The medical implications of vehicle-mounted water cannon with special reference to the Ziegler Wasserwerfer 9000 (WaWe 9) system

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Dstl
Biomedical Sciences
Porton Down
Salisbury
Wilts
SP4 0JQ

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Author	**< redacted >**	Signed on original	19 July 2013

Executive summary

The Scientific Advisory Committee on the Medical Implications of Less-Lethal Weapons (SACMILL) has been tasked by the UK Less-Lethal Technologies and Systems Strategic Board to advise on the medical implications surrounding use of a type of vehicle-mounted water cannon that has not previously been available to support policing of serious public disorder in the UK.

To facilitate their consideration of the new system, SACMILL have asked Dstl to review the medical implications of water cannon. The present report has therefore been prepared for the purpose of providing SACMILL with sufficient evidence to enable the committee to produce an interim medical statement. This interim statement will focus on the Ziegler Wasserwerfer 9000 (WaWe 9) water cannon, two examples of which are currently being considered for procurement by the Metropolitan Police Service.

The present review has addressed all aspects of water cannon use that have the potential to influence the medical implications surrounding operational use of water cannon. These aspects include what is currently known about the two WaWe 9 water cannon vehicles under consideration and how they compare with the Somati RCV 9000 water cannon currently in-service in Northern Ireland and previously tested by Dstl for the Defence Scientific Advisory Council sub-committee on the Medical Implications of Less Lethal Weapons (DOMILL – the predecessor to SACMILL).

Medically relevant evidence from operational use of water cannon in Northern Ireland and elsewhere has been sought and assessed, as has the medical literature concerning the effects of high pressure water jets on the body. No clinical case reports concerning injuries sustained specifically from use of water cannon in civil disorder were found in the peer-reviewed literature, although there is good evidence from other sources to indicate that serious injuries have been sustained by people subjected to the force of water cannon jets.

No novel mechanisms of injury from high pressure water jets were found over and above those already identified and considered in earlier reviews by Dstl. The eyes appear to be particularly vulnerable to impact from high pressure jets, and limited (but dramatic) evidence for this emerged during public disorder in Germany in 2010, where one individual sustained major ocular trauma from the force of a water cannon jet. The ability of water cannon jets to topple a person has been evidenced during water cannon use in Turkey and, very recently, in Northern Ireland. Such an effect of the water cannon jets has the potential to lead to serious medical outcomes.

Documentation relating to User Guidance and Training around UK use of water cannon in serious disorder has been reviewed, and it is evident that work needs to be done to make this documentation applicable to the WaWe 9 system (it currently addresses only those aspects of the Somati RCV 9000 system). Specific areas of concern are brought out in the recommendations made as a result of the present review.

Similarly, there is currently limited technical information on the WaWe 9 vehicles, and this lack of detail is reflected in the recommendations made in this report.

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1.1 Historical setting

Hansard records the following exchange between Members of the Lower House on the 29th October 1970 [1]:

> *Sir G. Nabarro asked the Minister of State for Defence what authority he has given to bring into Great Britain water-cannon to quell civil commotion and disturbances; where such cannon are to be used; what regulatory instructions he has given for their use; and whether he will make a statement concerning water-cannon.*
>
> The Under-Secretary of State for Defence (Mr. Ian Gilmour): *"I am not aware of any proposal to introduce water cannon into Great Britain. The procurement of water cannon for use in Northern Ireland has been authorised in order to extend the range of riot-control devices available to the security forces in the Province."*
>
> Sir G. Nabarro: *"What is the constitutional difference between employing water cannon for the purpose of quelling civil disorder and disturbance in Northern Ireland and refusing to equip the Metropolitan Police in London with these admirable weapons, for quelling civil disturbance or disorderly persons in Grosvenor Square, for example?"*
>
> Mr. Gilmour: *"I do not think there is any constitutional difference. Whether or not water cannon should be employed in Great Britain will be a matter for my right hon. Friend the Home Secretary."*
>
> Mr. St. John-Stevas: *"Is not the answer to my hon. Friend's question that blood is thicker than water?"*

Described by Her Majesty's Inspectorate of Constabulary (HMIC) as *"…mechanised creators of distance between police and protestors"* [27], water cannon were first employed in Northern Ireland on 12th August 1969 in Londonderry, on the first day of what became known as the 'Battle of the Bogside' (see Figure 1).

Figure 1 <Copyrighted media – refer to cited source reference>. Water cannon in use in Northern Ireland in 1969 [2][3].

Official records do not document the circumstances in which water cannon were used during the early years of The Troubles in Northern Ireland, as evidenced by the following exchange in the House of Commons in 1997 [4]:

> *Mr. Livingstone: To ask the Secretary of State for Northern Ireland how many times water cannons have been used by the security forces in Northern Ireland since 1967; for what reasons they were used; on what dates they were used; in what places they were used; and if the security forces are currently authorised to use water cannons.*
>
> Sir John Wheeler: *"It is not possible to provide details of the use of water cannons in Northern Ireland as no separate statistical records of their use were kept at the time. It is believed they were last used around 1970."*

"The Royal Ulster Constabulary is authorised to use "reasonable force" in situations of public disorder, which could include the use of water cannons. The force does not, however, hold any water cannons and has not done so for some years."

The last use of water cannon during The Troubles in Northern Ireland appears to have been in 1973 [5].

Further consideration of water cannon as a less-lethal option for police use in the UK continued into the 1980s, with two prototype vehicles undergoing extensive mechanical and road testing in 1983 [6]. Evaluation of a water cannon capability, including a preliminary assessment of the medical implications of its use in public order policing, continued into the mid-1980s [6].

Water cannon next saw operational deployment by the RUC in Northern Ireland in July 1999 (Drumcree; deployed but not used) and July 2001 (Portadown; used to disperse crowds) [7]. The type of water cannon available to the RUC at this time was the Belgian Mol CY NV MSB 18, two of which had been borrowed in 1999 from the Belgian police authorities [8].

On 4th November 2001, the RUC became the Police Service of Northern Ireland (PSNI) and the first PSNI-trained officers took up duty in April 2002 [9].

1.2 DOMILL interim medical statement on water cannon – May 2002

The Defence Scientific Advisory Council Sub-committee on the Medical Implications of Less-Lethal Weapons (DOMILL) was invited by the UK Less-Lethal Weapon Steering Group to provide an interim statement on the medical implications of the use of water cannon *in Northern Ireland* by March 2002 [10] in line with the Northern Ireland Office led Steering Group to address the safety [11] and medical implications of new technologies [12].

The purpose of the interim statement was to facilitate consideration by the PSNI of use of water cannon and, particularly, to inform any future procurement decisions [10]. Given the short time-scales available to DOMILL, the committee were unable to consider any detailed, independently verified, technical data relating to the water output of any specific model of water cannon under consideration by the PSNI.

For this reason, DOMILL adopted an expedient approach involving a generic review of the evidence surrounding injuries sustained during operational use of water cannon, review of the evidence around injuries from other sources of high pressure water jets, a consideration of the physics of water jets, and a review of the RUC/PSNI guidance [10]. This activity was undertaken by Dstl on behalf of DOMILL and is reported in [13].

DOMILL concluded that there was no evidence to indicate that any person had been killed by the direct or indirect effects of the impact from a water cannon jet in operational use. The committee noted the extremely low incidence of reports of "life-threatening" injuries caused by water cannon jets, but cautioned that the application of force of any nature inevitably carried a risk of injury [10].

DOMILL underlined the importance of empirical measurements of the effective loading on the body produced by the water jets because of the complex nature of the jet. The committee also stressed that the measurements had to be undertaken using

water jets from actual water cannon vehicles, and could not be meaningfully derived from theoretical considerations based upon the bulk properties of water jets (namely, mass flow rate and average jet velocity) [10].

The then security minister at the Northern Ireland Office, Jane Kennedy, was reported in July 2002 as saying that she welcomed DOMILL's interim statement as:

> *"…a very positive first step. It clears the way for the PSNI to procure water cannon in the knowledge that world-wide research shows an extremely low incidence of potentially life-threatening injuries.*
>
> *"The deployment of these systems will further expand, in line with Patten's recommendation, the equipment available to the police in dealing with all too frequent public disorder in Northern Ireland. They should both help to defuse violence and defer the point at which usage of baton rounds would be considered."* [15]

The PSNI ordered six water cannon in July 2002, in anticipation of delivery of these vehicles before the summer of 2003 [15]. After a competitive tendering process, the vehicles ordered were Belgian Somati RCV 9000 water cannon. These vehicles were of a new design and there was no history of operational use [16]. The first two RCV 9000 vehicles were delivered to the PSNI in August 2003 and would be accepted into service subject to an independent assessment by DOMILL of the medical implications of this new system.

DOMILL's interim statement on water cannon may be found at APPENDIX A.

1.3 DOMILL statement on the Somati RCV 9000 water cannon – March 2004

To facilitate DOMILL's consideration of the medical implications of the Somati RCV 9000 system, Dstl were tasked with updating their initial review of the evidence concerning injuries associated with water cannon and other high pressure water sources that was undertaken in 2002 [13]. This updated review, which was published in February 2004 [17], did not differ in its conclusions from the earlier review:

> *"There was no evidence in the peer-reviewed journals, press, police or fringe literature reviewed that any person has been killed by the direct impact of a jet from a water cannon in operational use (although there was one unconfirmed case where the victim was reported as being subjected to wholly inappropriate use of water jets). This should not be interpreted to imply that water cannon are incapable of inflicting fatal injury, under operational conditions. This statement encompasses primary, secondary and tertiary injury.*[1] *There was an extremely low incidence of injuries attributed to, or actually caused by water cannon in the world-wide literature, that could be classed as life threatening."* [17]

The review also considered the extant guidance and training, and concluded that this should incorporate reference to the potential for an increased risk of injury under the following circumstances [17]:

[1] Primary injuries were defined as those caused directly by the water jet impacting the human body; secondary injuries were defined as those caused by the impact on the body of street furniture or other debris, energised by the water jet; tertiary injuries were defined as those caused by impact of the body with other items, such as being thrown against a wall or falling.

- Jets directed at the ground in front of personnel where there may be debris or gravel on the ground, or street furniture that may be projected at the person;
- Jets striking the head, even peripherally;
- Jets interacting, even peripherally, with personnel using optical equipment or with the equipment (cameras etc) directly;
- Personnel adjacent to obstacles such as walls, barricades and vehicles, or lying on the ground;
- Personnel on top of structures (walls, vehicles) who may be toppled by the jet;
- People adjacent to weak structures (such as weak walls or windows) that may collapse under the water jet pressure;
- People who are struck by two jets simultaneously;
- Children, the elderly and small adults struck by the jet.

In addition to the injury review, Dstl were tasked with designing and implementing a technical assessment in line with that set out in DOMILL's 2002 interim statement [10]. The various elements of the technical assessment were outlined in <redacted> *et al.* [17] and are described in Section 4.2 of the present report.

The assessment of the first two Somati RCV 9000s was undertaken in September 2003 [18] with some additional testing of these two and testing of the 3rd and 4th vehicles in February 2004 [19].[2] Testing of the output of the 5th and 6th Somati RCV 9000s was also undertaken in April 2004 [20]. These results were all compared with the testing of the loaned Belgian Mol CY NV MSB 18 Vehicles [21].

Having considered the evidence surrounding the Somati RCV 9000, DOMILL drafted a medical statement on the new system and this was endorsed by the committee on 3rd March 2004 (see APPENDIX B).

The first operational use of the newly acquired PSNI Somati RCV 9000 water cannon was by the Garda Síochána during anti-globalisation protests in Dublin on 1st May 2004 (two vehicles were loaned from the PSNI). Since then, the PSNI has deployed and used them in Northern Ireland on multiple occasions (see Section 1.4).

It should be emphasised that DOMILL's 2004 medical statement on the water cannon system applies to use of this less-lethal capability throughout the UK, and is not restricted to its use in Northern Ireland, but it is limited to the six Somati RCV 9000 Vehicles (Serial Numbers 001-006) used under the Guidance and Training reviewed by DOMILL.

Representative images of the Somati RCV 9000 in operational use in Northern Ireland are shown below:

[2] Familiarisation trials undertaken by the PSNI had identified technical problems with the first two RCV 9000 vehicles that necessitated modifications by the manufacturer. This meant that the final DOMILL medical statement on the Somati system was delayed until the outcome of the additional testing could be considered by the committee [14].

Figure 2 - Copyrighted media – refer to cited source reference

Figure 2. The Somati RCV 9000 water cannon in use during serious disorder in Northern Ireland.

1.4 PSNI water cannon use of force statistics

The Northern Ireland Policing Board's Human Rights Annual Report of 2008 recommended that the PSNI provides the Policing Board with six-monthly statistics on all categories of uses of force recorded on the PSNI electronic use of force monitoring system [22]. The PSNI make these statistics publicly available on its website [23]. The use of force reports cover uses of the following: Attenuating Energy Projectile (AEP), baton, CS spray, TASER, conventional firearm, police dog and water cannon.

The PSNI use of force statistics for water cannon, which extend back to April 2008, detail the number of times that this option has been used (i.e. activated) during deployments in Northern Ireland [24]:

Period	Uses	Period	Uses
Apr 2008 - Jul 2008	0	Apr 2010	3
Aug 2008	1	May 2010	2
Sep 2008 - Oct 2008	0	Jun 2010	1
Nov 2008	1	Jul 2010	3

Dec 2008	1	Aug 2010	0
Jan 2009	1	Sep 2010	1
Feb 2009	0	Oct 2010	1
Mar 2009	1	Nov 2010 - Dec 2010	0
Apr 2009	3	Jan 2011	2
May 2009	0	Feb 2011	1
Jun 2009	1	Mar 2011 - May 2011	0
Jul 2009	1	Jun 2011	2
Aug 2009 - Sep 2009	0	Jul 2011	12
Oct 2009	2	Aug 2011 - Jun 2012	0
Nov 2009	1	Jul 2012	2
Dec 2009 - Feb 2010	0	Aug 2012	0
Mar 2010	1	Sep 2012	2

Table 1. Statistics for PSNI use of the Somati RCV 9000 over the period April 2008 to September 2012 [24]. 'Use' refers to activation of the water jets.

Although the PSNI statistics given in Table 1 only document activations of the water cannon, the mere presence of these vehicles at venues where there is the potential for serious disorder will, in itself, constitute a use of force which, in turn, could influence crowd behaviour (positively or negatively). During the period from 1st April 2012 to 30th September 2012, for example, the PSNI activated water cannon on only 4 occasions, although the vehicles were deployed (without activation) 53 times over this same period [24].

One way in which the PSNI water cannon use (activation) statistics may be used is to place the number of injuries reported into perspective, thereby providing insight into the overall safety of this less-lethal capability when deployed and used operationally by trained individuals.

The evidence concerning injuries attributable to water cannon use in serious disorder in Northern Ireland and elsewhere is the subject of Section 5 of the present report.

2 The GB operational requirement for vehicle-mounted water cannon and the tasking of SACMILL

2.1 Background to the GB operational requirement for water cannon

In the wake of anti-capitalist protests in London in May 2000, the following exchange took place in the House of Commons [25]:

> Mr. Baker: *"To ask the Secretary of State for the Home Department, pursuant to his oral statement of 22 May 2000, Official Report, column 656, if he will make a statement on his policy in respect of the use of water cannon against crowds (a) comprised entirely of adult males, (b) comprised of adult males and adult females and (c) comprised entirely of adult females."*
>
> Mr. Straw: *"Water cannon are not currently in use for public order purposes in England and Wales. The possibility of providing the police with water cannon to deal with serious public disorder was carefully considered by a joint police and Home Office working party in the 1980s. Tests were conducted into all aspects of the water cannon's operational capabilities. Models in use on the continent were examined and a wide range of tests were carried out using custom-built British prototypes, as a result of which a number of operational problems emerged. Water cannons cannot be mobilised quickly in order to deal with spontaneous disorder and when mobilised are slow and difficult to manoeuvre, particularly in narrow streets. When water cannon were used in Northern Ireland in the early 1970s they were not found to be effective and, in fact, they became prize targets for rioters. For these reasons, chief police officers in England and Wales have not been persuaded that water cannon would be of operational value in dealing with public disorder in this country."*

The negative sentiment expressed by the then Home Secretary pre-dated the deployment and use by the RUC of the Belgian Mol CY NV MSB 18 water cannon in July 2001 in Portadown, where it was used, with apparent success, against loyalists after they attacked security forces with a blast bomb [35][36]. The Somati RCV 9000 came into service in Northern Ireland in 2004 (see Section 1).

Whether vehicle-mounted water cannon should be available to police in GB as an additional less-lethal option for managing serious public disorder has recently been brought into focus by the serious disorder that took place in England in the summer of 2011. This disorder prompted the following Commons' exchange [26]:

> Nadine Dorries (Mid Bedfordshire) (Con): *"If these riots had broken out in any city or town in Australia or America, the police would have had at their instant disposal water cannon, plastic bullets and tear gas. Across the UK, British people watched on television while police were instructed to stand back when shops were looted, homes were torched and cars were set on fire. Does the Prime Minister really believe that 24 hours' notice of the use of water cannon is good enough? Is it not the case that this is not about police numbers, but about police being given the tools to do the job?"*
>
> The Prime Minister: *"First, let me say to my hon. Friend that the police have access to baton rounds [Attenuating Energy Projectiles] and they can make the decision to use them — in London, they came quite close to making that decision. That must be an operational decision for the police. The very strong*

advice from the police is that because, on the whole, they were not dealing with very large crowds, but with very mobile crowds who were intent on criminal behaviour, water cannon would not have been appropriate. That is the police view. The point that I have made is that we should be ready for every possible contingency in future, so we should know how we would answer future questions. That is why [the PSNI] water cannon are now available at 24 hours' notice."

The Prime Minister's view was subsequently reflected in a December 2011 report prepared by Her Majesty's Inspectorate of Constabulary, which recommended use of water cannon as one of the tactics to be considered for the management of serious disorder involving use of barricades and missiles, use of petrol bombs, violent attacks on the public in the presence of the police, arson attacks on buildings and threats to the fire and ambulance services [28].

In their own review of the serious disorder in London during the period 4th-19th August 2011, the Metropolitan Police Service (MPS) made the following observations concerning use of water cannon to manage serious disorder in mainland UK [29]:

"Water cannon is widely recognised as an effective tactic to disperse and distance aggressors. It requires a precise environment and works most effectively against large static crowds that are, for example, throwing missiles at police, or other communities. It does have tactical limitations, such as manoeuvrability in an urban environment.

"Currently the MPS has no water cannon capability but relies on an agreement with the Police Service of Northern Ireland (PSNI) to have the resource available for use at 24 hours notice. It is the opinion of this review that had it been available for use, it would have been considered as a tactical option during this disorder. However it is unlikely to have been an appropriate and practical option owing to the speed and agility of the disorder.

"Examples in recent history where the use of this tactic might have been a consideration for commanders had it been available include the Countryside Alliance demonstrations in Parliament Square (2004), the 'Gaza' demonstrations against The Israeli Embassy (2008/9) and potentially the student protests of 2010 where specific locations were targeted. In all these cases police had to face significant levels of violence in order to protect key locations and buildings and the staff within them.

"The events of August and subsequent interest in this option have opened the public debate as to whether it is appropriate to have this option more readily available on the UK mainland. As such the MPS is contributing to the national discussion and has concluded that water cannons would be valuable in a few rare situations.

"The MPS looks forward to the Home Office resolving its position on licensing and the funding of water cannon as a national asset. It is estimated that ACPO will be in a position to issue guidelines to forces in May 2012. The MPS continues to be involved in discussions regarding the potential purchase of water cannon vehicles to be based regionally in England and Wales."

It is against this desire by the MPS to enhance their serious public disorder options that SACMILL have recently been asked to consider the medical implications of water cannon (see below). This tasking is in anticipation of the proposed procurement by the MPS of two Ziegler WaWe 9 vehicle-mounted water cannon.

2.2 The tasking of SACMILL

On 18th March 2013, the Chair of the UK Less-Lethal Technologies and Systems Strategic Board (LLT&SSB) wrote to the Chair of SACMILL to inform him that confirmation had been received from the Association of Chief Police Officers (ACPO) that they had an urgent desire to investigate the possibility of having water cannon available for use in England and Wales.

In the letter, the Chair of the LLT&SSB, who is also the Director of the Home Office Public Order Unit, noted that she had recently been made aware that ACPO were considering borrowing water cannon from other European countries to provide an interim capability to meet an urgent deadline.

In accordance with Government policy on the introduction of new weapons into operational use, the procurement process would be required to consider the following elements of the system [31]:

> *"Evaluation and assessment processes for such weapons will include where appropriate a needs analysis, determination of operational requirement, technical evaluation, medical assessment and operational performance trials, and will take into account relevant strategic, ethical, operational and societal issues."*

In line with the requirement for medical assessment, the letter requested that the Chair of SACMILL makes time available at the scheduled meeting of SACMILL on 25th March 2013 for the independent medical committee to review and, if considered appropriate, endorse the 2002 interim statement prepared by SACMILL's predecessor committee, DOMILL (see Section 1.2).

DOMILL's 2002 interim statement specifically concerned the medical implications of use of water cannon in Northern Ireland, a part of the UK where there was already operational experience in the use of this capability in serious public disorder and where vehicle specific mature guidance and training was already in existence (see Section 2). It was therefore unclear how SACMILL's adoption of DOMILL's interim statement would satisfy the medical assessment component of the UK's less-lethal weapon acquisition policy and how any endorsement would directly inform ministerial decisions around the authorisation for use of water cannon in mainland UK.

The SACMILL meeting on 25th March 2013 was attended by the SACMILL independents, the SACMILL Executive Officer (MOD Surgeon General, supported by a member of the SACMILL secretariat) and two SACMILL Official Members (the Director of the Home Office Public Order Unit and the Chief Medical Officer, Dstl Porton Down). Technical specialists from Dstl and the Home Office Centre for Applied Science and Technology (CAST) were also in attendance.

Also present for part of the SACMILL meeting were <redacted> (Commander, Public Order, MPS) and <redacted> (Chief Instructor, Public Order, MPS). These public order specialists advised the committee on why water cannon was needed in GB as a tactical option, the tactical application of water cannon, the various modes of

operation (diffused, pulsed, continuous jet) and fielded questions from the SACMILL independents.

At the time of the SACMILL meeting, it was understood that the water cannon would be sourced from the Danish, German or Belgian authorities. However, it is now apparent that the MPS are considering only the German water cannon and that the specific models (one example of each) being offered for sale by the German police authorities are the Ziegler 2628 WaWe 9 and the 2629 WaWe 9 [32]. All the information provided to Dstl for the purposes of this report indicate that the capability will be centred around use by the MPS.

The MPS, CAST and other stakeholders made an initial assessment in Germany of the Ziegler water cannon on 3rd and 4th July 2013. This visit was designed to establish which Ziegler model is being offered and sought to answer a series of technical questions around the suitability for use of these water cannon in the UK. Technical aspects of the WaWe 9 vehicles are considered in Section 3.

At the time of writing, pressure testing of the Ziegler water cannon has not yet been undertaken.

During the SACMILL meeting on 25th March 2013 the Chair of the committee expressed the view that SACMILL would require an update on an earlier report by Dstl which looked at the medical implications of water cannon [17], as this report was nearly ten years out of date. This report would, *inter alia*, provide SACMILL with an update on injuries associated with operational use of water cannon internationally.

Dstl took an action from the SACMILL meeting to prepare an updated medical implications report for the independent medical committee, and the present report constitutes the response to that action.

The purpose of the present report is to provide SACMILL with sufficient information to enable the committee to formulate an interim statement on the medical implications of use of water cannon based on the latest available information on the injury-causing potential of this technology in the context of the equipment itself and the controls around use of that equipment (including the guidance and training). The Home Office has asked for this interim statement to be finalised by the end of July 2013.

The interim statement must necessarily be generic for at least two reasons:

- In-depth technical assessment of the WaWe 9 vehicles being offered to the UK may lead to the conclusion that either or both of the German water cannon vehicles may not meet the acceptance criteria for purchase.

- The technical report emerging from the pressure testing of the WaWe 9 in July 2013 will not be available to meet the timeline for production of the interim statement. Furthermore, the proposed plan for pressure testing will not have been endorsed by SACMILL, who may request a duplication of the more extensive testing endorsed by DOMILL for the Somati RCV 9000.

The next section of the present report summarises what is known about the two WaWe 9 water cannon vehicles being considered by the UK.

3 The Ziegler Wasserwerfer 9000 (WaWe 9)

3.1 Preliminary technical data

The following information is based upon a preliminary report summarising the outcome of the visit to Germany by CAST staff and others on the 3rd and 4th July 2013. The German authorities are offering to sell the UK two water cannon vehicles: a Ziegler model 2628 and a Ziegler model 2629. These vehicles are about 20-years-old.

Dstl has been advised that the external appearance and water cannon functionality of the two models are identical (but this has not been physically tested) [33]. The difference apparently lies in the power of the vehicles' main engines, which is 280 bhp in the 2628 model and 290 bhp in the 2629.

Images of the Ziegler 2628 reviewed by CAST in July are shown in Figure 3:

Figure 3. The Ziegler 2628 WaWe 9 water cannon during its initial review in July 2013. (© Home Office)

The CAST visit report may be found at APPENDIX C of the present report.

Immediate issues of potential relevance to the medical implications of the WaWe 9 water cannon are:

- There is no video-assisted targeting, which may make target acquisition more difficult and influence the ability to apply force discriminately in a crowd setting. "[The German] operators rely on skill and experience to accurately place the jets."

- The jets operate only in 'continuous' mode – there is no 'diffuse' mode. It is assumed that a pulsed mode may be achieved by intermittent activation of the continuous jet.

- The front monitors are capable of being directed downwards such that the water jets for front-, side- and rear-directed firing are estimated to hit the ground at 3.4, 4.3 and 7.5 metres, respectively. Hence, persons closer than 3.4 metres to the vehicle could be impacted.

- According to the German operators, the maximum “effective” distance of the jets is 60 metres.

- The maximum pressures are nominally 20, 16, 12, 8 or 4 bar. The appropriate pressure setting for a given target is determined (and selected) by the Water Cannon Commander. The two Water Cannon Operators (each one in control of a single monitor) have the additional option of adjusting the output of the monitor under their control to 20%, 40%, 60%, 80% or 100% of the pressure determined by the Water Cannon Commander. There is a suggestion that the water jet pump could be operated at 30 bar, though the circumstances under which this could be attained require clarification.[3]

- It is suggested that the directional control system for the monitors is “more responsive and stable” than that on the PSNI Somati water cannon. There is currently no objective technical evidence to support this assertion.

- There is a rear-mounted monitor close to ground level. It is unclear whether this monitor would be used operationally.

- The WaWe 9 has a functional public address system, though the formal technical testing of this system has yet to be done. One purpose of this system is to warn crowds that the water cannon is about to be used, giving less determined people the option of avoiding being subjected to the water jet.

- The water cannon vehicles generate audible reversing warnings and each has a rear-facing camera.

3.2 Comparison with the Somati RCV 9000

The following list of Somati characteristics is not comprehensive, but serves to illustrate some of the key areas in which the Belgian cannon differs from the candidate German cannon:

- Target acquisition of the monitors is video-assisted.

- The Somati RCV 9000 water cannon has three modes of operation: continuous jet, pulsed or diffuse.

- When the monitors are directed to the ground, the water jet (in continuous or pulsed mode) strikes the ground at 12 metres from the front and sides of the vehicle (distance estimated by CAST in trials at Longmoor Army Base in May 2013).

- The maximum range to target that the Somati would be used is 30 metres. [34]

[3] It is believed that this may involve increasing the rpm of the main engine.

- The maximum pump pressure is 15 bar.[4] The pressure (and mode of operation) is set by the Crew Commander, but the two Water Cannon Operators have the ability to reduce the pressure in their respective cannons by 5 or 10 bar or can shut-off their cannon entirely [39].

- Water capacity is 9,000 litres; flow rate for each monitor is 21.5 litres/second (at maximum pump pressure); both monitors running on full pump pressure will exhaust the water reservoir in 3.5 minutes [39].

- One of the design requirements of the Somati RCV 9000 vehicles was to minimise the chances of a protestor climbing on the vehicles.

Several aspects of potential concern arise from the initial assessment of the WaWe 9 vehicle:

- The absence of video-assisted target acquisition system in the German vehicle. This may raise the risk of injury to persons other than the intended target(s). It may be possible to address this deficit by fitting a suitable system.

- The WaWe 9 monitors are able to projecting water jets much closer to the vehicle than the Somati monitors are able to. The forces and pressures generated on targets decrease with distance from the jet source [19][20], hence there is increased scope with the German water cannon for injury at close range. This aspect may be addressed as part of the development of user guidance and training for the WaWe 9 system.

- The lack of a capability in the WaWe 9 to produce a diffuse spray of water may limit the versatility of the German vehicle compared with the Somati. It is understood that German operators of the WaWe 9 have developed tactics to simulate a form of diffuse mode (APPENDIX C).

- In contrast to the Somati vehicle, the WaWe 9 has an additional monitor located low down at the rear of the vehicle. It is currently unclear whether this feature would be used should the WaWe 9 be adopted for UK use.

- It is unclear whether the safeguards designed to prevent protesters climbing the water cannon vehicles are effective on the WaWe 9 vehicles. This may have implications for injuries sustained from falls from the vehicle.

- The reported ranges are different. This is potentially due to different Guidance on use, different water jet technologies (pumping, transfer or monitors) or jet flow parameters (more coherent flow, higher pressure, higher flow rates, etc).

- The system pressures are reported differently. This may be due to the location in which the pressure is measured or different readings, but the consequences of these pressures need to be understood.

[4] There is no direct read-across in pump pressures between the Somati and Ziegler water cannon: pressures are dependent on where in the pumping system the readings are taken. Also, the flow velocity of water ejected from the monitors will be dependent on pump pressure and the monitor nozzle diameter.

At the time of writing, the gathering of information on the WaWe 9 is still at an early stage, and there are many unanswered questions around the overall suitability of the two candidate vehicles for UK use, the extent to which they will require modification to meet the UK police requirement and other UK-specific requirements (such as meeting the London exhaust emission regulations and ensuring that UK standard pipe fittings are capable of mating to the fittings present on the German vehicle).

The existing guidance and training curriculum for UK water cannon is, in part, specific to the use of the Somati vehicle and these aspects will require revision should the WaWe 9 vehicles be acquired for the UK. The extant guidance and training developed by ACPO and the College of Policing (formerly the NPIA) are considered in Section 6 of the present report.

Section 4 of this report considers the nature of the water cannon jets and discusses how their injury potential may be assessed.

4 The dynamics of water jets and the assessment of their potential to cause injury

4.1 The dynamics of water jets

Water jet dynamics have been considered previously by <redacted> and others [17]. The overall conclusion was that, while the bulk properties (mass flow rate and average jet velocity) may be calculated, the behaviour of water jets in air is complex. This complexity arises in part from the fact that the distribution of energy in the jet may be altered by ostensibly minor changes in pump/nozzle characteristics, while these changes would exert little influence on the bulk properties of the jet [17].

The complex and variable nature of water cannon jets may be seen in Figure 4, which shows a collage of images captured during recent unrest in Turkey:

Figure 4 - Copyrighted media – refer to cited source reference

Figure 4. Images of water cannon jets used in serious disorder in Taksim Square in June 2013.

The above images, together with those shown in Figure 2, serve to illustrate how the water exits the monitor as a coherent jet, but then transitions into turbulent flow as air and water mix. This results in a high velocity coherent core surrounded by an annular cloud of water moving in an entrained air stream [17].

The complexities of the jets generated by water cannon do not lend themselves to a meaningful analysis from first principles of the loads generated on individuals [17]. Hence, <redacted> *et al.* concluded [17]:

- The effective loads on the body must be determined experimentally.
- All evaluations must be undertaken on operational equipment, not prototypes or test rigs.
- More than one example of each specific water cannon should be evaluated.

Section 4.2 details how the effective loading on the body was empirically determined in the case of the Somati RCV 9000 water cannon.

4.2 Assessment of the effective loading on the body from water cannon jets

The technical assessment of the Somati RCV 9000 was undertaken in accordance with the recommendations set out in <redacted> *et al.* [17]:

- Measurement of the bulk fluid output and comparison against an existing vehicle design with a known history of use.
- Definition of the biologically effective loading within the jets using instrumentation that will measure force/time profiles.
- Measurement of the contact velocity/acceleration of the head with a rigid object such as a wall or the ground; this could be achieved using Hybrid III anthropomorphic dummies.
- Measurement of the initial linear and rotational acceleration of the head/neck assembly following direct or sweeping interaction of the jet with the head, and with the torso. This could be undertaken using the Hybrid III.
- The distribution of representative debris accelerated by the cannon directed to the ground, and the potential for specific injuries such as ocular trauma.
- The risk of primary injury to the torso and head assessed using models such as:
    - the chest deflection gauge in the Hybrid III, which could be used to calculate the Viscous Criterion;[5]
    - an instrumentation system that would determine the forces to the tympanic membrane and the eye.

The above approach was endorsed by DOMILL, and the outcome of the trials subsequently undertaken on the PSNI water cannon was reported in <redacted> (2004) [37]. Among the observations made were:

- Eye and ear injuries from direct impact of the water jet are possible.
- Eye injuries may occur through impact of energised debris.
- Head and neck injuries may arise as a result of the body being propelled by the jet into rigid structures.
- Sufficient force may be generated by the jet to topple weak structures which may then indirectly lead to injury.
- The peak pressures and peak forces of the water jets developed at the test targets decreased with increasing range.

[5] The *Viscous Criterion* (VC) is an index used in the automotive industry to predict the severity of torso injury due to crushing. The VC is the instantaneous product of product of velocity and the relative compression of the torso. Thus, in the case of the thorax, relative compression is defined as the displacement of the chest in relation to the spine normalised by the initial thickness of the thorax.

An understanding of the peak pressures and forces developed by the water jet at the target, together with an indication of how these physical attributes of the jet have the potential to lead to injury, all have an intimate bearing on the way that water cannon technology may be operationally exploited in the safest way. In turn, safe operational exploitation is intimately linked to the quality and appropriateness of the user guidance (when, where and how the technology will be used), user training, and the assessment of competency of those who have received training. These latter issues are considered in Section 6 of the present report.

4.3 Proposed methodology for pressure testing of the Ziegler WaWe 9

CAST have provided Dstl with a summary of the pressure tests that they propose to use to assess the jet outputs of the two WaWe 9 vehicles [38]. This document is reproduced at APPENDIX D. The proposed testing regime has not been endorsed by SACMILL and differs in some respects from that used by Dstl in its pressure testing of the six PSNI water cannon in 2003/4 [19][20] (see Section 4.5).

In the 2003/4 tests by Dstl, a custom-designed force plate rig was used (Figure 5):

Figure 5. The force plate rig used in the 2004 testing of the PSNI water cannon. The force plates are the five circular elements located in a horizontal array at the top of the rig. (© Dstl)

The diameters of the force plates ranged from 25 mm (approximating the frontal exposed area of the eye) to 400 mm (approximating the shoulder width of a 50th percentile male). The intermediate force plate diameters were 50, 100 and 200 mm.

Force plates may be used to quantify force (SI unit: Newtons, N) and pressure (SI unit: N/m^2 or pascal, Pa). Pressure is equivalent to force/area, hence pressure may be derived from force. The pressures generated by the impact of water cannon jets may be conveniently expressed in bar (where 1 bar = 100,000 N/m^2 or 100,000 Pa).

Because of the complex structure of the jets generated by water cannon (see Section 4.1), the peak forces and peak pressures developed at the various diameter plates are more meaningful measures of the potential to cause injury, as the averaged forces and pressures generated over a large presenting area will not capture the peaks to which a small presenting area (such as the eye) may be exposed.

In this way, <redacted> in 2003/4 [19][20] measured the forces and pressures generated by the water jets from the six Somati cannon currently in service in Northern Ireland. The strategy adopted in these studies involved directing the water cannon jets at the force plate array from various distances ranging from 10 to 30 metres and operating the water cannon at different pump pressures (5, 10 or 15 bar). In practice, this meant sweeping the jets across the array in an effort to ensure that all the elements of the array would be exposed at some stage to the higher energy components within the complex water jets.

Despite the considerable scatter in the forces and pressures developed at the plates, the data demonstrated the decrease in these parameters with increasing distance from the water jet source and their increase with increasing pump pressures [19][20]. This scatter was believed to be due to the accuracy of aiming and the sweeping of the jet. Examples of the type of data recorded are given in Figure 6 and Figure 7:

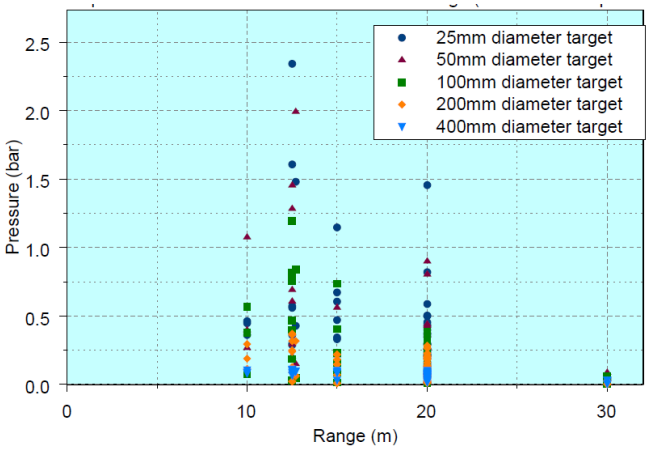

Figure 6. Influence of range on peak equivalent pressures on the force plates. Somati RCV 9000, pump pressure 15 bar [19]. (© Dstl)

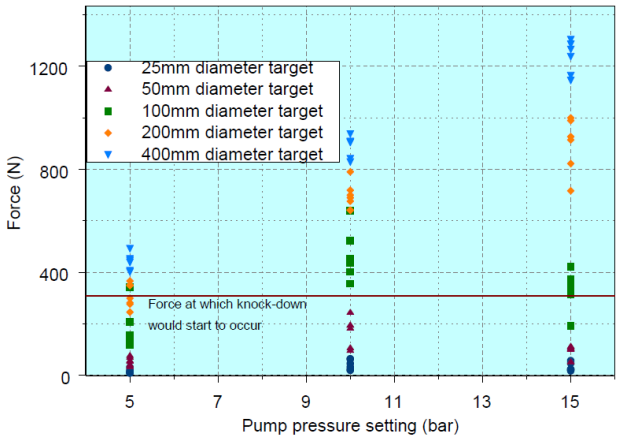

Figure 7. Effect of pump pressure on peak forces measured. Somati RCV 9000, 20 metres from force plate array [20]. (© Dstl)

4.4 Interpretation of force plate measurements

Earlier reviews of the medical implications surrounding use of water cannon identified the following principal at-risk structures [13][17]: eye, ear, rectum and vagina. Whole-body knock-down (with associated blunt trauma) was also considered a risk. The

following observations were made concerning the risk of injury and the pressures (or forces) exerted by water jets:

- Ocular injuries: petechial and conjunctival haemorrhage at 0.6 bar; large corneal abrasion and hydroinjection of orbital tissue at 0.8 bar.
- Tympanic membrane rupture at 0.5-2.1 bar (but more typically at 1.1 bar).
- Rectal/vaginal injuries at pressures above 1.4 bar.
- Knock-down: Forces of 310-445 N have been shown to be sufficient to initiate knock-down of a 104 kg man.

While the above pressure/force criteria for injury provide a context against which the force plate measurements may be interpreted, the large variations in peak pressures and forces measured at the force plates, together with the unique operational circumstances in which a water cannon jet will interact with any given individual, mean that the force plate data should be considered as providing an indicative, rather than a definitive, guide to the injury-causing potential of the water jets at a given pump pressure or targeting distance.

Notwithstanding the above caveats, <redacted> concluded from their observations of the water jet output of the six Somati water cannon [19][20]:

- The water jet profile is such that the force produced by the jet will be sufficient to start knocking people over before it reaches sufficient pressure to cause injury to the eye or ear, **unless the water jet is traversed directly onto the head/neck**. *[Emphasis added.]*
- There is a high risk of injury resulting from ground impact, when thrown by a water cannon jet, if a high-pressure jet is focussed on the body at short range. It is therefore suggested for normal use that the jet pressure is controlled at short range (either by pump-pressure or distance) so that the force imparted is gradually increased, or that the spray mode is used to make the person wet, depending upon the present threat and the need for proportionality.

For the above reasons, much of the safety of water cannon in operational use is tied into how Water Cannon Commanders determine the appropriate pump pressure and mode of use in the first instance and how Water Cannon Operators (Cannoneers) react to the way in which targeted persons respond to the application of the water jet. As <redacted> observed [20]:

> *"Some risk of injury has been identified, but this may be mitigated through training, to highlight to operators the potential hazards, and through appropriate guidance to operators."*

The guidance to users and training curriculum are considered in Section 6 of the present report.

4.5 How do the proposed CAST trials for the WaWe 9 differ from the 2004 Dstl trials?

CAST have provided Dstl with a summary of the pressure tests that they propose to use to assess the jet outputs of the two WaWe 9 vehicles [38]. This document is reproduced at APPENDIX D.

The proposed testing regime has not been endorsed by SACMILL and differs in some respects from that used by Dstl in its pressure testing of the six PSNI water cannon in 2004 [19][20]. The principal differences of which Dstl are aware are as follows:

- CAST propose only to use the two largest force plates (200 and 400 mm diameter). Their rationale is that the smaller plates (25, 50 and 100 mm diameter) are very difficult to target and that this reduces confidence in the peak force (and pressure) measurements determined with these plates.

- CAST propose to use a force mat (known technically as a stance pad sensor).[6] The force mat has a sensing area of 406 mm x 406 mm (16" x 16") comprising 64 force-sensing elements each 6.35 mm (0.25") square. CAST believe that this technology, which was not available in 2004, will provide the information required to estimate peak forces and pressures at the eye (by combining the outputs from several contiguous sensors).

The force mat will also provide a convenient means for measuring the force produced by the rear-mounted monitor on the WaWe 9.

4.6 Hybrid III automotive impact dummy and gravel/debris projection studies

The initial studies of the water jet output from the Somati RCV 9000 incorporated trials to examine the effect of the jets on a Hybrid III human surrogate and the ability of the jets to energise gravel and debris at street level. These tests were in addition to force plate trials outlined in Section 4.3. The outcome of these earlier trials is reported in [18].

The use of the Hybrid III dummy, equipped with accelerometers and load cells, was designed to assess the ability of the water jets to topple a person, and to gain insight into the possibility of neck injury (by examining rotational movement of the head/neck assembly). The study concluded that it was possible to induce high head and neck loads when the water jet was directed at the head/neck assembly, and concluded that such targeting of the head/neck region should be avoided during operation of the water cannon [18]. The study also concluded that there was a high risk of injury from ground impact, in the event that the jet is sufficiently forceful to topple a person (for example, when a high pressure jet is focused on a person at short range) [18].

The study also noted the potential of energised street debris to produce eye injury and to produce injury to the lower limbs. The report cautioned that operators should be aware of this risk and highlighted that this may be a particular risk to people lying on the ground or squatting [18].

For subsequent testing of the Somati RCV 9000 water cannon [19][20], it was determined that it would not be necessary to include the Hybrid III testing, *"…primarily due to the variability of the human surrogate tests"* [19][20].

[6] <redacted>

Indeed, it was considered that only the force plate testing would be necessary to determine any differences in peak forces and pressures generated by the water jets, and this is the cut-down approach proposed by CAST (Section 4.5).[7]

4.7 The rationale for the proposed testing of the WaWe 9 water cannon

It has been proposed that characterisation of the jet output of the two WaWe 9 water cannon vehicles should be confined to measurements of the peak forces and pressures developed at the 400 mm and 200 mm diameter force plates and at the force mat array (Section 4.5). It is proposed that a direct comparison of the WaWe 9 jet characteristics is made with the characteristics of the Somati RCV 9000 water jet. It is asserted that if the WaWe 9 water jet characteristics do not exceed those of the Somati, then the risk of injury from the 'new' German cannon will not exceed that from the Belgian cannon.

SACMILL are invited to comment on the suitability of the proposed CAST testing of the water cannon and whether sufficient data will be gathered to allow comparison of the jet flow. In particular the proposal not to use the small diameter plates on the load cells, and whether sufficient data to assess eye injury, ear injury and the flow dynamics with range will be gathered from the two large plates and the force mat alone.

The next section considers:

- Dstl's earlier reviews of the medical implications of water cannon.
- Whether there is any new information that might add insight to the injury-causing potential of water jets.
- Evidence for injuries associated with operational use of the Somati water cannon in Northern Ireland over the past 9 years.
- The types of injuries observed during water cannon use internationally.

[7] The proposed CAST pressure testing is further cut-down by being limited only to use of the two largest diameter force plates.

5 Injuries from water jets

5.1 Earlier reviews by Dstl of the medical implications of water cannon

At the request of DOMILL, Dstl produced two earlier reviews of the medical implications surrounding use of vehicle-mounted water cannon. The first review [13] served to inform DOMILL's 2002 interim medical statement on the use of vehicle-mounted water cannon (APPENDIX A), while the second review [17] informed DOMILL's 2004 medical statement on the Somati RCV 9000 system (APPENDIX B).

As previously noted (Section 1.3), injuries sustained from water cannon output may be defined as primary, secondary or tertiary [17]:

- Primary injuries are those caused by the water jet impacting the body.
- Secondary injuries are those produced by impact on the body of street furniture or other debris.
- Tertiary injuries are those caused by impact of the body with other objects, such as may arise, for example, if the water jet causes people to fall over or to be thrown against rigid structures.

There is good recent evidence for primary and tertiary injuries produced by water cannon in operational use (discussed later in this section).

Of note is that the earlier reviews by Dstl found little other than anecdotal evidence relating to injuries caused by water cannon jets used in serious public disorder internationally [13][17].

Only one peer-reviewed clinical report pertaining to injuries from use of water cannon was identified [17]. This 1995 report described ocular injuries attributed to Israeli use of water cannon in public disorder [40].

The paucity of evidence on injuries sustained from water cannon use in serious disorder may be taken to imply that this less-lethal technology is relatively benign in use. However, this paucity may alternatively reflect under-reporting by clinicians or may be due to the circumstances in which water cannon are often used, as observed in a June 2000 report from the human rights organisation, the Omega Foundation [41]:

> *"Water Cannon are predominantly used in conjunction with other riot technologies. Although there are many reports of their deployment, unless injuries are of a very specific nature they tend to be aggregated with the general injuries recorded from other weapons such as batons or chemical irritants."*

Because of the paucity of robust evidence on water cannon injuries, the scope of the Dstl review was widened to include injuries from water jets in general. In this way, evidence for injuries involving water jets from devices such as fire-fighting hoses, paint guns and children's water toys were also considered [13][17].

In terms of the injury potential of water cannon jets, the Dstl reviews considered injuries caused by whole-body impact with water (produced, for example, by diving from excessive height), head and neck injury, injury to the eye and auditory system, pneumocephalus (a single case report associated with a waterskiing accident),

laceration/injection injuries associated with high pressure liquid industrial equipment or with high speed interaction of the body with water (such as in water sport activities) and torso/abdominal injuries (associated with water sports activities and other situations involving high velocity water interaction with the body).

The Dstl reviews noted that little of what was reviewed had direct and substantiated relevance to the medical consequences associated with use of water cannon. However, the evidence reviewed did enable an estimation of the magnitude of water impact pressures and forces that may be associated with injury (see Section 4.4).

It is important to recognise that the Dstl reviews on the medical implications of use of water cannon did not consider injuries within the following contexts:

- Injury arising from impact with the water cannon vehicle itself.
- Injury resulting from a person falling from the vehicle.
- The implications of a wet person becoming hypothermic.
- Implications of any water additives (e.g. irritants, surfactants, viscosifiers).
- Use of contaminated water.
- Psychological aspects of use of water cannon.
- Use of water cannon in icy conditions.
- Use of water cannon in high winds (affecting accuracy).
- Use of water cannon in poor visibility conditions (e.g. fog, dusk, rain, fog, smoke).
- Injuries secondary to protester's weapons (including, for example, petrol bombs) being dislodged and energised into the crowd.

5.2 Update on evidence surrounding injuries from water cannon and other water jet sources

5.2.1 Injuries in association with operational use of water cannon

The PSNI were asked for an update on whether any injuries have been observed during operational deployment and use of the Somati water cannon since Dstl last reviewed the medical implications of this technology [51]. Dstl were advised that:

> *"It remains the case that there have been no reports of injury caused by the Water Cannons. There is footage from the 12th July 2013 disorder that shows a rioter being knocked off a police vehicle by a jet from Water Cannon. He appears to fall into the crowd behind and we have not received any complaint or report of injury."*

An image of the person referred to in the PSNI reply is shown in Figure 8:

Figure 8 - Copyrighted media – refer to cited source reference

Figure 8. A man on top of a police Land Rover is toppled by a water cannon jet (North Belfast, 12th July 2013). (From reference [52].)

In Dublin in 2004 a news cameraman was toppled backwards over a wall by the force of the jet from a Somati water cannon, with one source claiming that he was temporarily rendered unconscious (see [53] and Figure 9). The wall was a retaining wall and was low on the side in which the cameraman was originally standing, but was high on the other side (where he was toppled).

Figure 9 - Copyrighted media – refer to cited source reference

Figure 9. The cameraman pictured after the water cannon jet had toppled him off a wall. Dublin 2004. (From [53].)

The PSNI contact was not aware of the camera man being injured, although he was aware of a complaint from a camera man that his equipment had been destroyed by the water cannon [51].

A similar question to that posed to the PSNI was put to a public order contact in the Belgian Police [54]. Part of the response is reproduced below:

<redacted>

As of writing, no information has been received from the German authorities. Serious public disorder involving use of water cannon in Stuttgart in 2010 received widespread media coverage in 2010. One incident in particular illustrates the potential for water cannon jets to cause ocular injury (Figure 10):

Figure 10 Copyrighted media – refer to cited source reference

Figure 10. A protester in Stuttgart in 2010 sustains eye injuries from a water cannon jet [55].

A separate source reported that the man's doctor said that the man *"…was currently blind and might never have his sight fully restored"* [56]. The article goes on [56]:

> *"Egon Georg Weidle, senior doctor at Stuttgart's Katharinen Hospital, diagnosed Wagner with "serious eye injuries". As well as suffering major bruising on both sides, Wagner's eyelids were torn, and on one side, part of his orbital bone – which encases the eye – was fractured. The retina on the same side also suffered suspected damage. The lenses of his eyes were damaged and will need to be replaced by artificial lenses."*

Deaths and serious injury associated with operational use of water cannon have been reported. A reporter was allegedly killed by water cannon fired at "close range" in Tanzania in September 2012 [57].

There are also reports that on 30th May 2013 a protester in Turkey was seriously injured – some reports say killed – via the action of a water cannon jet fired at close range [58]. Dramatic video imagery of the incident shows the heavy-set man being hit in the face with a water jet and being thrown backwards head-over-heels [59]. It is recommended that this video is viewed in order to appreciate the potentially lethal force that can be exerted by a water cannon when it is misused.

Other images from recent protests in Turkey further serve to underline the injury-causing potential of water cannon jets (Figure 11):

Figure 11 - Copyrighted media – refer to cited source reference

Figure 11. Images illustrating use of water cannon in protests in Turkey in May/June 2013.

5.2.2 Peer-reviewed articles

A search was conducted on the NCBI PubMed database using the MeSH (Medical Subject Heading) terms consistent with the putative mechanisms of water jet injuries identified in previous Dstl reviews. Only citations dating back to 2003 (inclusive) were considered:

- *Water* AND Eye Injuries*

  Georgalas *et al.* (2011) [42] present a case report of a fireman with severe eye injury caused by a high-pressure water jet from a fire hose directed principally against the left eye. Damage was inflicted to almost all intraocular tissue in the affected eye. Hyphema (blood in the anterior chamber) in the left eye and bilateral lid ecchymosis (purple discoloration of the skin) was observed. The longer-term outcome from these injuries was not reported. No meaningful information concerning the hydrodynamic nature of the injury-causing water jet was presented.

A PubMed search for 'related citations' (to Georgalas *et al.*) found a study by Sponsel *et al.* (2011) [49], who examined the thresholds for injury to pig eyes *ex vivo* produced by paintballs. The paintballs, which were 16-18 mm diameter, were fired at the eyes at velocities of 26-97 m/s, which the authors estimate correspond to impact kinetic energies of 2-13.5 J. Injuries recorded ranged from posterior lens dislocation and choroidal detachment at 2 J, moderate angle recession (3.5 J), anterior lens dislocation (4 J), peripapillary retinal detachment (4.8 J), iridodialysis and cyclodialysis (7 J), corneal stromal distraction (7.5 J), choroidal segmentation (9.3 J) and globe rupture (10 J). Paintballs are gelatine-encapsulated spheres of containing paint, and therefore do not exactly mimic 'unencapsulated' water. Nevertheless, the paintball velocities used in the study are similar to the water jet velocities that may be encountered by those exposed to water cannon output (see footnote 8), and thereby give some indication of the potential range of injuries to which the unprotected eye may be prone. (Note that the impact from a paintball is transient, whereas that from a water cannon jet will likely be of longer duration.)

A second study by Sponsel *et al.* (2011) [50], using pig eyes *ex vivo* in combination with numerical modelling, examined the ability of paintballs to produce optic nerve injury. The study demonstrated that tangential (grazing) shots to the eyes had the potential to shear the optic nerve. The paintballs penetrated the orbit, producing rotation and globe repulsion.

Duma *et al* (2012) studied the effects of water jets on porcine eyes *ex vivo* [43]. Two water stream diameters (3.2 mm and 6.4 mm) were tested at water velocities of 3.0 to 8.5 m/s. Using intraocular pressure as an indirect measure of ocular injury risk, they concluded that an upper limit of flow velocity of 8.5 m/s for water streams would minimise the risk of serious acute eye damage. To put this flow velocity injury threshold into perspective, the estimated initial velocity of the water jet exiting the Somati monitors is about 70 m/s.[8]

- *Water* AND Tympanic Membrane* (no relevant citations).
- *Water* AND Civil Disorders* (no relevant citations).
- *Water* AND Law Enforcement/methods** (no relevant citations).
- Musculoskeletal and other injuries.

  It is evident from Section 5.2.1 that the force of the jet projected from water cannon has the potential to lead to a wide range of musculoskeletal complications (for example, sprains, dislocations, fractures) mediated either by a direct interaction of the jet with body tissue or by an indirect effect (for example, from the body being thrown against rigid structures). The latter indirect mechanism could also lead to penetrating injuries. Other injuries that

[8] At a 15 bar pump pressure, each of the Somati's monitors projects water at a flow rate of 21.5 litres/s (0.0215 m^3/s). When this flow rate is delivered through the monitor's 19 mm (0.019 m) orifice, the velocity, V, is given by 0.0215/(pi()*0.00975^2) = 72 m/s.

may be associated the direct and indirect actions of the water jet could involve adverse effects on the brain (for example, concussion) and spinal cord (for example, herniated vertebral disc).

5.2.3 Death from a work-related incident involving a high pressure water jet

The death of a ranch worker who was struck in the eye by a stream of pressurised water from an irrigation line was investigated under the U.S. National Institute for Occupational Safety and Health (NIOSH) Fatality Assessment and Control Evaluation (FACE) program. The outcome of the investigation may be found at reference [60]:

In brief, the worker was exposed to a high pressure water jet as a result of the failure of a component in an agricultural irrigation system. The water jet struck the man in the face and right eye and rendered him unconscious.[9] He was found face down in a growing pool of water and died in hospital five days later [60]. The NIOSH accident report does make clear whether the man's death was due directly to exposure to the high pressure jet or was secondary to hypoxaemia due to his lying face down in the water. The water jet was reported to have caused multiple lacerations and severed an artery in the affected eye [60]. The water jet emerged from a 4-inch riser and the pressure on the irrigation line was estimated to be 60 psi [60], resulting in a water flow velocity of 29 m/s (estimated in reference [43]). This water velocity is within the range expected from a water cannon jet (see footnote 8).

5.3 General observations on the injury potential of water cannon jets

It is self-evident from the foregoing discussion that high pressure water jets, whether generated by vehicle-mounted water cannon or by other sources, have the potential to cause serious injuries. Examples of deliberate or unintentional misuse of water cannon have been described.

The scientific and medical literature may offer insights into injury mechanisms associated with high pressure water jets and the forces and pressures required to invoke these mechanisms, but, in the final analysis, the application of excessive force[10], or the application of apparently reasonable force in a high risk context[11], may result in serious injury.

Evidence from operational use of water cannon (Section 5.2.1) illustrates that the eyes are at high risk from the impact of water delivered at high velocity. Similarly, several circumstances in which individuals have been toppled (and even over-turned) by water cannon jets have been identified. These latter effects have the potential to induce various musculoskeletal injuries as well as injuries to the central nervous system (brain and spinal cord).

The safety of water cannon in operational use is therefore **critically and fundamentally dependent** on how the water jets are applied to the targeted person or persons. Important factors include:

[9] The component that failed was the cap of the irrigation riser. It is unclear from the investigation report whether it was the cap or the water jet that induced concussion.
[10] For example, using an inappropriately high water cannon pump pressure when targeting a person who is close to the jet source.
[11] For example, the force of the jet throwing an individual from an elevated position.

- Pump pressure.
- Distance of targeted person(s) from the water jet source.
- Mode of use (continuous or pulsed jet; diffuse mode).
- Local topographical knowledge (awareness of potentially high risk circumstances).
- Vulnerabilities of targeted persons and bystanders (the young, the elderly, and so on).

How the above factors are incorporated into decision-making by water cannon crew is the subject of the following section.

6 Water cannon in the UK: User Guidance and Training

6.1 PSNI, ACPO AND Metropolitan Police Service Guidance and Training Documents

During the initial review of the PSNI instructions on the police use of water cannon [13], several recommendations were made that have relevance to the medical implications of the use of water cannon. These recommendations were, on the whole, adopted by the PSNI in their training and guidance. The guidance was later adopted as the *ACPO Guidance on the Deployment and Use of Water Canon*, which is appended to the published DOMILL statement [16] and is still understood to be current. This ACPO Guidance has now been largely incorporated into the draft National Policing Improvement Agency (NPIA) National Police Public Order Training Curriculum (reference [44] and reproduced at Appendix E). This document is still in draft form and the NPIA has now been replaced by the College of Policing.

Additional documents that refer to the use of water cannon have also been provided from the NPIA [45] and the Metropolitan Police Service [46][47]. These documents have all been used as the reference documents for this section.

6.2 Review of submitted Guidance and Training documentation

The ACPO and NPIA Guidance [16][44][45] all refer to the Somati RCV 9000 vehicles. Section 3 of the present report provides a brief comparison between the Somati RCV 9000 and the Ziegler WaWe 9 vehicles, highlighting several differences that need to be reflected in the controlling documentation. In particular, for the Guidance [16]:

- The lack of a diffuse mode of operation of the water cannon may be an issue given that this is seen in the current guidance as the lowest level of the graduated response (Guidance Section 1, paragraph 5 and paragraph 10).

- The fact that the Ziegler WaWe 9 vehicles are purchased second-hand and not designed to a bespoke UK requirement may present its own concerns, given that the current Guidance states '*The design and use of the vehicle mounted water cannon system is subject to strict criteria.'* (Section 1, paragraph 6). These vehicles may therefore perform outside the UK criteria and may have different levels of performance from the current Somati RCV 9000 vehicles.

- The reference to the Somati RCV 9000 only, without mention of any other vehicles types (Section 1, paragraph 6 and Section 2).

- Reference to the need for local geographical and topographical knowledge – this was previously controlled in PSNI use with defined areas of operation. This is not stated in Metropolitan Police Service use (Section 1, paragraph 10).

- The pressure settings in the Guidance refer, it is believed, to experience gained from use of the Somati RCV 9000 (Section 9, paragraph 2). The pressures may not be measured in the same locations in the water feed system and are unlikely to be relevant for the Ziegler WaWe 9. It may be anticipated that this would affect the water output, but it cannot be predicted

whether this would be more or less injurious (or render the output more or less effective).

- The references to recording equipment and vision around the vehicle may not be relevant to the Ziegler WaWe 9 (Section 9, paragraph 4). These may limit the evidence-gathering capability of the German vehicles, as well as affecting the manoeuvrability of the vehicles. If the visibility is not properly understood, then the risks of injury from movement of the vehicle will not be fully understood.

The Module E4 Training [44]:

- References to spray or diffuse to mode (Section 1, paragraph d and paragraph i).

- Reference to the RCV 9000 Vehicle (Section 1, paragraph e, Section 2) – this is reinforced in [45].

- Reference to the graduated response of the water cannon and flexible application of force (Section 1, paragraph i) - no reference to how these are trained or the impact of not having a diffuse spray mode in the Ziegler WaWe 9 vehicles.

- No reference to the expectation of training of personnel in the local topography (Section 1, paragraph k) to avoid incidents such as happened during the PSNI support to the Garda Síochána when a cameraman was toppled off a wall by the force of a Somati jet (see Section 5.2.1).

- Reference to capturing data from water pressures sensors (Section 2, paragraph b).

- Reference to visual appearances of vehicle (Section 2, paragraph c).

- Although there is an admission that there is a risk that the moving vehicle could result in collision and injure individuals, there is no stated requirement for visibility or escorting of the vehicle (Section 3, paragraph b and Section 9) or training requirements to minimise the risks.

- Reference to 5 or 10 bar pressures that probably relate to the measurements taken on the Somati RCV 9000 vehicle (Section 9, paragraph a, 2nd bullet point).

- The section entitled ’Tactical Adaptability’ appears to refer to the Somati RCV 9000 Vehicle (Section 9).

- The section entitled ‘Potential deployments and Use of water cannon’ appears incomplete (Section 9).

- There is no information on training to educate operators on potential injuries. Although the mechanisms themselves are mentioned, there is no mention of the type of injury that may occur to police personnel, intended targets or bystanders.

- There is no training relating to recording of information from the vehicles or about the vehicles.

- There are no selection requirements for Water Cannon Commanders and Crews (as appears in [16]).

- There is no warning about the potential of protestors climbing onto the vehicles.

The 'Water Cannon Foot and Vehicle Tactics' document [46]:

- Provides no training on possible injuries to the police in support of the vehicle.

- Provides no training on possible injuries that may occur to civilians.

- Provides no guidance to police who are supporting the vehicles and how they may be able assist Water Cannon and Crew Commanders to minimise the risk of injury to the public (for example, by identifying individuals standing on walls where there may be a significant drop on one side).

6.3 Review of previous guidance

The 2002 Dstl review of the medical implications of the use of loaned vehicle mounted water cannon [13] examined the (then) instructions on the police use of water cannon used by the PSNI. In particular, a comprehensive set of questions were raised for the PSNI relating to the training of personnel; these were addressed by the PSNI. However, the following aspects still have relevance for the proposed use of vehicle-mounted water cannon by the Metropolitan Police Service:

- The PSNI personnel were trained by the Belgian Federal Police in the use of the loaned water cannon. It is not clear from the documentation provided to Dstl whether an equivalent training programme will be made available to the Metropolitan Police Service should a decision be made to procure the Ziegler WaWe 9 vehicles. This should be clarified.

- The (then) German guidance on the use of the Ziegler WaWe 9 water cannon was also obtained during this review for PSNI. This guidance stated '*that the use of water blast against a target was believed to be the most intensive form of water deployment and should be aimed at the troublemaker, but not at the head. It should only be used against violent troublemakers, to prevent them from committing or continuing to commit crimes.'* It was not explained why the German guidance was worded like this.

- The original Guidance stated *'that's jets are directed from the ground up towards the lower part of the body'*. This was removed from later versions, however, there is no evidence in the current guidance or training on how jets should be introduced to personnel to minimise the injuries. This requires clarification.

6.4 The command structure for the policing of serious public disorder

The *ACPO Guidance on the Deployment and Use of Water Cannon* [16] gives a command structure for Gold, Silver and Bronze Commanders. This is slightly different to the version provided by the Metropolitan Police Service [47] (and see APPENDIX

F). The main difference appears at the Bronze Commander level, with the interaction of Territorial and Functional Commanders (TFCs). This requires clarification.

6.5 Discussion on Guidance and Training

Review of the Guidance and Training has noted several discrepancies in the documentation that is fundamental to control safety of vehicle-mounted water cannon. Notably:

- There is a lack of mention of the Ziegler WaWe 9 vehicle. This has particular relevance where vehicle-specific attributes are mentioned, such as the reference to pressure settings, pressure sensors, vehicle mobility and visibility from the cab, or design features that may allow people to climb onto the cab.

- The Guidance and Training repeatedly refer to the use of a spray or diffused mode, which is regarded as the lowest level of the graduated application of force. Diffused mode does not exist on the Ziegler WaWe 9. The users of the water cannon need to articulate the consequences of the lack of this lowest level of force, since this may accelerate the use to short bursts of water or use of continuous water jets.

- The Guidance and Training repeatedly refer to the use of video monitoring and recording systems. The implications of a lack of these with the Ziegler WaWe 9 vehicle also need to be considered. Additionally, the other data recording requirements that are mentioned in the Guidance and Training (such as pressure recording) need to be integrated into the use of the Ziegler WaWe 9.

- It is understood that the Ziegler WaWe 9 vehicles may be used over a wider geographic area than the Somati RCV 9000 vehicles. Some consideration needs to be given to ensure that a good local knowledge is made available wherever these vehicles are deployed.

- The current training (Module E4; reference [44]) is incomplete as it currently stands. This training curriculum needs to be fully developed.

- The only mention of selection criteria for Water Cannon Commanders and crews is provided in the ACPO Guidance [16]. This needs to be articulated in the Training [44].

- There is limited mention of injuries apart from the mention of injury mechanisms. This should be expanded to specific items within the training so that injury mechanisms are included along with injury types and ways in which they may be exacerbated (for example, by energising of broken glass, debris and gravel on the roads, impact of jets on weak structures, carrying bulky items [such as photographic equipment or boards/shields] and falls from structures). This training should be delivered to Water Cannon crews and support personnel. This training should consider injuries to police personnel in protective lines as well as to civilians.

- There is no evidence that training will be provided from police services with experience of use of the Ziegler WaWe 9 water cannon. This should be considered as part of the purchase price of these vehicles.

- There is nothing in the Guidance or Training relating to the introduction of water jets to a person (or persons) in a crowd to minimise the risk of injury. Specifically, the German Guidance indicates that the water jets from the Ziegler WaWe 9 vehicles should only be used against '*violent troublemakers'*. The training for the Ziegler vehicles should include guidance on how to introduce the water jet to people an minimise the risk of injury.

- Certain differences between the ACPO Guidance [16] and the MPS Guidance [47] require clarification.

7 Conclusions

The medical implications of use of water cannon in serious public disorder have been reviewed with the aim of providing the Scientific Advisory Committee on the Medical Implications of Less-Lethal Weapons (SACMILL) with sufficient evidence to enable the committee to produce an interim medical statement. This interim statement will focus on the Ziegler WaWe 9 water cannon, two of which are currently being considered for procurement by the Metropolitan Police Service. Should the WaWe 9 water cannon be procured, it will build upon an existing capability – the Somati RCV 9000 system – which is currently in-service with the Police Service of Northern Ireland (PSNI).

The present review has addressed all aspects of water cannon use that have the potential to bear on the medical implications surrounding operational use of this less-lethal technology. These aspects include what is currently known about the two WaWe 9 water cannon vehicles under consideration and how they compare with the Somati water cannon that have been used operationally in Northern Ireland over the past decade.

Medically relevant evidence from operational use of water cannon in Northern Ireland and elsewhere has been sought and assessed, as has the medical literature concerning the effects of high pressure water jets on the body (with an emphasis on the potential for induction of ocular trauma). No clinical case reports concerning injuries sustained specifically from use of water cannon in civil disorder were found in the peer-reviewed literature, although there is strong evidence elsewhere to indicate that serious injuries have been sustained by people subjected to the force of water cannon jets.

No novel mechanisms of injury from high pressure water jets were found over and above those already identified and considered in earlier reviews by Dstl. The eyes appear to be particularly vulnerable to impact from high pressure jets, and limited (but dramatic) evidence for this emerged during public disorder in Germany in 2010, where one individual sustained major ocular trauma from the force of a water cannon jet. The ability of water cannon jets to topple a person has been evidenced during water cannon use in Turkey and, very recently, in Northern Ireland. Such an effect of the water cannon jets has the potential to lead to serious adverse medical outcomes.

Documentation relating to User Guidance and Training around UK use of water cannon in serious disorder has been reviewed and it is evident that work needs to be done to make this documentation applicable to the WaWe 9 system (it currently addresses only those aspects of the Somati RCV 9000 system). Specific areas of concern are brought out in the recommendations made as a result of the present review (Section 8).

Currently, there is limited technical information on the WaWe 9 vehicles. Particular concerns that have emerged at this early stage are: the absence of video-assisted targeting of the water cannon monitors, the absence of data concerning the impact forces and impact pressures developed by the WaWe 9 water jets at different pump pressures over a range of targeting distances, and the shorter engagement range of the WaWe 9 monitors compared with the Somati. Each of these concerns has a direct bearing on the medical implications of this new water cannon system. CAST have proposed a series of tests to address some of these issues, particularly relating

to water pressure output and SACMILL are invited to comment on the appropriateness of these tests.

8 Recommendations

8.1 The Ziegler WaWe 9 water cannon vehicles

- Measurements of the peak forces and peak pressures developed by the WaWe 9 water jets should be made over a range of engagement distances and at various pump pressures (including the 30 bar maximum). These data should be compared with analogous measurements made on the Somati RCV 9000 water jets. Peak forces and pressures generated by the rear-mounted monitor should also be assessed. SACMILL should provide comment on the appropriateness of the CAST proposed testing regime.

- A video system to assist target acquisition should be associated with each monitor should be fitted. The accuracy and consistency of this targeting system should be verified for a range of target distances and pump pressures.

- A service and maintenance schedule for the WaWe 9 vehicles (main vehicle + water delivery system) should be instigated and a strategy developed for sourcing spare parts (especially those components whose ageing or failure may have a bearing on the medical implications of the water cannon).

- The public address system of the WaWe 9 should be of comparable efficiency (or better) than that of the Somati RCV 9000 water cannon.

8.2 Recommendations arising from review of the User Guidance and Training

- The Ziegler WaWe 9 vehicle-mounted water cannon should be explicitly referenced in the documentation. This has particular relevance to parts where vehicle-specific attributes are covered.

- The current documentation repeatedly refers to use of spray (or diffused) mode, while the WaWe 9 has only a continuous jet mode. The users of the WaWe 9 need to understand the consequences of this, as the absence of the lowest level of force on the German vehicle may lead to an earlier introduction of a higher level of force than is the case with the Somati water cannon.

- The Guidance and Training repeatedly refer to the use of video monitoring and recording systems. The implications of a lack of these with the Ziegler WaWe 9 vehicle also need to be considered. Additionally, the other data recording requirements that are mentioned in the Guidance and Training (such as pressure recording) need to be integrated into the use of the Ziegler WaWe 9.

- Consideration should be given to ensuring that WaWe 9 users have a good geographical knowledge of the area in which these vehicles are deployed.

- The ‘Module E4 – Water Cannon in Public Order’ training documentation is incomplete in its current form. This needs to be completed.

- The criteria for selection of Water Cannon Commanders and crew should be articulated in the training documentation.

- The nature, types and sources of injury that might be anticipated from use of water cannon should be articulated in the training documentation and delivered in the training of water cannon crew and support personnel. This should consider injuries to police personnel in protective lines as well as to civilians.

- Training should be sought from German WaWe 9 operators experienced in the use of these vehicles in public disorder.

- Guidance and training should include instruction on how water jets are to be introduced onto person(s) either in isolation or as part of a crowd.

- The operational and tactical implications of the shorter engagement range of the WaWe 9 water cannon monitors (versus the Somati monitors) should be covered in the guidance and training.

- There are some differences between the ACPO and MPS guidance that require clarification.

- Additional warnings should be included within the Guidance and Training that risks of injury also exist if people are able to climb onto a vehicle (especially if moving).

8.3 Recommendations for SACMILL

It is recommended that SACMILL adopt this report as the basis for their discussions on the possibility of writing a statement on the Medical Implications of the use of the Ziegler WaWe 9 Vehicle Mounted Water Cannon (Models 2628 and 2629), noting that:

- The Guidance and Training for the introduction of the Ziegler WaWe 9 Vehicle Mounted Water Cannon are immature.

- The water outputs of the Ziegler WaWe 9 have not been measured or compared with a known water cannon output.

- There are differences in the quoted performance of the Ziegler WaWe 9 Water Cannon with Somati RCV 9000 (currently in service with the Police Service of Northern Ireland) therefore comparison between the two vehicle types is not recommended, but it should also be noted that there is substantial experience of the use of the Ziegler vehicles in Germany with the only known injuries reported in Section 5 of this report.

- This review has not identified any new injury mechanisms, but this review reinforces the observations of the reviews in 2002-2004.

SACMILL members are also recommended to watch the video provided in Reference [59] to gain an appreciation of the power of these systems, noting that this video was compiled with a specific purpose and may be biased.

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Dstl Knowledge and Information Services (KIS)

List of abbreviations

ACPO	Association of Chief Police Officers of England, Wales and Northern Ireland
CAST	Home Office Centre for Applied Science and Technology
CoP	College of Policing
DOMILL	Defence Scientific Advisory Council Sub-committee on the Medical Implications of Less-Lethal Weapons.
DSAC	Defence Scientific Advisory Council
HMIC	Her Majesty's Inspectorate of Constabulary
LLT&SSB	Less Lethal Technologies and Systems Strategic Board.
MPS	Metropolitan Police Service
NPIA	National Policing Improvement Agency (became CoP in 2013).
PSNI	Police Service of Northern Ireland
RUC	Royal Ulster Constabulary
SACMILL	Scientific Advisory Committee on the Medical Implications of Less-Lethal Weapons

APPENDIX A DOMILL INTERIM STATEMENT ON THE USE OF VEHICLE-MOUNTED WATER CANNON – 13th May 2002.[12]

Medical Implications of Less Lethal Weapons

Interim statement on the medical implications of the use of vehicle-mounted water cannon in a public-order role

Background

1. The role of the DSAC[1] Sub-Committee on the Medical Implications of Less Lethal Weapons (DOMILL) is to provide the Secretary of State for Northern Ireland with:

   a. Advice on the medical implications of generic classes of less-lethal (LL) weapon systems (which includes biophysical, biomechanical, pathological and clinical aspects);

   b. Independent statements on the medical implications of use of specific LL systems, when used according to the formal guidance provided to users;

   c. Advice on the risk of injury from identified LL systems striking specific areas of the body, in a format that would assist users in making tactical decisions, and developing guidance to users to minimise the risk of injury.

2. This advice is in support of the UK Government's requirements arising from:

   a. Recommendations 69 and 70 of the Patten Report into policing in Northern Ireland[2]: (i) a research programme to find an acceptable, effective and less potentially lethal alternative to the Baton Round, (ii) provision of a broader range of public-order equipment to the police;

   b. The desire of the Association of Chief Police Officers (ACPO) to have a wider range of options in conflict management scenarios, including those most commonly associated with self-defence and restraint, and the Police use of firearms.

In summer 2000, the Secretary of State for Northern Ireland set up a UK-wide inter-departmental Steering Group to co-ordinate a programme to address both requirements.

3. The second report of the Steering Group has described the various classes of LL weapon systems being evaluated to address the requirements[3]. The report categorises the technologies according to the requirement for research and evaluation. Within

[1] Defence Scientific Advisory Council.
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[3] Patten Report Recommendations 60 and 70 relating to Public-Order Equipment – A research programme into alternative policing approaches towards the management of conflict. Second report of the Steering Group; November 2001.

[12] This interim statement may be found at pp.39-42 of the third report (dated Dec 2002) prepared by the Steering Group led by the Northern Ireland Office, in consultation with the Association of Chief Police Officers.

Category A (devices which may be subject to research and evaluation immediately) are vehicle-mounted and portable water cannon.

4. DOMILL was invited to provide a statement on the medical implications of the use of vehicle-mounted water cannon in public-order role, by October 2002. At a meeting of the Steering Group on 20 December 2001, DOMILL was requested to provide an interim statement by February 2002; at a subsequent meeting of the Steering Group in January 2002, this was extended to March 2002. The interim statement was required to facilitate the consideration of future water cannon use and in particular, the proposal for purchase of water cannon for use by the Police Service of Northern Ireland (PSNI). This document is the interim DOMILL statement.

Technical approach

5. In view of the short time-scales necessary to inform the procurement process, the Steering Group was advised by DOMILL that the statement could only be considered expedient. It would encompass a review of published medical and technical data, and of official reports on operational use of water cannon by UK and some European police forces. The statement would not be able to address detailed technical assessments of water cannon output, or experiments using physical or computer models of human injury. These tests would be undertaken subsequently on the water cannon identified for purchase.

6. The review of the literature and the assessment of the reported technical performance of specific water cannon were undertaken on behalf of DOMILL by the Defence Science and Technology Laboratory (Dstl). Over 500 references and web-sites were reviewed. The documents and web-sites addressed the use of water cannon and injuries attributed to that use, the physics of water jets, and injuries reported from the impact of water in other scenarios, such as water sports. Dstl reviewed the technical specification of some of the water cannon used recently in Northern Ireland, Belgium and Germany, and the specification of the water cannon to be purchased for future use in Northern Ireland.

Conclusions

7. On the basis of the review of a diverse body of literature – little of which had direct, substantiated relevance to the medical consequences of the operational use of water cannon or its use in training – the following conclusions are offered.

8. **Deaths:** There was no evidence in the peer-reviewed journals, press, police or fringe literature reviewed that any person has been killed by the direct or indirect effects of the impact of a jet from a water cannon in operational use. This conclusion encompasses injuries directly from the jet impact (primary injury), penetrating or blunt impact injuries form debris and street furniture accelerated by the jet (secondary injury) and the impact of the accelerated human body against solid objects or the ground (tertiary injury).

9. **Life-threatening injuries:** In the world-wide literature, there was an extremely low incidence of injuries that could be classed as life-threatening attributable to, or actually caused by water cannon jets. The Belgian and German police authorities, and the Police Service of Northern Ireland (PSNI) have no reports of serious or life-threatening injuries to the public that could be attributed to the jet of the Belgian Mol CY NV MSB 18 or the German Ziegler water cannon. It should be recognised however that the use of force of any nature carries a risk of injury.

10. In public-order incidents in which water cannon may be deployed, it may be difficult to differentiate injuries arising directly from its use, or from other potential sources of trauma such as batons, kinetic energy projectiles, assaults or irritants. This clouded the review of all sources of published information on the use of water cannon, and will have implications for assigning injuries arising from future deployments and use, in the subsequent audit.

11. **Water jet dynamics:** The behaviour of free water jets is complex. Although the bulk properties of a jet of water can be calculated (mass flow rate; average jet velocity), it is extremely unlikely that the effective loading on the body could be calculated from first principles. The distribution of energy in the jet (and thus risk of injury) can be altered by ostensibly minor changes in pump/nozzle characteristics, with little overt effect on bulk output. This has three consequences:

a. The effective loads on the body must be determined experimentally;

b. All evaluations must be undertaken on operational equipment, not prototypes or rigs;

c. More than one example of each specific water cannon should be evaluated.

12. **Future vehicle-mounted water cannon:** It is currently unlikely that a water cannon built to the proposed specification of the PSNI would result in a notable change in probability or severity of injury (compared to that from existing water cannon) if used according to the extant PSNI guidance to users. This should not inhibit a review of the extant guidance to reduce the risk of injury from the currently deployed and future water cannon. In the light of the known complexity and variability of water jets, it is essential that the injury potential of the water cannon be verified experimentally.

Recommendations

13. **Guidance to users and training:** The impact of a high-pressure water jet from a water cannon is a high momentum event and may therefore lead to the displacement of the body. In certain scenarios (such as people close to solid obstacles), the potential for an increased risk of injury exists. Future guidance and training should reflect the risks arising from the displacement of people and objects.

14. **Future assessment:** DOMILL has been requested to deliver a final statement on the medical implications of the use of water cannon by October 2002. A formal technical plan for the experimental work to support the statement must await confirmation of the availability for testing of existing and future water cannon equipment. At this stage, it is envisaged that the scope of the programme my encompass:

a. Measurement of the gross fluid output of both the Mol CY NV MSB 18 water cannon, and the new water cannon proposed to be procured by the PSNI;

b. Definition of the biologically effective loading within the jets;

c. Measurement of the contact velocity and acceleration of the head with a rigid object such as a wall or the ground;

d. Measurement of the initial linear and rotational acceleration of the head/neck assembly following direct or sweeping interaction of the jet with the head, and with the torso;

e. The distribution of representative debris accelerated by the cannon directed to the ground, and the probability of specific injuries such as ocular trauma;

f. The risk of primary injury to the torso and head assessed using computer or physical models.

APPENDIX B DOMILL STATEMENT ON THE SOMATI RCV 9000 – dated 3rd March 2004.[13]

DSAC Sub-committee on the Medical Implications of Less Lethal Weapons (DOMILL)

Statement on the medical implications of the use of the Somati RCV9000 Vehicle Mounted Water Cannon

Introduction

1. This statement addresses the use of the Somati RCV9000 Vehicle Mounted Water Cannon as a less-lethal option for dealing with unlawful protest, disorder and threats of violence in the United Kingdom. The statement supercedes an interim statement that considered the medical implication of use in Northern Ireland of the MoI CY NV MSB 18 water cannon[50]; the interim statement was placed in the Library of the House of Commons in July 2002.

Background

2. The role of the DSAC[51] Sub-committee on the Medical Implications of Less Lethal Weapons (DOMILL) is to provide the Secretary of State for the Home Department and the Secretary of State for Northern Ireland with:

   d. Advice on the medical implications of generic classes of less lethal (LL) weapon systems (which includes biophysical, pathological and clinical aspects);

   e. Independent statements on the medical implications of use of specific LL systems, when used according to the formal guidance provided to users;

   f. Advice on the risk of injury from identified LL systems striking specific areas of the body, in a format that would assist users in making tactical decisions, and developing guidance to users to minimise the risk of injury.

3. This advice is in support of the UK Government's requirements arising from:

   a. Recommendations 69 and 70 of the Patten report into policing in Northern Ireland[52]: (i) a research programme to find an acceptable, effective and less potentially lethal alternative to the Baton Round, (ii) provision of a broader range of public-order equipment to the police;

   b. The desire of the Association of Chief Police Officers (ACPO) to have a wider range of options in conflict management scenarios, including those most commonly associated with self-defence and restraint, maintenance of public order, and the police use of firearms.

   In Summer 2000, the Secretary of State for Northern Ireland set up a UK-wide inter-departmental Steering Group to co-ordinate a programme to address both requirements.

4. The second report of the Steering Group described the various classes of LL weapon systems being evaluated to address the requirements. The report categorised the technologies according to the requirement for research and evaluation. Within Category A (devices which may be subject to research

50 DSAC Sub-committee on the Medical Implications of Less Lethal Weapons (DOMILL). Interim statement on the medical implications of the use of vehicle-mounted water cannon in a public-order role. DSTL/CBS/BTP/DOC/592/1.0 dated 13 May 02.

51 Defence Scientific Advisory Council.

52 Report of the Independent Commission on Policing in Northern Ireland; September 1999.

[13] Taken from Annex 11 of the Fifth Report of the UK Less-Lethal Steering Group set up to implement recommendations 69 and 70 of the Patten Report [27].

and evaluation immediately) were vehicle-mounted and portable water cannon. The third report of the Steering Group concluded that portable water cannon did not merit further study, and were unsuitable for use as a less-lethal option in a public-order role. The Steering Group took forward the assessment of commercially available vehicle-mounted water cannon.

5. DOMILL was invited to provide, by March 2002, the interim statement on the medical implications of the use of water cannon in a public-order role. Prior to and during this period, the Police Service of Northern Ireland (PSNI) were deploying the MoI CY NV MSB 18 water cannon. These cannon had been borrowed from the Belgian police authorities. The interim statement was required to facilitate the consideration of future water cannon use and in particular, the proposal for purchase of water cannon for use by the PSNI.

6. On 18 July 2002, the Northern Ireland Office Minister of State announced that the PSNI - following discussions with the Northern Ireland Policing Board and the Association of Chief Police Officers (ACPO) - would shortly place an order for six new vehicle-mounted water cannon. Upon the announcement, a PSNI, ACPO and Home Office project team took forward the procurement, and following an objective review of the specifications of water cannon from two manufacturers that had responded to a technical requirement, a contract was negotiated with Somati of Belgium to supply six water cannon – the Somati RCV9000 Vehicle Mounted Water Cannon. The first two of these vehicles were accepted by the PSNI in August 2003, subject to a medical statement by DOMILL. ACPO produced guidance on the deployment and use of the water cannon in the UK. The water cannon are a new design, and there is no history of operational use.

7. DOMILL was requested to produce a statement on the medical implications of the use of the Somati RCV9000 within the ACPO Guidance. The Defence Science and Technology Laboratory (Dstl) developed and implemented a technical strategy to gather experimental data to underpin DOMILL's statement. The strategy was based on the recommendations presented in para 14 of the interim DOMILL statement. Dstl undertook tests on the MoI CY NV MSB 18 water cannon in October 2002, and on the first two Somati RCV9000 vehicles in Belgium in early September 2003.

8. A DOMILL statement was prepared in October 2003. However, familiarisation trials undertaken by PSNI identified technical problems in the first two vehicles that required modifications by the manufacturers. DOMILL withheld its statement until additional tests could be undertaken by Dstl to ensure that the modifications had not increased the injury potential of the systems. The additional tests on the first and second vehicles took place in February 2004; the water jet outputs of the third and fourth vehicles were also determined at the same time. This statement encompasses these data.

Technical approach

9. The approach was two-fold: a comprehensive review of the literature pertinent to water jets, and a comparison of the water jet output and its effect on responding structures selected to predict the principal hazards. The potential injuries from a jet of water are defined thus:

   - Primary injuries are those caused directly by the energy of a water jet impacting the human body (including rotational injuries to the head and neck).
   - Secondary injuries are those caused by the impact on the human body of street furniture or other debris, energised by the water jet.
   - Tertiary injuries are caused by impact of the body with other items, as a result of the initial event, such as being thrown against a wall or falling.

10. For the literature review, over 500 references and web-sites were reviewed. The documents and web-sites addressed the use of water cannon, and injuries attributed to that use, the physics of water jets, and injuries reported from the impact of water in other scenarios, such as water sports. DstI reviewed the technical specifications of some of the water cannon used recently in Northern Ireland, Belgium and Germany, and the nominal specification of the Somati water cannon to be purchased. DstI updated the review to gather any new information published between the interim DOMILL statement (May 2002) and February 2004.

11. The technical assessment comprised the following activities on the MoI and Somati water cannon:

    c. Measurement of the gross fluid output;

    d. Definition of the biologically effective loading within the jets;

    e. Measurement of the contact velocity and acceleration of the head with a rigid object such as a wall or the ground;

    f. Measurement of the initial linear and rotational acceleration of the head/neck assembly following direct or sweeping interaction of the jet with the head, and with the torso;

    g. The distribution of representative debris accelerated by the cannon directed to the ground, and the risk of specific injuries such as ocular trauma;

    h. The risk of primary injury to the torso and head assessed using physical models.

12. Vehicle-mounted water cannon are less accurate than those LL options that are designed to strike specified individuals. However, they can be used in a variety of modes that reduce the energy transferred to the body by the water: spray or diffused output; short bursts of water jets; continuous water jets. The technical assessment used continuous water jets; uses of lower forces, such as spray output, were considered to be less hazardous. Specifically designed force plates of five different diameters were used to measure the force and the pressure (force per unit area) from the jets. Hybrid III automotive dummies and other injury assessment models were exposed to the jets to assess the hazard. The force and pressure from the jets, and the responses of the injury assessment models were determined at a number of ranges, and cannon output pressure settings. The tests in February 2004 to check the output of the first two vehicles after the modifications, and the tests on the third and fourth vehicles, only employed force plates. The ACPO Guidance was reviewed to assess how the risks were to be controlled in operational use.

Conclusions

Literature review

13. On the basis of the review of a diverse body of literature - little of which had direct, substantiated relevance to the medical consequences of the operational use of water cannon or its use in training - the following conclusions are offered.

14. **Deaths:** There was no evidence in the peer-reviewed journals, press, police or fringe literature reviewed that any person has been killed by the direct or indirect effects of the impact of a jet from a water cannon in appropriate operational use. This conclusion encompasses injuries directly from the jet impact (primary injury), penetrating or blunt impact injuries from debris and street furniture accelerated by the jet (secondary injury) and the impact of the accelerated human body against solid objects or the ground (tertiary injury).

15. **Life-threatening injuries:** In the world-wide literature, there was an extremely low incidence of injuries that could be classed as life-threatening attributable to, or actually caused by water cannon jets. The Belgian and German police authorities, and the PSNI have no reports of serious or life-threatening injuries to the public that could be attributed to the jet of the Belgian MoI CY NV MSB 18 or the German Ziegler water cannon. It should be recognised however that the use of force of any nature carries a risk of injury.

16. In public order incidents in which water cannon may be deployed, it may be difficult to differentiate injuries arising directly from the use of water cannon, as opposed to those caused by other LL weapons such as batons, kinetic energy projectiles, physical assaults or chemical irritants, in cases where such approaches are also used. This clouded the review of all sources of published information on the use of water cannon, and will have implications for assigning injuries arising from future deployments and use, in the subsequent audit.

Technical assessment

17. **Water jet dynamics:** The measured forces and pressures were very variable; this was principally a consequence of the natural structure of water jets, and the difficulties in directing water jets to small experimental targets. Overall, the forces and pressures from the Somati water cannon at maximum pressure were greater than those of the MoI at the same range, although this was not reflected in the variable response of the principal injury model deployed. There was no significant difference between the water output of the four examples of the Somati water cannon.

18. The pressures measured by the force plates were predicted to be sufficient to displace personnel at medium range. At short range, the predicted pressures to the ocular area exceeded a threshold developed from the medical review, and could result in ocular injury.

19. **Response of the injury models:** Unsurprisingly, the responses of the models were also variable. Jets from both types of water cannon directed to the head/neck area could result in high forces that directly accelerate the head/neck assembly. Using a Hybrid III dummy restrained at the torso, the accelerations, forces and moments indicated that according to criteria developed for automotive impact, serious injuries would not be expected, although there was undoubtedly a risk of injury.

20. An unrestrained Hybrid III dummy was accelerated and displaced by the jet, and struck either the ground, or a barrier placed 2 m behind the dummy. The peak accelerations to the head upon the secondary impact were high, and in some cases exceeded the automotive thresholds for serious injury. The high accelerations were observed with the MoI and Somati water cannon. The loads in the neck were also high, and were close to but did not exceed the automotive criteria for serious injury. The loads indicated that there was a risk of injury ("moderate" as defined by the Abbreviated Injury Scale). The Hybrid III dummy does not model the controlled fall of a human; in practice, it is likely that in a human, forces on the head and neck would be less.

21. There was no evidence from the models deployed that there was a significant risk of direct thoracic injury from the jets, arising from body wall deflection. However, in a few of the instances when the dummy was displaced by the jet, high accelerations to the rear of the thorax were observed, as a result of impact with hard surfaces.

22. The application of the water jets to the ground resulted in the acceleration of small pieces of debris to a height that resulted in the risk of non-penetrating impact to standing and seated personnel. The principal risk was impact to the eye.

Overall assessment

23. The hazards identified in the trials have been reviewed in the context of the ACPO Guidance, and the information acquired from the literature survey. It is concluded that the use of the Somati RCV9000 Vehicle Mounted Water Cannon within the ACPO Guidance is unlikely to result in serious or life threatening injuries.

Recommendations

24. Any modifications to the vehicles relevant to the jet output or use of the jest, or any changes to the ACPO Guidance, should be reported promptly to DOMILL.

25. The output of the jest from the two remaining Somati vehicles should be determined prior to operational deployment and use.

26. The maintenance schedule and routine review of the suitability for service of the vehicles should include a check of the calibration of the water pressure sensors in conjunction with the control system.

27. The training syllabus for Water Cannon Commanders, Operators and Drivers should be reviewed by DOMILL to ensure that the medical risks of the use of the systems (declared in the ACPO guidance) are clear and understandable.

28. DOMILL should be advised immediately of any injuries specifically attributable to the operational use of the water cannon, or in training.

29. DOMILL request a joint report from ACPO, the Home Office and the Northern Ireland Office on the operational performance of the Somati water cannon, and the frequency and type of injuries directly or indirectly attributed to the water cannon. It is requested that this report is provided within one year of the formal acceptance of the first four Somati water cannon by PSNI.

Chairman, DSAC Sub-committee on the Medical Implications of Less Lethal Weapons 3rd March 2004

APPENDIX C Report of the CAST visit to Germany: 3rd-4th July

Summary
Members of CAST and the WC working Group visited Germany on 3rd and 4th July to see the German WaWe9 Water Cannon being offered to the UK. We were able to inspect and use the cannon and had full access to them. The Cannons are almost 25 years old but have been well maintained, they will be undergo a complete (6 week) service prior to any delivery to the UK . The age of the cannon does present some issues though. The Cannons do not have any exhaust emission equipment and are classed as 'Euro 0'. The emissions regulations for the UK require that vehicles entering London are to Euro 4 or above. The MPS mechanical team are investigating whether the cannon could be uprated and how much this would cost. If they cannot be uprated it may be that a temporary exemption could be arranged for them or daily charges could apply – this would also need investigation. Another age related issue is parts availability, whilst spare parts are available for the normal mechanical aspects of the cannon (engine, suspension, drive etc) the parts availability for the special fitments (water pump, pipe work, tank, external panels) is poor or non-existent and the Germans fabricate their own new parts where they are needed. An option may be to purchase an extra cannon to cannibalise for spares.

There are also issues which may affect the medical statement. There are no cameras mounted on the monitors (the roof mounted jets which fire the water). The PSNI cannon has cameras mounted on the monitors and these are used to assist with aiming the cannon as part of the bench mark assessment. The lack of cameras may therefore make the German cannon less easy to aim and to bring the cannon up to the same level as the PSNI cannon cameras and viewing screen for the operators would need to be retro fitted. The possibility of this is also being investigated by the MPS. We were also able to confirm that the output pressure of the cannon can be regulated so CAST would be able to use the benchmark data gathered from the PSNI cannon to set the German cannon to deliver similar pressures. This could be carried out in Germany or the UK.

Whilst the above issues are not insurmountable the cannons should not be seen as a long term solution. The full report will detail where the German Cannon meet the operational requirement and where they fall short, it is clear that they will not have the longevity to last beyond the envisaged interim requirement of approximately two years.

Technical Observations
Key technical observations are listed below and a detailed question and answer table is also attached at the Annex. This provides references to the technical and operational requirements where relevant.

- Without conducting the planned force and pressure data capture trials of the WaWe 9 it is not possible to make any definitive statement on pressure comparisons with the PSNI Somati RCV 9000. However, from the design of the pressure control apparatus we believe that it would be possible to adjust the output pressure to bring the WaWe9 in line with the pressures measured on the PSNI Cannon.

- The directional control system for the monitors on the WaWe9 appears to be more responsive and stable than the PSNI Cannon. The monitors however have no targeting system or camera system linked to the operators this may result in the initial targeting of a person being less accurate than the PSNI cannon. It should be noted that the each monitor can rotate through 270° providing a 360° coverage at two different speeds (2 gears). The minimum engagement distances are closer at the front than the sides and rear (jets hit the ground at 3.4m, 4.3m and 7.5m respectively).

- The vehicle has the ability to act as a pump unit to clear flooding, a clean water supply vehicle (once the tank has been sterilised) and has fire fighting capability including the addition of foam to the hand held hose (not the monitors). The jets from the monitors can apparently reach 40m in height.

- The underside of the vehicle has no protection and a large amount of cabling is exposed, this may be a risk to the vehicle if a petrol bomb is deployed under the vehicle.

- The windscreen is polycarbonate and needs to be protected from UV and cold when stored. In addition it can be come scratched and damaged. The replacement cost for this is estimated to be 4000 Euros with a lead time of 5 weeks.

- Although some sound and video recording capability is included it is likely to be old and in need of updating to be compatible with modern evidence gathering requirements.

[In the following table, the column titled 'Link to WC-TR' indicates how each of the listed questions and answers relate to the Home Office technical requirements for an interim water cannon capability.]

Annex to CAST report

Question	Response	Link to WC-TR
Are there full service and maintenance records available?	The MPS are dealing with this, but the Germans do have a full service history for the vehicles and are willing to share this.	n/a
Were there any independent (of manufacturers) tests carried out by the Germans to determine safety in use or output pressures?	Tests were carried out in 1981 on the vehicles, but this was by the Ministry of the Interior and not the police. What was actually covered in the tests is unclear and the report is unavailable.	n/a
Are spare parts readily available?	No	n/a
What needs translation into English (instructions or pressure monitoring systems etc?)	Everything, speedometer needs mph markings.	n/a
What is the effective operational travelling distance of the water cannon on 1 tank of fuel?	Estimated to be 600km, fuel tank is a 300Ltr tank. The pump engine takes fuel from the same tank and uses between 25-30l/hr and the main engine takes 30-40l/hr when not driving	WC-TR-10 Meets the req
Can the spray from the monitors be adjusted to give different spray patterns (diffused, pulsed, continuous etc)?	No, the Germans have developed tactics which enable them to do pulse, spray etc by operator skill. The jet itself is continuous.	WC-TR-24 Does NOT meet Req
Can the pressures for each monitor be controlled independently?	Yes – max pressure is limited to 20bar, 16bar, 12bar, 8bar or 4bar from commanders seat, although apparently the pump could be run at 30bar. The speed of the pump engine also affects the pressure. Each cannonier has control of the water from their monitor from 20% to 100% of commander set pressure.	WC-TR-23 Meets the req
What is the maximum pressure?	20 bar set by the commander. (system may be able to go to 30 bar)	WC-TR-23 Currently goes to 20 bar need to investigate potential to adjust
How are lower pressures obtained?	Solenoid values on output from pump.	WC-TR-23 Meets the req

Are there outlets other than the main two monitors?	Firehouse outlet, rear monitor at ground level, high pressure water jets on windows (to clear obscurants), sprinkler system on vehicle.	N/A
How are the monitors controlled – does this still function adequately? Is there an aiming system and if so how does it work?	Controlled via joysticks, on the two vehicles examined the systems were fully functional. Note, seats rotate with monitors, all worked. There was no camera on the monitors and operators rely on skill and experience to accurately place the jets.	N/A
What are the minimum and maximum distances the water cannon is effective over?	3.4m at front, 4.3m at side, 7.5m at rear (to hit ground) to approx 60m (according to operators). As the jet is fired from above persons closer than 3.4m could be targeted higher up on their bodies.	WC-TR-26 Meets the req
Can the water cannon be refilled from an open water source and, if yes, does it have a filter on the inlet to prevent debris from entering the water tank?	Yes, filter attachable to hose, vehicles also have a mesh basket which can go round end of hose. Filter has approximately 5mm holes	WC-TR-31 Meets the req WC-TR-32 Meets the req
Is everything compatible (GER vs. GB) regarding filling of the WC tank with water (threads, pipe diameters etc)?	Needs to be determined. – will be checked by MPS/LFB	WC-TR-30 The WC is refillable from hydrant, however unknown if connections on current pipe work is suitable.
Is the water tank and pipe work resistant to the effects of salt water (rusting)	Water tank is alloy as is all pipe work, believed to be resistant to salt water.	WC-TR-33 Meets the req
Can additives be added to the water (eg foam, CS etc), can this be disabled/easily removed?	Yes, CS/CN already used by Germans. Foam attachment is available for hose pipe, but not monitors. CS/CN system could be easily removed	WC-TR-35 Meets the req
Does the water cannon have a public address system and if so, what is the quality (any tests assessments or standards?)	Yes, functionality demonstrated, not formally tested. Two speakers to front and two to rear. The PA can be operated remotely.	WC-TR-37 Not technically tested only functional

Does the water cannon have the ability to project pre recorded messages?	Apparently, but not tested.	WC-TR-38 Meets the req WC-TR-39 Meets the req
Does the water cannon have a audible reversing warning?	Yes, and rear camera.	WC-TR-40 Functional tested not technical
Does the water cannon have any facility to record/log actions, if yes what are these?	Not automatically, one seat is for a loggist/recorder.	WC-TR-43 Does NOT meet the Req
Does the water cannon have any CCTV capability and recording capability, if yes what is this (media type, standards, age etc.)?	It has a capability – simple sony camcorder with recording to a number of hard discs, however this system is old and unsure if it is functioning. There are no cameras on the Monitors	WC-TR-45 Does NOT meet the Req WC-TR-46 Does NOT meet the Req
Does the water cannon have a water heater to ensure the water does not freeze?	Yes (needs checking), heating is delivered by a liquid fuel jet heater, it will need further investigation as to how it operates.	WC-TR-51 tbd
Are the doors internally lockable, are there external handles?	Doors are internally lockable and they have external handles	WC-TR-51 Does NOT meet the Req
Are the tyres resistant to fire?	Standard tyres so unlikely	WC-TR-57 Does NOT meet the Req
Are the tyre run flat?	yes	WC-TR-51 Meets the req
Is the cabin equipped with any air conditioning or air filtration system?	Cabin has A/C however it is limited in size and only functions when engine is running. It was very hot in the cabin during the testing and the air-conditioning was running. Although the vehicle was originally air tight with filters the seals to the doors are now perished or ill fitting so the seals cannot be relied upon.	WC-TR-61 tbd WC-TR-59 tbd
Does the water cannon have a system for extinguishing fires on the external surfaces of the vehicle, how does this operate? Is there a method to deal with fires under the vehicle or in the engine bay?	External extinguishing system. No system, for extinguishing fires in the engine bay or under the vehicle. Also the vehicle has no under-body protection which would leave wiring etc vulnerable to a petrol bomb attack.	WC-TR-63 Meets the req Not for under body
Is there a method for removing obscurants such as paint from the windows?	High pressure water jets and large wipers on front screen. Jets alone on the side screens. Do not know how effective they are.	WC-TR-62 Meets the req

What is the maximum speed of the water cannon?	Approximately 85km/hr (52mph)	WC-TR-66 Does not meet the req
How long does it take to prepare the water cannon for operational usage?	Approximately 15mins to fill. Apart from pre vehicle checks not aware of anything else that needs to be done prior to deployment.	WC-TR-71 tbd
Do the water jets/pump run off their own power source/engine, is there a separate tank?	Yes the pump has its own engine in the rear of the vehicle. Draws fuel from the same tank as the main engine.	WC-TR-73 Part meets the req
Does the water cannon have points to enable it to be towed? If yes where are they?	Yes, front and rear	WC-TR-74 Meets the req
Does the water fill system have a one way valve to prevent water from the tank entering the water supply network?	Yes (not seen or checked)	WC-TR-77 tbd
Does the water cannon have any ballistic protection?	No	WC-TR-60 Does NOT meet the req
Does the water cannon have any protection against public order threats, e.g. bricks, etc being thrown at the windows?	All windows are polycarbonate, lights are covered by polycarbonate panels. Front polycarbonate screen is still available as a part (£4000)	N/A
Apart from engine power, what are the differences between the 2628 and 2629 WaWe9 vehicles?	None (solenoids for control of pressure appear to be different but these could be retro fitted replacements, needs checking)	N/A
What methods are incorporated to prevent protesters climbing on the vehicle?	Steps are covered by doors, not many foot holds on outside of vehicle.	WC-TR-56 Part meets the req
Is there a toilet facility on board?	No	N/A
Are there auxiliary power supplies in the cab or on the exterior – what are their outputs?	No, appears to be 24Vdc charging connection inside cab by commanders foot well. All power is 24V.	N/A
Are there mounting points on the exterior of the cannon (roof) for auxiliary equipment?	None seen	N/A
Is there a calibration regime for the pressure sensors on the Water Cannon?	No	N/A

How has the stability of the Water Cannon been tested when travelling at speed?	No evidence given but informed vehicles are more stable if you travel with 3000l of water in tank or a full tank.	WC-TR-79 Part meets the req
Is it possible to drain the water tank/pipe work manually and if so how long does it take to empty it?	Yes, unknown how long.	N/A
How is it recommended that the vehicle blind spots are controlled during operation of the vehicle?	Each cannon has the ability to rotate through 270° covering most points, plus rear monitor mounted under rear bumper. The cannons can be rotated at a slow or fast rate (2 gear settings).	N/A
What is the recommended maintenance regime of the water delivery system?	MPS to investigate	N/A
How is the tank cleaned?	Tank can be sterilised if required, no particular cleaning regime defined. It can be use for potable water.	N/A
Is there a start-up pulse on the jets?	Not tested but not obviously apparent, will need investigating	N/A
Is any of the monitor direction control system exposed?	Yes, visible on top of vehicle, but this is 4m plus high.	N/A
Is there an intercom from outside the vehicle to the cab	Yes there are external microphones, would probably need upgrading.	N/A

APPENDIX D Proposed methodology for testing of German Water Cannon

[This is V0.1 of document supplied to Dstl from CAST. The author is <redacted> *and the document is dated 2nd July 2013.]*

This document gives a brief overview of the proposed testing regime that will be used to gather data to support the evidence presented to SACMILL. The data will directly compare the contact forces and pressures of the PSNI water cannon to the German Water Cannon.

Due to difficulties in gathering data due to the accuracy and control of the monitors on the water cannon and with the capabilities of the pressure mat system, it has been decided to use an alternative approach to gather data from any future testing.

It will be possible to still compare this data with the testing performed on the PSNI water cannon, although if required additional data will be collected.

Testing protocol

Measurement of force using force rig

Using the force rig measurements will be taken on the 400mm and 200mm diameter plates. With both of these plates we have confidence that we will be able to target them accurately to get a good force reading. Targeting of the 100, 50 and 25mm plates is very difficult and I do not have the confidence that any readings from these plates will be accurate and provide the peak force.

Each test conducted will be repeated three times for approximately 10 seconds to ensure we get a good data set.

From this data set the peak average force will be determined. A 2khz low pass filter will be used to remove unwanted noise in the signal. (This will be applied using a FFT filter) The data will be sampled at 20kHz using a 24bit adc.

Measurement using the force mat

The force mat will be used to gather the remaining data. Using the mat we are able to identify the peak force and pressure applied during any test. In addition we can measure the applied force and pressure over a 100, 50 and 25 mm diameter area.

Additionally we will be able to collect the peak and average contact area of the spray.

Data will be collected at a rate of 25Hz for a 30 second period.[14] Each run will be repeated 3 times.

In addition we will also have to use the pressure mat to measure the output on the rear monitor due to its positioning.

[14] 25 Hz is the multiplexing frequency of the force plate elements.

APPENDIX E National Police Public Order Training Curriculum Module

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RESTRICTED operational material

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APPENDIX F MPS Public Order Command Structure

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16a. Abstract:

This report has been prepared for the purpose of providing SACMILL with sufficient evidence to enable the committee to produce an interim medical statement on a new water cannon system (the Ziegler WaWe 9). The present review has addressed all aspects of water cannon use that have the potential to influence the medical implications surrounding operational use of water cannon. These aspects include what is currently known about the two WaWe 9 water cannon vehicles under consideration and how they compare with the Somati RCV 9000 water cannon currently in-service in Northern Ireland. Medically relevant evidence from operational use of water cannon in Northern Ireland and elsewhere has been sought and assessed, as has the medical literature concerning the effects of high pressure water jets on the body. No clinical case reports concerning injuries sustained specifically from use of water cannon in civil disorder were found in the peer-reviewed literature, although there is good evidence from other sources to indicate that serious injuries have been sustained by people subjected to the force of water cannon jets. No novel mechanisms of injury from high pressure water jets were found over and above those already identified and considered in earlier reviews by Dstl. The eyes appear to be particularly vulnerable to impact from high pressure jets, and limited (but dramatic) evidence for this emerged during public disorder in Germany in 2010, where one individual sustained major ocular trauma from the force of a water cannon jet. The ability of water cannon jets to topple a person has been evidenced during water cannon use in Turkey and, very recently, in Northern Ireland. Such an effect of the water cannon jets has the potential to lead to serious medical outcomes. Documentation relating to User Guidance and Training around UK use of water cannon in serious disorder has been reviewed, and it is evident that work needs to be done to make this documentation applicable to the WaWe 9 system (it currently addresses only those aspects of the Somati RCV 9000 system). Specific areas of concern are brought out in the recommendations made as a result of the present review. Similarly, there is currently limited technical information on the WaWe 9 vehicles, and this lack of detail is reflected in the recommendations made in this report.

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