications from ballistic armour for people and vehicles, to connections in skydiving equipment and even in astronaut tethers in space, and now swiftwater rescue. A review of other high performance water rescue ropes was also undertaken for comparison (table 2), with TEC REEP being 3-6 times more expensive than other water rescue ropes.

The nearest product found in this rudimentary study was PMI Dura-Shield (table 2: rope colours; table 3: water rope comparison), however the colour options did not provide sufficient visibility for swiftwater applications and had a slightly lower MBS (accepting that test methods may vary between the options reviewed).

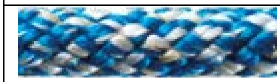
Rope name	Rope variant
	TEC REEP 8mm Yellow
	TEC REEP 8mm Blue
	TEC REEP 8mm Red
	RESC TECH 8mm Tan/Olive/Black
	PMI Dura-Shield 8mm (Green/Blue/Tan)

Table 2: Rope colours (images from Teufelberger and PMI respectively)

	Diameter (mm)	MBS (kN)	Floats	Sheath	Core	Cost USD$/m
Teufelberger TEC REEP	8	30	Yes	Technora/ Dyneema/ Polypropylene (XLF)	UHMWPE	6.40
Teufelberger River Rescue	11	16.5	Yes	Nylon	Polyolefin	1.08
PMI Water Rescue Rope	7	8	Yes	Nylon	Polypropylene	2.09
PMI Dura-Shield	8	27.8	Yes	Technora/ Polyester	Dyneema	6.20
CMC NFPA Throwline	8	15	Yes	Polypropylene	Dyneema	1.16

CMC SRT Throwline	9.5	15	Yes	Nylon	Polyester	1.03

Table 3: Water rope comparison

DMM Revolver Karabiner

For a few years the author has using the DMM Revolver Kwik Lock karabiner (MBS 22kN, Figure 1), a compact lightweight alloy karabiner that had an integrated pulley and a two-stage gate (DMM, 2020). The DMM Revolver is also available in a wire gate, screw gate and triple (three stage) gate option. The Kwik Lock (two-stage) allowed for a locking karabiner that could also be easily opened using one hand, a common necessity in swiftwater. Wire-gate karabiners are generally not suitable for swiftwater rescue as they are prone to unintentionally snagging or clipping onto ropes; and screw-gate karabiners though suitable and common, do have the limitation they may not be easily undone with one hand which is important during zipline rescues or containment.

When TEC REEP is used with the DMM Revolver, the rope nicely sits without lateral overhang on the integrated pulley. These characteristics made it a good choice to use when rigging swiftwater systems such as mechanical advantage and travelling across a zip line.

Figure 1: DMM Revolver Kwik Lock

VT Prusik in Swiftwater

And finally adding to the mix, was the VT Prusik which appears to be gaining traction for those needing micro rope systems such as in tactical and mountain rope operations. The VT Prusiks, like the TEC REEP are made of heat resistant Aramid fibre sheath allowing them to be used in high friction situations that traditional nylon Prusiks would be unsuitable. It is the combination of these new ropes that allow for us to completely rethink what ropes we use for swiftwater rescue. We now can have a single type of rope that can be used from throwlines to rope rescue systems for the swiftwater environment. Testing carried out by *Rigging for Rescue* in 2019, concluded that the “VT Prusik appeared to be a superior alternative to the traditional nylon Tandem Prusik” (Gibbs, 2019). As space in one’s PFD is limited, having a rescue load belay method (i.e. the VT Prusik) that only required one Prusik rather than two (as required for the tandem Prusik) saves precious space. Simply put, two VT Prusiks replaces four traditional prusik slings. For this study, we used a Tendon Timber Prusik (80cm, 8mm, 22kN MBS) which we will refer to as the VT Prusik. It is important to note that in this study, the Valdotain Truss was used to allow for release of load, over the Schwabisch ‘Max over One’ hitch as used in the *Rigging for Rescue* testing.

With a combination of using the TEC REEP rope, along with VT Prusiks and the DMM Revolver – the platform was set for modernising swiftwater rigging. The last hurdle to was confirm this hypothesis with some initial testing of using these products in real life swiftwater situations. With Teufelberger supplying 100m of TEC REEP for testing, a scheduled swiftwater rescue technician course for Coastguard New Zealand held in Canterbury (NZ) was used to do initial testing.

How the testing went

Dry rigging of swiftwater rope rescue systems were undertaken to pre-test suitability prior to in-water testing, including boat on highline, zip line and low angle stretcher set ups. Feedback from students at that point was that TEC REEP was easy to work and tie knots with. We then moved out onto the water in two locations including the Jollie Brook on the Hurunui River, a Class II-III flow ideal for the swiftwater technician course.

Low Angle

As part of the International Technical Rescue Association’s (ITRA) Introduction to Swiftwater Technician (IST) course, students were introduced to construct a basic low angle lowering and raising system for situations where resources were limited during swiftwater incidents. The system comprised of using TEC REEP as the main rope connected to webbing at the head of the litter, protected with a Valdotain Truss using a VT Prusik, with either an Italian (Munter) hitch for lowering, or running through a pulley when in raising (3:1) mode (figure 2). A doubled up Prusik sling was used to offset the VT Prusik away from the Italian hitch and allowed for the hitch to be changed over to a pulley for hauling and vice-versa while protected. This simple method allowed students to rig a low angle system capable of rescue loads with ease that are easy to change over between raising and lowering using minimal equipment available. The heat resistance of the Technora® covered VT Prusik and TEC REEP mainline in this system allows for this unique combination. It is imperative that users understand with this proposed system that only Prusik slings and micro ropes made of specific fibres make this combination possible and safe.

Figure 2. Valdotain Truss VT Prusik on TEC REEP low angle system, being changed over with optional karabiner below pulley across both ropes to assist with Prusik minding during haul. In this photo the 80cm Tendon Timber Prusik was used, however the author recommends using the 100 or 120cm variant instead to remove the additional off-set prusik sling as illustrated.

Throw bagging

Three 20m polyester throw bags were retrofitted with TEC REEP (figure 3). These were used throughout the course for numerous techniques including throw bagging. Prior testing using a NRS Co-Pilot knife confirmed through abrasion resistant, the TEC REEP was able to be cut without much issue. This is advantageous as being able to cut the TEC REEP in the event of an emergency such as throw bag entanglement, is critical to safety in swiftwater activities. TEC REEP when both dry and wet was easily gripped. No major limitations were observed in using the TEC REEP for throw bagging swimmers or rescuers. The only limitation is that the yellow colour of the TEC REEP may not be as visible has traditional water rescue throwlines, but this limitation was not significant.

Figure 3: Throw bags retrofitted with TEC REEP. Note red inner core (unsealed).

Tethered Swim

The floating TEC REEP performed well comparable with traditional economical type throwline with no observed limitations.

Zip Line

The Zip Line (Tensioned Diagonal) is where the TEC REEP showed significant advantages. Having a low elongation (core 3.5% cf. Polyester 10-16%, Polypropylene 20-25%) meant that tensioning the system was easier due to less creep, and after initial loading, less requirement to re-tension. Two 20m TEC REEP throwlines were used as anchors, connecting to a 20m TEC REEP zip line through a Valdotain Truss VT Technora® Prusik as part of a 3:1 mechanical advantage (same set up as per low angle to keep methods simple)(figure 4). There was some initial slippage of the VT Prusik, but this was easily resolved with two extra wraps added to the Valdotain Truss. This initial slippage was likely due to the mainline and VT Prusik being the same diameter and both being new. In conjunction using the DMM Revolver (figure 5) as the travelling device across the zip line, the TEC REEP performed well for both single and two person zip line operations. The benefit of using TEC REEP over traditional ropes was that retrofitted throw bags could be used for anchoring and the zip line, and that the lack of elongation decreased the amount of time wasted re-setting the tension during instruction.

The author also left a part of the loaded TEC REEP rope unprotected to a sharp edge and monitored it for abrasion degradation. It was observed that though the rope suffered minor abrasions at that contact point, in the authors experience it was felt traditional polypropylene or polyester ropes would have suffered more adversely in placed under the same conditions. This is not to suggest that TEC REEP does not require edge protection, in fact given the cost of this rope such protection is strongly encouraged. One related benefit of the TEC REEP is that the UHMWPE core is distinctively red in colour, so any damage to the light yellow covered sheath should easily indicate damage (figure 3).

No limitations were observed in using the TEC REEP for the zip line.

Figure 4: Technora® VT on TEC REEP

Figure 5: DMM Revolver in use as the travelling device on the zip line.

Strainer Drill

Using the same river right anchor, the zip line was reconfigured for the strainer drill (figure 6). Both upstream tag lines used TEC REEP. Traditionally, ropes used for this activity ranged from lifelines (i.e. 11mm nylon static kernmantle) to throwline (8mm polyester/polypropylene). Both of these traditional ropes generally have markedly more elongation which leads to the strainer post constantly recoiling back upstream, causing a serious risk to student safety. The recoiling of the strainer post in high flow can often result in facial, head, and/or dental injuries. To minimise this risk, it is best practice to place an attendant (often an instructor) at one or both ends of the strainer to soften the recoiling motion of the post. In this test, the water depth and speed did not allow for this, so a downstream tag line was set up to provide downstream tension to soften the recoil. The minimal amount of elongation using TEC REEP in this trial resulted in the strainer post having minimal recoil and the downstream tag line became unnecessary. The use of TEC REEP in the strainer drill proved effective in reducing post recoil and improving student safety. No limitations were observed in using the TEC REEP for the strainer drill.

Figure 6: Strainer drill with TEC REEP tag lines.

Boat on Highline

Though there are numerous ways to rig boat on highlines, the author opted for simple rigging with hand controlled tag lines with a 2:1 reeve on a TEC REEP main (track) line. The use of TEC REEP in rigging this technique showed how versatile having a high strength 8mm rope was. It was easier to carry in with the TEC REEP being already carried as throw bags, so no extra big/heavy (11mm) ropes were needed. Like in the strainer drill and zip line, the low elongation meant less time re-tensioning the system and more time for students to focus on the skill of boat on highline. We used an inflatable rescue sled which proved effective for the task. The smaller diameter rope (TEC REEP) also meant larger diameter pulleys were not required. The dry rig of the boat on highline (figure 7) has pulleys that could easily be replaced with the DMM Revolver.

There were no observed limitations in using TEC REEP for the boat on highline technique.

Figure 7: Boat on highline dry rigging using TEC REEP.

Shore Based Vehicle Stabilisation

The author’s original interest in high strength micro rope systems for swiftwater was for shore based vehicle stabilisation. Traditionally, low strength throwlines were used to create the initial stabilisation, and then a lifeline rope (i.e. 11-12.5mm static kernmantle rope, with >30kN MBS) could be pulled through to replace them to provide a stronger connection. Anecdotal evidence at swiftwater vehicle rescue courses, found that stabilisation lines and their respective anchors were not loaded as much as previously expected. However, it makes sense to maximise the strength of such systems if rigged with lower strength (typically around 6kN) conventional low-cost throw rope, with high strength micro ropes such as TEC REEP (30kN). The abrasion resistance of TEC REEP also may be more effective in protecting the rope from glass and sharp edges, often found in vehicle accidents. In dry testing there was no limitations observed in using TEC REEP for shore based vehicle stabilisation. However, though conceptually the use of TEC REEP for shore based vehicle stabilisation appears promising, realistic testing in high flows is needed to provide any conclusion to its suitability or not in such applications.

Figure 8: TEC REEP being used for shore based vehicle stabilisation (dry rigging).

Post use inspection

After the TEC REEP rope was washed and dried, an inspection was carried out. The area that was subjected to intentional abrasion on had minor wear and the core was not exposed (figure9). Upon palpation of the rope, it was able to be compressed (figure 10) and evened out. When used for swiftwater rescue in the methods described in this study, this sheath slippage is unlikely to be of significant concern. Further research is needed to determine if this slippage is an issue for use with mechanical devices.

Figure 9: Abrasion on TEC REEP

Figure 10: Flattened TEC REEP by palpation

Limitations & Further Research

Scientific test conditions were not used in this study. This rudimentary review would benefit from an empirical study being conducted. Further research on the application of TEC REEP for swiftwater vehicle rescue operations in swiftwater environments is also needed as this was not wet tested during the study. Additionally, further research is required to more comprehensively evaluate the effectiveness of the Valdotain Truss and similar Prusik knots using a VT Prusik sling in the swiftwater environment. Though the author made reasonable efforts to identify other similar rope to TEC REEP, no other with similar specifications and colours could be found. It is possible that other brands and variations exist that would be suitable but were unknown at the time of study. As mentioned previously, the observed sheath slippage warrants further research in regard to the rope's suitability for use with mechanical devices.

Discussion

The initial hypothesis was that TEC REEP could be a game changer for swiftwater rescue, as much as an evolution as the change from manilla to nylon ropes in the 1950s. Back then the argument would have been similar "but we have been using this for years, it is fine – and this new stuff costs too much anyway". The cost of TEC REEP is high, but only about 20% more than conventional NFPA "T category rope, and has the additional benefits of saving space and weight which is often restricted when wearing a PFD. TEC REEP also is more abrasion resistant than traditional nylon, polyester or polypropylene, so it could be assumed that it may wear out slower over time, thus saving on rope replacement costs. The accessories recommended such as a Technora® VT Prusik and the DMM Revolver are also typically less expensive than larger mechanical devices such as descenders, ascenders, pulleys and the like. The whole of system cost may be less with the new generation swiftwater rigging explored in this paper (TEC REEP, VT Prusiks, and DMM Revolver), than traditional rigging systems. This however is an assumption that will need to be challenged.

The application of TEC REEP as a main line, beyond being an accessory cord (of which it is certified to EN 564) challenges the traditional standards for rescue ropes with the NFPA 1983 standard requiring Technical "T" ropes to be 9.5-12.5mm in diameter and 20kN in its simplest terms (NFPA, 2017). The same NFPA standard also requires throwlines to have a breaking strength of loss less than 13kN, but between 7 and 9.5mm (and float). To recap, TEC REEP is 9mm and has a 30kN breaking strength. This means the NFPA standard fails to consider a rope that can be both a throwline and a technical ("T") category rope and may no longer be relevant or a new category is needed for water rescue ropes or micro rope systems used in swiftwater, mountaineering and tactical applications.

There are some caveats with the new generation swiftwater rigging systems discussed in this paper. As with any rope or webbing, it needs to be protected from UV/Sunlight given part of the sheath fibre is Technora® which has poor UV resistance (table 1). The use of the VT Prusik does require new knots to be learned not common in swiftwater such as the Valdotain Truss. The users of the system must also critically know that both the TEC REEP and Technora® VT Prusik are specialised products and substituting them for traditional nylon or polyester ropes may lead to serious injury or death. Swiftwater practitioners should always carry a knife, and it is essential that the knife has a sharp serrated edge for the emergency cutting of TEC REEP (but this is should be true of working with any rope around water anyways).

From a manufacturing perspective, there could be benefit in future productions to include a contrasting red strand or fleck to make TEC REEP more visible in aerated water, commonly encountered in the swiftwater environment. Options to include a reflective marker could be advantageous also.

The VT Prusik (80cm) used in this study appeared to be too short and in future application (figure 2), the 100cm or 120cm may be a better option to eliminate the need to extend the connection.

As some swiftwater rescue teams are mobilised by helicopter, the need for lightweight, multi-purpose, high strength equipment is needed. The TEC REEP enables this by replacing multiple variations of rope diameter to a simple 8mm micro rope that can be used for rescue loads when used in conjunction with other accessories such as the VT Prusik.

Conclusion

This preliminary study highlights the potential new generation swiftwater rope systems using Teufelberger TEC REEP have for significantly improving the efficiency and safety of future swiftwater rigging activities.

The integration of the VT Prusik and DMM Revolver karabiner enhanced the versatility of the systems and all key components exceeded a MBS of 22kN (less knot efficiency and stand alone). The combination of these products resulted in light weight, flexible and high strength rope systems suitable for the swiftwater environment. The unique yellow colour option for TEC REEP made it more suitable for swiftwater rescue than competing products reviewed.

The cost of TEC REEP though two to six times higher than other throwlines could be justified with the 8mm cord replacing traditional nylon/polyester 11-12.5mm rescue ropes, meaning savings through reduction in the number of ropes (and rope bags) required for a swiftwater rescue team. As TEC REEP offers higher abrasion resistance than traditional water throwlines, it may well be that this also contributes to savings in the long term. It may be easy to fall into viewing the change to TEC REEP as an expensive way to replace throwlines, but maybe it is more appropriate to view it as the cost, weight and storage space benefits of replacing both throwlines and rescue ropes with a single rope type solution.

If further testing validates the findings of this study, then manufacturers and equipment suppliers should give consideration for the supply of both standard (bucket type) and waist-mounted throw bags being fitted with TEC REEP (or equivalent product if available). Rescue kits could be also supplied containing such throwlines along with DMM Revolvers and VT prusiks.

In summary, preliminary testing using TEC REEP for swiftwater rope operations observed the following benefits:

- ✓ Lightweight
- ✓ High strength – able to cater for rescue loads
- ✓ Acceptable visibility in water
- ✓ High abrasion resistance
- ✓ Easily gripped when wet or dry
- ✓ Easy to tie knots and work with
- ✓ Works well with the DMM Revolver given the diameter of the integrated pulley
- ✓ Less elongation reducing time spent on tensioning mechanical advantage systems
- ✓ Less elongation for strainer drills leading to reducing the risk of timber post recoil injuries
- ✓ Highly versatile – able to be used from throw bagging to highline and stretcher work
- ✓ Compact – saving space in storage and in user pockets (often limited with PFDs)
- ✓ Potential long term cost savings due to using a single type of rope and abrasion resistance

There were minimal limitations in using TEC REEP, but the following were

- Initial cost outlay may be prohibitive to some users/organisations

- When used in conjunction with a VT prusik, users must be aware of fibre limitations
- A sharp serrated knife should always be available when in use
- Observed sheath slippage requires further research before use with mechanical devices.

As the rescue industry moved from manila rope to nylon hawser laid, then kernmantle rope in decades gone by, maybe now we are at another era for rescue rigging and it is important that the swiftwater industry further explores and challenges the systems tested in this study to ensure we can provide the best possible and safest response to water emergencies in the future.

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Conflicts of Interest

The author discloses the conflict that the rope supplied for testing was provided at no charge by Teufelberger. No other incentive or benefit was received as part of this testing. No other conflicts are disclosed. DMM and Tendon devices were used in this study, but without affiliation sought or received.

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About the author

Steve Glassey has been a swiftwater instructor for 20 years, having started his interest in the subject by becoming a Rescue 3 International Swiftwater Technician Instructor and later Instructor Trainer for rope, water and animal rescue. In 2014, Steve along with colleague Geoff Bray became New Zealand's first recipients of the prestigious Higgins and Langley Memorial Award for their development of the first global training programme for swiftwater body recovery. He was Rescue 3 International's Instructor of the Year (2014) and has trained and qualified more swiftwater instructors in Australasia to international standards than any other person. He is an expert witness to the New Zealand Coroners Court for swiftwater rescue and river safety inquiries. He is a founding member of the International Technical Rescue Association and is an active Level 3 Advanced, Boat and Vehicle Swiftwater Rescue Instructor and Assessor. Steve owns and operates the Public Safety Institute, a company that delivers consulting, research and training services world-wide in emergency management and technical rescue. Steve holds a number of postgraduate qualifications including a Masters in Emergency Management and is currently a PhD candidate with the University of Otago.

Contact: steve@publicsafety.institute

Website: www.publicsafety.institute