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„Geographic Information Systems in Disasters“

Developing a User-friendly GIS Framework in the WASH Sector

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Philipp Polanski

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Abbreviations

DM	Disaster Management
GIS	Geographic Information System
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
GUI	Graphical User Interface
GWC	Global WASH Cluster
IASC	Inter-Agency Standing Committee
IFRC	International Federation of Red Cross and Red Crescent Societies
IM	Information Management
(I)NGO	(International) Non-governmental Organisation
OS	Operating System
OSM	OpenStreetMap
SOP	Standard Operating Procedure
(UN) OCHA	(United Nations) Office for the Coordination of Humanitarian Affairs
WASH	Water, Sanitation and Hygiene

Abstract

The research of this diploma thesis explores user-friendly approaches for utilising and institutionalising *Geographic Information Systems (GIS)* in humanitarian emergency response. In the focus are basic GIS capabilities, tools and applications to support emergency responders and agency coordination in the *Water, Sanitation and Hygiene (WASH)* sector. An emphasis is placed on analysing workable solutions for the field taking into consideration aspects of hardware, software, data and people (users and management). Two research questions are examined drawing attention to broader aspects of using GIS as well as technical issues such as hardware and software selection: What are the requirements of a GIS framework for the WASH sector that can be deployed from small to large scale disaster response operations and integrated into other GIS? Which technological options are available that can be utilised to set up a GIS in the field meeting both demands on and of the user?

The thesis elaborates a view on GIS claiming its main pillars hardware, software, data and people to be integral and relating. It is argued that an approach towards developing a user-friendly GIS framework in the WASH sector can only be successful if it is twofold: On the one hand user demand driven, because that is where critical data is generated and needed in the first place; and on the other hand, implementing policy decisions that aim at standards for all sectors of humanitarian emergency response. The research is based on a combination of literature/document reviews, analysis of existing GIS guidelines/systems, hardware and software tests, and interviews with selected WASH and *Disaster Management (DM)* personnel of different organisations.

It is concluded that a modular GIS approach with lighter and targeted applications can aid *Information Management (IM)* in disasters in a better way and provides needed solutions for users at a level where these are lacking. But technology alone is not the solution – GIS will only unfold its potentials and benefits if its management is fully incorporated into DM. This involves e.g. that GIS is constantly developed through lessons learnt in the field or changes in the environment of GIS and IM in emergency response operations, and is based on standards, clear operating procedures and trainings.

Kurzfassung

Die vorliegende Diplomarbeit beschäftigt sich mit benutzerfreundlichen Anwendungen *Geographischer Informationssysteme (GIS)* in der humanitären Katastrophenhilfe und untersucht Ansätze zu deren Institutionalisierung. Im Mittelpunkt stehen grundlegende GIS Funktionen mit einfachen Werkzeugen für den Bereich *Water, Sanitation and Hygiene (WASH)* zur Unterstützung der Koordinierung von Organisationen wie der Arbeit ihres Personals im Einsatzgebiet. Der Forschungsschwerpunkt liegt dabei in der Analyse praktischer Anwendungen mit Bezug auf die zentralen Bestandteile eines GIS: Hardware, Software, Daten und BenutzerInnen sowie das Management dieser Komponenten. Die untersuchten Forschungsfragen lauten: Was sind die Anforderungen an ein GIS-Framework im WASH Sektor das in klein wie groß angelegten Katastropheneinsätzen eingesetzt werden kann und gleichzeitig in andere GIS integrierbar ist? Welche technologischen Möglichkeiten stehen für GIS Anwendungen zur Verfügung und entsprechen sowohl den Anforderungen an die AnwenderInnen wie auch ihren Bedürfnissen?

Der in der Arbeit verfolgte Ansatz begreift die elementaren GIS Bestandteile Hardware, Software, Daten und NutzerInnen als integral und zueinander in wechselseitiger Beziehung stehend. Es wird argumentiert, dass Ansätze zur Entwicklung eines benutzerfreundlichen GIS-Frameworks im Bereich WASH nur dann erfolgreich sein können, wenn sie zwei Bedingungen erfüllen: Erstens, dass sie sich an den Bedürfnissen der AnwenderInnen orientieren, da gerade sie kritische Daten generieren und als erstes benötigen; zweitens, dass sie sich auf Richtlinien beziehen, welche auf übergreifende Standards für alle Bereiche humanitärer Katastrophenhilfe abzielen. Die Forschungsarbeit basiert auf einer Kombination aus Literatur-/Dokumentenrecherche, Analyse bestehender GIS und Richtlinien, Hardware- und Softwaretests und Interviews mit ausgewählten MitarbeiterInnen verschiedener Organisationen in den Bereichen WASH und *Disaster Management (DM)*.

Aus den Forschungsergebnissen folgt, dass ein modularer GIS Ansatz mit weniger anspruchsvollen aber zielgerichteten Anwendungen das *Informationsmanagement (IM)* in Katastrophen besser unterstützen kann und für die BenutzerInnen jene benötigten Problemlösungen bereitstellt die anderweitig nicht vorhanden sind. Jedoch sind die zur Verfügung stehenden Technologien nur ein Teil der Lösung – Es wird darauf ankommen, das Management von GIS gänzlich im DM zu verankern, um dessen Potentiale und Nutzen zu entfalten. Dies involviert beispielsweise, dass GIS durch Anwendungserfahrungen in Katastrophensituationen oder bei Veränderungen der Rahmenbedingungen (für GIS und IM) kontinuierlich weiterentwickelt wird, und auf Standards, klaren Einsatzabläufen und Trainings aufbaut.

Preface

The idea for the topic of this diploma thesis has come a long way. It developed gradually over the past five years out of my interest in geospatial technologies spurred by studying geography, my involvement with the *Emergency Response Unit 'Water and Sanitation'* as an Austrian Red Cross volunteer (including GPS and GIS trainings) and probably a general map fetish too. Also, I have always been looking for ways to combine what I picked up at university with applications to be used in everyday life. *Geographic Information Systems* have definitely developed great potentials in this regard. The past few years have brought remarkable advancements, changing my mind on its usability for the majority of people working in emergency response. I clearly remember my first GPS and GIS experiments during disaster response exercises, and struggling with geo-referencing photographed topographic maps, getting coordinates from different teams, program crashes when the GPS device was plugged into the computer and so on.

The suspicion arose that by using more than basic satellite navigation in emergency response operations, just another world of problems would be imposed on people, leading to excessive demands, frustration and less time for their main tasks. However, since then (many) things have become a lot easier and it was time to see how new developments can implement GIS as a practical tool in disasters with more value and less burdens. To have this opportunity combined with a diploma thesis I want to express my gratitude and acknowledgements to a number of persons. First of all I would like to thank Andreas Riedl for supervising the thesis and his generous support in all aspects. Also I want to acknowledge and thank the interview respondents as well as numerous Red Cross volunteers for providing me with valuable feedback and lines of thoughts during GIS trainings and exercises. Last but not least my most sincere thanks go to my parents and family for simply making all of this possible.

Vienna, November 2012

1 Introduction

1.1 Background and Problem Statement

Continuing developments in *Geographic Information System (GIS)* software and related tools, especially geo-browsers, are opening up a number of possibilities for non-GIS professionals for capturing and processing geographical data (hereinafter called geo-data), and then sharing and presenting it via the internet. The ability to manage information on water and sanitation infrastructure and services has wide-ranging benefits for disaster response from initial assessments to long-term projects in the recovery phase. Given the varied international and national actors involved in humanitarian non-state disaster response (i.e. the research field of this thesis) not only active in the *Water, Sanitation and Hygiene (WASH)* sector and the fact that collecting and processing geo-data is not the primary task of relief workers, the importance of easy to use (as easy as it can get) and user friendly standardised GIS approaches becomes evident. So far mainly big relief operations like e.g. after the earthquake in Haiti in 2010, have been assisted and coordinated through GIS; although highly professional operated by GIS units, specific sector work like WASH demanded its own appropriate solutions and depended mainly on the capabilities of some experienced field staff. These smaller and more flexible GIS solutions centred on the application range of the digital globe geo-browser *Google Earth* as the main user interface. Those won't be able to carry out high-level analytical tasks, but most people neither need nor want that level of functionality for supporting their work in the field.

While technological solutions for everyone are made available, the potential of their application in emergency response remains largely unexploited in the absence of a framework that promotes guidelines for collecting, processing and sharing geographic information and facilitates its sector wide/intra-sectorial/intra-organisational use. So far several organisations, agencies and stakeholders in the field of WASH have developed their own approaches and tools for managing information and handling, disseminating geo-data. These reflect to a large degree their specific tasks and responsibilities and/or are aiming at generating general geo-referenced information for providing an overview like e.g. *Who, What, Where (3W)* maps.

It can be considered that these existing solutions mark an important step towards mainstreaming GIS in disaster response but do not necessarily reflect all levels and areas of WASH interventions, i.e. they don't cover day to day field work. This means that solutions are lacking at a level where data collection and sharing is most likely to happen and needed. Furthermore, the use of GIS as part of disaster response is often limited to the resources of specialists in the field, which in turn are not made available for the majority of disasters, i.e. small to medium scale disasters. Hence, the challenge is to bring together the specific needs of WASH field work for GIS tools with portable user adapted solutions in a framework that enables interoperability and further development of GIS approaches to close the gaps of sophisticated ad hoc GIS add-ons with limited geographical, temporal and organisational availability. In this sense, the research of the thesis focusses on combining GIS solutions already in place and lessons learnt.

1.2 Research Questions

The thesis will examine two research questions that are regarded central for the context of humanitarian disaster relief in the area of WASH. The first question draws attention to broader aspects of using GIS, while the second one addresses the difficult choices for hardware and especially software selection. Still, both questions relate to each other in several ways.

- What are the requirements of a GIS framework for the WASH sector that can be deployed from small to large scale disaster response operations and integrated into other GIS?
- Which technological options are available that can be utilised to set up a GIS in the field meeting both demands on and of the user?

1.3 State of the Art

As humanitarian disaster response experienced professionalization, over the last years a substantive body of literature on *Information Management (IM)* systems and the use of new information technologies in disaster response have been developed. Several academic publications regularly touch on the topic of GIS in this context. Although GIS receives fairly good attention, the actual implementation of GIS as part of humanitarian relief operations remains a relatively new but growing field of academic research. This is indicated by recent reports titled like e.g. *Disaster Relief 2.0: The Future of Information Sharing in Humanitarian Emergencies*, published 2011 by the Harvard Humanitarian Initiative in collaboration with United Nations (UN) affiliates, which at the same time highlights the need for further research in this regard, particularly with respect to the WASH sector [HHI-11].

The coordinating bodies in humanitarian disaster response (under the leadership of UN agencies) and responsible for information management including GIS, so far established a compelling number of documents aiming at an overarching GIS framework. These relevant sources reach from e.g. the Inter-Agency Standing Committee's (IASC) *Guidelines on Common Operational Datasets in Disaster Preparedness and Response* [IAS-10] to e.g. map production guidelines, styles, templates and symbology collected by the United Nations Geographical Information Working Group (UNGIWG) covering a wide range of aspects that relate to the topic of the thesis. Additionally, several organisations have published information on, and their experience with GIS tools and approaches used. A good example might be MapAction's *Field Guide to Humanitarian Mapping* [MAP-11], which is a comprehensive manual to selecting and using free, open source GIS and other software for humanitarian operations. Nevertheless, the topic of the thesis has been explored fairly scientifically in terms of relating GIS not primarily to selected aspects like software or potential applications, but exploring a comprehensive view on GIS.

1.4 Own Theoretical Position – Defining GIS

Depending on the context the term “GIS” can have different meanings. As just mentioned, it may be used to refer to software (and hardware) as an overall system for handling geo-data. The term might also relate to a specific application, for example a spatial database. Last but not least GIS can be considered to be a science (geographic information science), the field of study concerned with all kinds of aspects in working with spatial data. However, in this work the acronym GIS will only be used for “Geographic Information System”. Among the many definitions of GIS there is great accordance regarding its main functionalities, which did not alter over time. With Aronoff [ARO-89] a GIS can be defined as follows:

A GIS is a computer-based system that provides the following four sets of capabilities to handle geo-referenced data:

- *input,*
- *data management (data storage and retrieval),*
- *manipulation and analysis, and*
- *output.*

Based on these characteristics, the thesis will elaborate a view on GIS emphasising its main pillars hardware, software, data and people as integral and relating. While hardware, software and data are standard components of describing GIS, people often tend to get overlooked or seem too obvious to receive notion. A well-known finding from decades of organisational GIS development is, that a GIS cannot be bought or imported, it must be built. This process requires time, involves training of the users and an implementation strategy on management level. While the early days (dating back almost 50 years) of GIS were characterised by overcoming technical problems, today mainly non-technical aspects became the bottleneck for making GIS work. Spatial data becomes increasingly available for everyone with internet access and new software applications have been developed to provide GIS functionalities to users with no specific background in this area. In the light of these developments a whole new application range for using GIS in disaster response that builds on user created contents open up. At the same time this points out the importance of a user adapted GIS environment to exploit their potentials.

The following work is based on the view that an approach towards developing a user-friendly GIS framework in the WASH sector can only be successful if it is twofold:

- user demand driven, because that is where the data ends up, is generated and needed in the first place, and
- implementing policy decisions that aim at a standardised framework covering all sectors of humanitarian emergency response.

1.5 Scope and Aims

The thesis is designed to be practical – language, structure and content wise – and aims at

- introducing to the context of using GIS in disaster response, specifically in the area of WASH,
- identifying existing guidelines for a GIS framework within the world of humanitarian organisations,
- examining the requirements for such a framework considering hardware, software, data and people (users and management),
- exploring the potential of digital globe based geo-browsers as user friendly interface options, and
- providing an overview of workable solutions to issues regarding hardware, software, data and people with low barriers to implement and based on field experience.

The intended audience is therefore management personnel within the respective organisations as well as those in the WASH sector in charge of IM or interested in applying GIS. The thesis' findings are not meant to be exhaustive and are best perceived as current relevant extracts from a broad field of possibilities, as a starting point for work in progress, i.e. the implementation and operation of a GIS. Overall, they shall foster further examination – may it be scientific or not – and contribute to on-going attempts of improving humanitarian action in disasters.

1.6 Methodology

The research for this thesis is based on a combination of literature/document reviews, analysis of existing GIS guidelines/systems, hardware and software tests and interviews with selected WASH and Disaster Management (DM) personnel (see the interview questions and list of interviewed persons in *Appendix 8.1*). The different approaches can be summarised as follows:

- Review of academic literature on GIS for disaster relief operations
- Analysis of relevant reports, documents and references of UN agencies, organisations and humanitarian bodies
- Tests of various hardware and software applications, also during field deployments and GIS trainings with Red Cross/Red Crescent volunteers
- Interviews with WASH and DM focal points of the International Federation of Red Cross and Red Crescent Societies (IFRC)/Austrian Red Cross to determine the use of GIS and organisational preconditions for implementing a GIS
- Interviews with selected WASH field personnel experienced with GIS tools in varying degrees to determine requirements and the feasibility of adapted solutions

1.7 Overview

The next chapter will give an overview of WASH and IM in the context of humanitarian disaster response and introduce to organisational and structural aspects for mainstreaming GIS in this regard. *Chapter 3* then provides an analysis of the requirements and preconditions of a GIS framework in the WASH sector. Afterwards, required hardware and user-friendly software are discussed and presented in *Chapter 4*. *Chapter 5* follows with considerations on data standards and sources; guiding standardisation approaches will be depicted and the range of both available and accessible data will be dealt with. Also selected user adapted applications for collecting, processing and sharing geo-data in the field and implications for geo-browser based information dissemination with *Google Earth* are explored. *Chapter 6* finally draws attention to user and management issues of GIS, completing the examination of a GIS framework for the WASH sector – after covering hardware, software and data – with aspects related to the implementation of GIS in an organisation including trainings. *Chapter 7* concludes with a summary of the main findings, answering the research questions and a critical review.

2 Setting the Scene – WASH and Information Management in Disasters

At the beginning of the thesis' main part, central aspects of WASH and IM in disaster response operations will be outlined. They mark underlying implications that affect how a user-friendly GIS framework can be elaborated. The first part of this chapter provides a quick look at the main actors, their role in disaster response and introduces to the organisation of disaster response in global clusters. The focus however will be on what relates to WASH. Additionally, general structural and organisational aspects of disaster relief will be highlighted. The second part then delivers background information on IM in disasters, the ways of information dissemination and features approaches in place for the WASH cluster. It will take a look at important WASH IM tools and how GIS is used.

2.1 WASH in the Context of Humanitarian Emergency Response

Disaster response or emergency response (an equal common term in the disaster[1] context) of the international humanitarian community has undergone some major changes in the last decades, even years. Spurred by discovered gaps and shortcomings in humanitarian response to disasters, in 2005 a response review of the global humanitarian system has been launched. A key element of the following reform process − facilitated through the IASC, the primary mechanism for inter-agency coordination of humanitarian assistance involving key UN and non-UN humanitarian partners − was the newly developed *Cluster Approach*.

This approach aims to strengthen the overall response capacity as well as the effectiveness of response efforts. The main areas of emergency interventions have been grouped into eleven clusters with designated global cluster leads (see *Figure 1*). For WASH, the United Nations Children's Fund (UNICEF) is acting as the global lead agency. The main responsibility of the global cluster leads in their respective sector of work covers:

- Standards and policy setting
- Building response capacity
- Operational support

[1] The term "disaster" in this work is used for all natural and man-made disasters, which include for example complex emergencies. In this sense and also for the purpose of this thesis no differentiation is being made between disaster and emergency response. E.g. the IFRC defines a disaster as a "sudden, calamitous event that seriously disrupts the functioning of a community or society and causes human, material, and economic or environmental losses that exceed the community's or society's ability to cope using its own resources. Though often caused by nature, disasters can have human origins" (http://www.ifrc.org/en/what-we-do/disaster-management/about-disasters/definition-of-hazard/).

Source: OCHA

Figure 1: The cluster system

Each cluster brings together a great variety of humanitarian organisations (UN and non-UN) and creates partnerships between them as well as national and local authorities, and civil society. They provide an open platform and a clear point of contact for emergency actors throughout the full DM cycle of disaster prevention, mitigation, preparedness, response, recovery and reconstruction as pictured above (*Figure 1*).

The main partners of the WASH cluster at a global level are (see also the section of the Global WASH Cluster (GWC) on the *OneResponse* website):

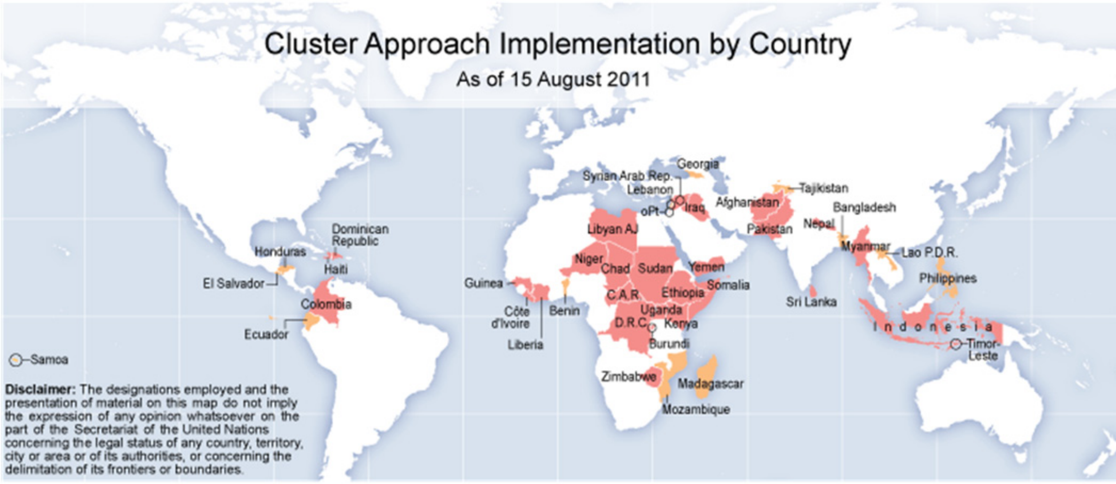
- Action Contre la Faim (ACF)
- CARE
- Center for Disease Control (CDC)
- Concern
- Catholic Relief Services (CRS)
- InterAction
- International Centre for Health and Migration (ICHM)
- IFRC
- International Medical Corps (IMC Worldwide)
- International Rescue Committee (IRC)

- Islamic Relief
- Medair
- Mentor Initiative
- Mercy Corps
- Norwegian Church Aid (NCA)
- Oxfam GB
- RedR UK
- Save the Children UK
- Shelter Center
- Solidarite
- Swedish Civil Contingencies Agency (MSB)
- TearFund
- Terre des Hommes
- United Nations High Commissioner for Refugees (UNHCR)
- United Nations Relief and Works Agency for Palestine Refugees in the Near East (UNRWA)
- World Health Organisation (WHO)
- World Vision International (WVI)

At the country level, the main partners of the WASH cluster – besides (international) non-governmental organisations ((I)NGO) – include:

- Government ministries and/or departments as appropriate to WASH (e.g. water, public works, environment, health, planning or disaster coordination body)
- United Nations Office for the Coordination of Humanitarian Affairs (OCHA)
- Local WASH NGOs
- Other clusters, especially *Health*, *Education, Emergency Shelter* and *Camp Management and Coordination*.

These extensive listings of actors from the global to the local level highlight the importance of a coordinating mechanism for all stakeholders. In the whole cluster system coordination is one of OCHA's core functions next to policy, advocacy, humanitarian financing and IM. OCHA, as pointed out on its website, supports the coordination between clusters and works closely with the global cluster lead agencies and NGOs to coordinate inter-cluster issues, develop policies, disseminate operational guidance and organise field support. While the cluster structure on a global level is established permanently to strengthen system-wide preparedness and technical capacity, the implementation of the *Cluster Approach* on a country level (to ensure a more coherent and effective response) is limited to certain conditions. It is designed to only get activated in case of clear humanitarian needs within a sector, when there are numerous actors within sectors and when national authorities need coordination support (see also the website of *OCHA* and *OneResponse* for further details and references). *Figure 2* below shows the latest available status of its implementation by country. It should be noted that not all clusters are currently active in the listed countries. Depending on the needs, national clusters are only activated in response to new or on-going emergencies.



Humanitarian Coordinator (HC) Countries

Afghanistan	7 August 2008	Myanmar	6 May 2008
Burundi	18 November 2008	Nepal	1 October 2008
Central African Republic	23 July 2007	Niger	5 March 2010
Chad	11 July 2007	occupied Palestinian territory	9 February 2009
Colombia	Early 2006 (IASC Pilot Country)	Pakistan	October 2005/3 July 2007
Côte d'Ivoire	27 February 2008	Philippines	5 January 2007
Democratic Republic of the Congo	Early 2006 (IASC Pilot Country)	Somalia	Early 2006 (IASC Pilot Country)
Dominican Republic	*November 2007/February 2010	Sri Lanka	9 January 2009
Ethiopia	1 May 2007	Sudan (Darfur)	14 January 2009
Guinea	25 February 2008	Sudan (South)	10 October 2010
Haiti	23 September 2008	Syrian Arab Republic	Not formalized
Indonesia	*May 2006 (Yog earthquake/Sumatra 09)	Timor-Leste	31 March 2009
Iraq	22 September 2008	Uganda	Early 2006 (IASC Pilot Country)
Kenya	*10 January 2008/August 2011	Yemen	17 February 2010
Liberia	Early 2006 (IASC Pilot Country)	Zimbabwe	25 Febraury 2008
Libyan Arab Jamahiriya	12 April 2011		

Resident Coordinator (RC) Countries

Bangladesh (2007 Cyclone Sidr)	26 November 2007
Benin	29 October 2010
Ecuador	25 February 2008
El Salvador	20 November 2009
Georgia	18 September 2008
Honduras (2008 tropical depression)	26 October 2008
Lao PDR	November 2009
Lebanon	July 2006
Madagascar (2007 floods)	1 May 2007
Mozambique (2007 and 2008 floods)	14 February 2007
Tajikistan (2008 cold-weather crisis)	27 February 2007
Samoa (tsunami)	October 2009

The cluster approach has been implemented in the countries listed above. However, not all clusters are currently active in all countries.

* Reflects Cluster Approach activation for different emergencies.

Source: OneResponse

Figure 2: Cluster approach implementation by country (as of 15 August 2011)

Hence, in many disasters WASH interventions are not coordinated through a country cluster. In general, the GWC strategy aims at mainstreaming the cluster based partnership approach, i.e. its incorporation into everyday business practices of all WASH stakeholders regardless of the context [GWC-11]. Either way, coordination among multiple WASH stakeholders and a shortfall in human and financial resources dedicated to preparedness and response remain basic challenges, as does the IM nexus as such [ibid.]. As Tupper [TUP-08] argues, inadequate information and coordination are common elements of humanitarian action problems, which have their roots in conditions that prevail long before the onset of many disasters. And rarely – once emergency response is under way – these are not further aggravated by a plethora of possible difficulties ranging from logistic obstacles and poor or non-existent infrastructure to environmentally hostile and insecure locations.

In a nutshell, these are relevant surroundings of WASH field work which comprises of *hygiene promotion, water supply, excreta disposal, vector control, solid waste management and drainage*. As disasters and disaster relief create a unique situation, focus, duration and operational support of WASH responses vary extensively. The global cluster system and the WASH cluster strive to deliver standardised tools and support services to the field that reflect these differences.

2.2 Information Management in the WASH Cluster

"Without information sharing there can be no coordination. If we are not talking to each other and sharing information then we go back 30 years." [HHI-11, interview with United Nations Disaster Assessment and Coordination (UNDAC) staff]

Internet communications have been a prerequisite for modern-day IM tools used in disasters. Although being "disconnected" is still a reality in some field operations, the problems are shifting to non-technical IM issues: the quality and quantity of information or simply how which information is shared [HHI-11]. Two main factors have contributed to this development [ibid.]:

- Increased expectations of what should be known in response operations
- Communications and information flows are growing more complex at a faster rate than current tools and practices can handle – especially in major disasters

Formally OCHA, together with the sector cluster leads, are tasked with IM (*Figure 1*). But in practice, the clusters often do not have the resources to perform work beyond their own analysis and to devote time and assets for coordination with OCHA [HHI-11]. Another issue is, that clusters tend to manage information in a way that is best for their own immediate needs, but not for the overall system respectively single stakeholders [ibid.]. It should be noticed, that a cluster's primary task is to facilitate coordination among the stakeholders within a sector and to ensure that needs are met rather than to carry out data collection for specific operational tasks of individual organisations. The individual ways of data collection and sharing by emergency response teams of different organisations often lead to a large amount of unstructured and fragmented data. Filtering, retrieving and verifying relevant data then becomes either a time consuming task or is frequently replaced with own assessments – a duplication of efforts. These IM issues are well known for a long time and are addressed in the WASH sector by the GWC through the promotion of a set of core IM tools which feature GIS compatibility. They have been developed by the GWC together with key stakeholders of the cluster with the intention to be further developed and refined based upon the experience gained from using them in the field [GWC-08].

The *Global WASH IM Tools* have been made available for free download through the GWC website on *OneResponse*, including a handbook describing the tools usage. As outlined detailed in the handbook [GWC-08], they consist of the following components which features are described below:

- **Multi-sector Initial Rapid Assessment (MIRA)**

  The MIRA is an assessment strategy and toolkit (spread sheet questionnaire) developed by the *WASH, Health and Nutrition Clusters* for the collection of needs related information in the early days of a disaster by generalist enumerators. It is designed to determine priority areas and assist in the planning and deployment of resources.

- **Survey tool**

  A catalogue (in the form of a *Microsoft Access* database) of WASH related indicators which produce tailored assessment checklists (data entry spread sheets) to be used by WASH sector specialists for field surveys. WASH subsectors are evaluated using a "traffic light" system of categorising areas ranging from good or not affected (green) over moderate (yellow, orange) to severely problematic (red).

  The WASH survey tool produces three types of tools for assessments/monitoring:

  - Rapid Assessment Tool (RAT)
  - Comprehensive Assessment Tool (CAT)
  - Monitoring Tool

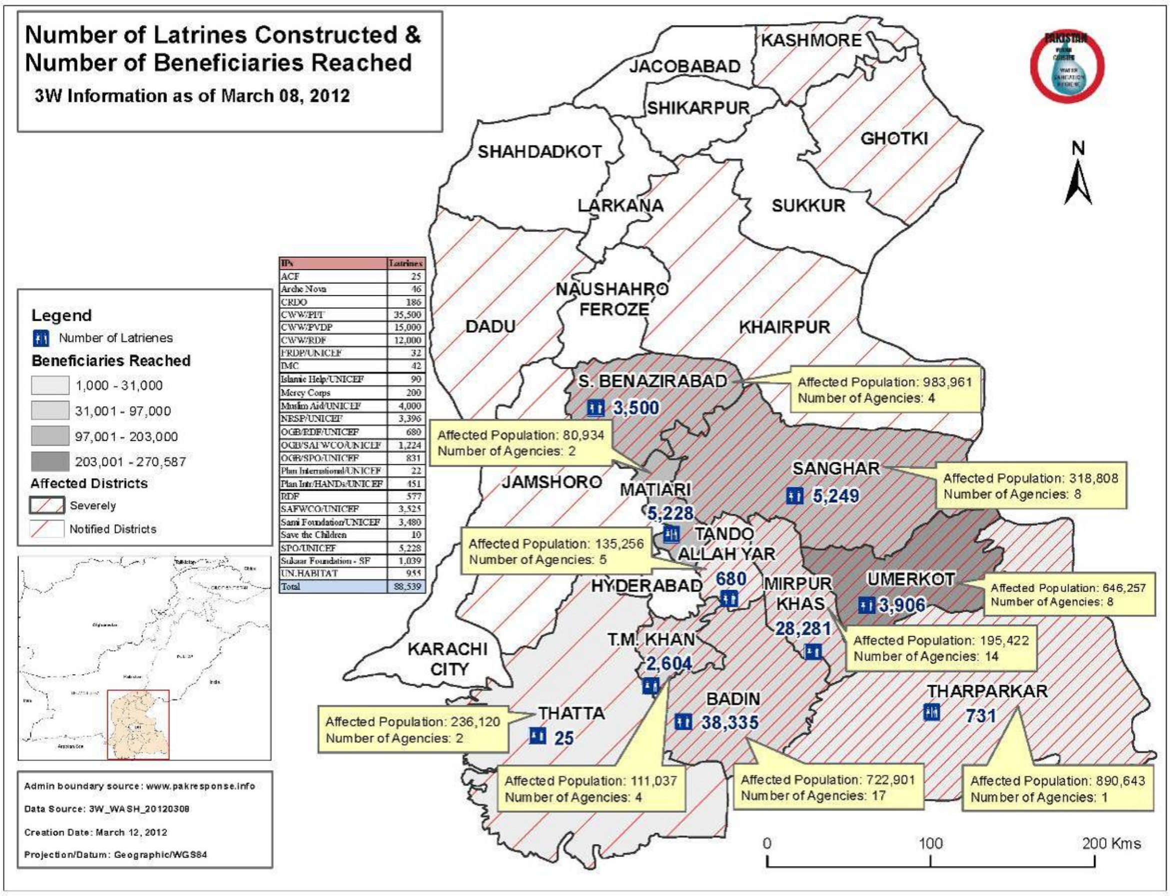
- **Who, What, Where and When (4W) Agency Reporting Template**

  A spread sheet template in which operational agencies report project locations, WASH subsector of activity, number of beneficiaries and the project time frame. This is the central tool for agency coordination.

- **Data tool**

  A *Microsoft Access* database which compiles data collected from all the tools above. It is intended for IM managers working on behalf of the cluster and produces standard reports detailing the priorities, progress on filling needs and gaps in the WASH response and facilitates the creation of maps with professional GIS software.

The data produced with these IM tools is aggregated by administrative units (states, regions, districts, etc.) of the disaster affected area and used to provide information for coordinating purposes to WASH stakeholders, other clusters and DM coordinators. Maps are a core IM output; an example produced by the WASH cluster in Pakistan during the *Monsoon 2011 Operation* is shown in *Figure 3* on the next page. The information displayed with maps typically features situational overviews regarding central operational aspects such as *Who is doing what, where and for which period of time?* or *Where are gaps in the response and which needs have not been covered?;* also, maps are used to monitor the progress of a WASH response. In general, they highlight what can be considered the most important information for decision makers who are managing or planning an emergency response.



Source: Pakistan WASH Cluster

Figure 3: Example of a WASH cluster 3W map (Pakistan, *Monsoon 2011 Operation*)

Maps and other WASH IM products (e.g. reports, key documents or contact details of field staff from the various organisations) are distributed through the cluster on the spot. Usually they are also made available online and free accessibly through the WASH cluster's website and other web based platforms for disaster related information dissemination, e.g. *ReliefWeb*. Depending on the resources of the WASH cluster, map production and provision of geo-data is done by GIS specialists who work for the cluster or by supporting GIS units deployed by OCHA [GWC-09]. Additionally, since a couple of years GIS NGOs are offering their services for humanitarian emergency response, having also provided GIS support to the WASH sector.

The three most notable GIS NGOs providing operational and emergency mapping support are:

- CartONG (http://cartong.org)
- GISCorps (http://www.giscorps.org)
- MapAction (http://www.mapaction.org)

Over the years, *CartONG*, *GISCorps* and *MapAction* have been active in several disaster assessments and bigger relief operations providing mapping, map making and GIS training services to the clusters and OCHA. Like the IM staff of the cluster system, they are experts in their field, operating professional GIS systems and offering specialised services. Albeit these GIS specialists present invaluable support in emergencies, their resources – if available – are hardly sufficient to be provided long-term on a large scale for day-to-day business of regular emergency response units of the different organisations. And unsurprisingly, the GIS professionals deployed by NGOs or the WASH cluster face fundamental IM challenges too, as their work depends on the input from WASH teams working in the field. For example an evaluation of MapAction's *Haiti Mission* in 2008 [JUL-08] highlights, that the different ways of data collection and data formats used by WASH field staff made it extremely time-consuming for MapAction to compile all the information in the form of a map. In this case, Global Positioning System (GPS) coordinates of water points have been gathered in diverse formats.

Overall, even when a WASH cluster is active or set up, this does not automatically imply that IM and GIS services will be provided right from the start of an emergency response operation or provided at all – mainly due to lack of human resources [HHI-11; JUL-08]. The WASH IM tools described earlier offer a standardised approach towards WASH data collection. However, they are not designed for mapping single objects relevant to WASH interventions – for instance wells or latrines – and sharing this information with other organisations in the field. As WASH emergency response workers have access to crucial operational information through their daily work on the ground, they need the possibility to map this information themselves in a way that makes it accessible and easy to use for others. At the same time, this data should be simple to integrate into professional GIS systems used for IM.

This last line of thought already paves the way for the next chapter, which discusses the requirements and preconditions of a user-friendly GIS framework in the WASH sector. Because humanitarian work is guided by principles, these should reflect in every aspect of it; also when it comes to the technical side of things which are not primarily related to the needs of beneficiaries. For IM, the IASC has published an operational guidance on the responsibilities of cluster/sector leads and OCHA [IAS-08b]. This document defines twelve principles for humanitarian IM and information exchange in emergencies which shall be taken into account in the thesis' approach for a GIS framework.

The operational principles to guide IM and information exchange activities in emergencies are [IAS-08b]:

- **Accessibility**

  Humanitarian information should be made accessible by applying easy to use formats and tools, and by translating information into common or local languages when necessary.

- **Inclusiveness**

  Information exchange should be based on a system of partnership with a high degree of ownership by multiple stakeholders, especially representatives of the affected population and government.

- **Interoperability**

  All sharable data and information should be made available in formats that can be easily retrieved, shared and used by humanitarian organisations.

- **Accountability**

  Users must be able to evaluate the reliability and credibility of information by knowing its source and having access to methods of collection, transformation and analysis.

- **Verifiability**

  Information should be relevant, accurate, consistent and based on sound methodologies, validated by external sources, and analysed within the proper contextual framework.

- **Relevance**

  Information should be practical, flexible, responsive, and driven by operational needs in support of decision making throughout all phases of a crisis.

- **Objectivity**

  A variety of sources should be used when collecting and analysing information so as to provide varied and balanced perspectives for addressing problems and recommending solutions.

- **Neutrality**

  Information should be free of political interference that distorts a situation or the response.

- **Humanity**

  Information should never be used to distort, to mislead or to cause harm to affected or at-risk populations and should respect the dignity of those affected.

- **Timeliness**

  Humanitarian information must be kept current and made available in a timely manner.

- **Sustainability**

  Humanitarian information should be open sourced, preserved, catalogued and archived, so that it can be retrieved for future use, such as for preparedness, analysis, lessons learnt and evaluation.

- **Confidentiality**

  Sensitive data and information that are not to be shared publicly should be managed accordingly and clearly marked as such.

3 Requirements and Preconditions of a GIS Framework in the WASH Sector

Based on the definition of a GIS elaborated for the research, this chapter analyses the essential requirements and demands as well as preconditions and given implications or limitations of/on a GIS framework in the WASH sector regarding hardware, software, data, users and management. Likewise, principles and guidance for these GIS elements reflecting humanitarian work and common challenges in the field will be given attention. The findings presented here are based on relevant literature/documents and interviews, and serve as a foundation for the remaining chapters.

3.1 Hardware

The hardware used by relief workers in disasters is for the most part predetermined; either because the deploying organisations provide their staff with designated equipment or because people use their own devices. While laptops can be considered standard equipment, Global Satellite Navigation System (GNSS) receivers (e.g. GPS handhelds) are less common, but they become increasingly used and are viewed as a very useful tool by many emergency responders [VER-07; MAP-11]. And with a laptop and a GNSS receiver the hardware side of GIS is covered, providing the base for a portable system that can be used "anywhere".

Despite several organisations have developed or adopted certain hardware standards, differences in hardware can and should be expected. With respect to GIS, a recurrent question – also in the conducted interviews – is: *Does it work with my computer (laptop)?* The answer should be *yes*. Clearly, this highlighting the importance of interoperability and suggests that the selection for GIS software should be based on its compatibility with a reasonable range of hardware configurations. If GIS does not work with the hardware used in the field, then it will not work at all. Anyhow, a few rather basic criteria for selecting hardware can be identified – based on considerations regarding typical situations in emergency response operations:

- Robustness in outdoor use and varying climatic conditions
- Reliability and long battery life
- Widespread use and worldwide availability
- Active online communities for support and trouble-shooting
- Featuring standard, non-proprietary connections/interfaces (e.g. for transferring data between a GNSS receiver and a computer, i.e. *Universal Serial Bus (USB) cable with Type A and Mini-B plug)*
- GNSS receivers with colour display and storage for maps

3.2 Software

With GIS software or software providing the needed GIS functionalities the situation is a different one. An ever-growing range of software tools for specific GIS applications is available, making it difficult for humanitarian field workers to choose the kind of programs suitable for their needs [MAP-11]. Similarly, often asked questions in the interviews were: *What software is available, needed and recommended? How much does it cost? Is there free and open source GIS software and where can I get it from? Can I share it with others in the field and is it compatible with software and data formats used by others? How easy is it to work with it? Can I learn to use it with a little practise or do I need a special training just for the basics? Chapter 4 and 6* are also intended to give answers to these questions.

Which software is needed? – Probably the most complicated question to answer. The answer is closely related to the kind of data available, but even more to the extent to which users want to make use of GIS. As it is with many tools people can use for different purposes, also with GIS software, its potentials are only limited by the imagination of the users rather than the tool itself. Plenty of the potentials for applying GIS in disasters have long been pointed out by researchers in several publications and studies too, e.g. in Verjee's dissertation on the *Utility of GIS-based Analysis to support the Coordination of Humanitarian Assistance* [VER-07] or to cite an even older example, Wood's article on *Complex emergency response planning and coordination: Potential GIS applications* [WOO-00]. But to a large degree, the GIS enthusiasm radiated by several academics has never materialised in humanitarian emergency response. Common applications in the field are far lagging behind the functionalities of GIS software. Typical applications mentioned in the conducted interviews, reports of field missions [JUL-08; DAV-11] and MapAction's documented experience [MAP-08; MAP-11] are:

- Viewing base maps for reference and navigation
- Mapping field data (points of interest, recording tracks, measuring distances, etc.)
- Transfer data between GNSS receivers and computers
- Basic editing of field data (deleting, renaming, adding additional information, etc.)
- Sharing field data with others
- Visualise up-to-date relevant situation data gathered by others
- Create and print simple maps showing mapped data on satellite imagery or base maps

Nevertheless professional GIS software suites provide all these functions, their user interface appears arcane to the majority of new users – especially users new to the world of geospatial data at all. These programs require long learning times, so without intensive trainings in advance they cannot be deployed for disaster response. An example of this kind is *ESRI's ArcGIS*, a proprietary software for GIS practitioners, which finds preeminent use in humanitarian organisations for DM and IM; e.g. GIS of OCHA [UNO-07], the WASH cluster [GWC-08], the IFRC [IFR-12] or GIS NGOs like MapAction

[MAP-12] are based on it. However, also on a policy level, there is increasing evidence that (in the light of the IM principles accessibility and interoperability) humanitarian GIS solutions should be shifted to open source software if feasible [UNO-07] and supported by GIS tools that enjoy widespread use (e.g. *Google Earth*) [MAP-12]. Generally, it can be assumed that if GIS software tools come with certain restrictions for immediate use (may it be simply costs or high demands on previous knowledge) then they are not appropriate for relief workers – in the sense of GIS applications for everyone. The rapidly increased use of geo-browser based applications by non GIS professionals – also in humanitarian disaster relief [MAP-08] – through *Google Earth* might be the most convincing evidence.

Summarising what has been revealed so far, the following criteria for selecting GIS software should be taken into consideration to promote a user-friendly GIS framework:

- Tried and tested for its appropriateness and usability (with respect to the typical applications mentioned, the amount of time it takes to learn how to work with it, multi-lingual support as well as built-in help/trouble-shooting functions and accessible online documentation)
- Compatibility with older hardware
- Compatibility with different operating systems (OS) (at least the two most widespread OS on personal computers, i.e. *Windows XP or later* and *Mac OS X 10.6 or later*)
- Supporting common data formats
- Available for download free of charge
- Easy to share and install
- Working with low bandwidth or even without internet access

3.3 Data

With Kemp and Khagram [KEM-06a] it can be argued, that GIS technology provides valuable services in all phases within the full life-cycle of disaster relief (prevention, mitigation, preparedness, response, recovery and reconstruction). However, this argumentation has one essential condition: the availability and accessibility of relevant, reliable, accurate and up-to-date geo-data. It is helpful to distinguish between two general types of geo-data: *base maps or core geo-data* (topographic information, technical infrastructure, settlements, etc.) and *situational or operational geo-data* for specific operational needs. The latter includes geo-data mapped in the field but also e.g. updated satellite imagery.

The need for standardised critical core geo-data for humanitarian emergency response and its availability for humanitarian actors have already been articulated over a decade ago in e.g. the UN report *Strengthening of the coordination of emergency humanitarian assistance of the United Nations* [UNG-00]. Although up to now important progress has been achieved in this regard (see *Chapter 5*), there is still no simple way to access and use core geo-data. It remains to be seen, when, if and how the multiplicity of data portals of the various UN agencies (which already combine several of this data in the countries where they are active) will lead to standardised datasets with baseline information available prior to a disaster for single humanitarian organisations. The latest version of the UN report mentioned before, dated May 2012, suggest that sharing of already existing geo-data within a humanitarian framework for disaster response remains challenging as ever [UNG-12]. It is considered that the adoption and propagation of common humanitarian data standards will be a critical first step [ibid.]. But this is an on-going and largely unresolved issue itself. For example MapAction felt the need to develop its own humanitarian spatial data models and standards to be able to compile data from multiple sources and to provide base maps for emergency response operations [MAP-10]. In this context MapAction points out five recurring problems with spatial data in disasters [ibid.]:

- **Problems of discovery**

  Data owners may not recognise the value of their data in the emergency, so may not offer it for use. The original creators of the data may no longer be working in the country. Data already discovered by one humanitarian organisation in the emergency may not be known about by another.

- **Problems of availability**

  Data may have been archived offline and not immediately accessible or worse, the data may be stored and backed up in a location that may itself be destroyed in the disaster

- **Release problems**

  Datasets may be subject to legal restrictions on their use.

- **Problems with data formats**

  Data may be unsuited for direct import into a GIS, and may require substantial pre-processing.

- **Conflicting data**

  The existence of updated or corrected versions may not be apparent or there may be unresolved inconsistencies between datasets.

It is therefore not surprising that so far GIS has had its difficulties to prove itself as a useful tool for humanitarian emergency response. But increasingly providers of web based, free available and worldwide vector maps are filling in the gaps – most notably *Google Maps* and *OpenStreetMap. Google* and the project *OpenStreetMap (OSM)* – a community of approximately 150,000 mappers dedicated to building a free and open map of the world – have also been supporting mapping of disaster areas, and became (at least after the earthquake in Haiti in 2010) the bearers of a shift in thinking about how to best provide digital base maps for humanitarian relief [HHI-11]. However, both map sources are characterised through a high level of variability in mapped information, varying from country to country and region to region. Despite these limitations, depending on the location, for the bulk of emergency response operations this offered base map quality is as best as it will get in the short run. In the long run, map quality and the level of details are constantly increasing through regular updates of both sources.

Another potentially highly valuable source of information is satellite imagery; if up-to-date and available at a reasonable resolution to identify e.g. the location, size and structure of camp sites of internally displaced persons (IDPs). But for the use of space-based information a similar situation as described before for digital base maps appears. Already long before the first launch of *Google Earth* in 2005 (still today's best known example for providing free satellite imagery to everyone with internet access) several international initiatives for providing remotely sensed data for GIS applications in disasters lead by UN agencies existed [VER-05]. Verjee [ibid.] documented some of their successful implementations in humanitarian emergency response, but concludes that the high price for obtaining satellite imagery, copyright restrictions and missing in-house expertise made it difficult for UN agencies to realise their potential. Some of these challenges have been overcome partially through the implementation of the *United Nations Platform for Space-based Information for Disaster Management and Emergency Response (UN-SPIDER)* in 2006; Its mission statement is: "Ensure that all countries and international and regional organizations have access to and develop the capacity to use all types of space-based information to support the full disaster management cycle." [JBG-10].

Albeit this sounds very promising, the main bottleneck for providing satellite imagery in a usable form at field level to be used by individual emergency responders is, that it is just provided as data, not as an application which can be used immediately. The satellite imagery available through the different UN initiatives requires pre-processing, professional GIS software and the expertise of specialists before it can be used as a tool (e.g. a map) by relief workers. Additionally, these approaches do not offer simple ways to access this data by individual organisations. They are intended as support to high-level DM bodies with the required resources to process such data and produce outputs [JBG-10]. For satellite imagery, *Google Earth* combines both the data and the application to view it. Again here, depending on the location and usually the publicity of a disaster, up-to-date, high-resolution satellite imagery can be available and be a valuable source of information or not.

Finally, although digital base maps and satellite imagery have become increasingly available, most GIS data in humanitarian emergencies, as Kaiser et al. [KAI-03] suggest, will "still require persons in the field to collect data and interpret it according to the circumstances on the ground". The geo-data which is gathered in the field by relief workers through GNSS and mapping for specific operational needs bears a different set of aspects, especially for sharing:

- **Reliability**

  How can organisations and individual field workers make sure that the mapped data shared with them is reliable? What information should be provided on the shared data itself? These questions highlight the importance of metadata, data about data, describing e.g. content, type, quality, creation and spatial information of a dataset. But what are suitable methods for providing metadata together with the shared geo-data, keeping in mind that many relief workers might not be familiar with the concept of metadata at all?

- **Data Standards**

  Which data standards and formats should be used for sharing geo-data? How should geo-data created in the field be structured to be interoperable with other GIS?

These questions, among others, will be addressed in *Chapter 5*. Summarising what has been outlined so far and reflecting the input from the interviews, a variety of aspects for data need to be considered at the backdrop of a GIS framework:

- Freely accessible geo-data which can be used without pre-processing
- Offline usage of digital base maps and satellite imagery
- Interoperability with other GIS on all levels (from data formats to structure)
- Shared geo-data should feature metadata to ensure accountability, verifiability, timeliness and sustainability

3.4 Users and Management

With the increased popularity of geo-browsing with *Google Earth* and the advancement of its built-in creating and editing capabilities for geo-data, the formerly made distinction between GIS users and viewers is not too relevant any more. This development does not indicate that background knowledge on GIS has increased and spread in an extraordinary way, rather that complex software applications have been adapted to more user-friendly ones. While this may mean more potential users of geo-data applications in disaster response, GIS also requires management to be a sustainable tool. GIS approaches need to be refined and improved through lessons learnt during emergency deployments. Currion [CUR-01] argues that both low-tech (this thesis) and high-tech (OCHA, WASH cluster) approaches are useless unless the "right attitudes" underpin them. These, the author suggests, can best be described as an "open information culture". IM, Currion further states, is a "multi-sectoral requirement that should underpin all activities, and should extend through the transition from relief-oriented to development-oriented activities" [ibid.]. The same then applies for GIS management. For organisations this means that GIS requires a long-term commitment to benefit from it and to implement humanitarian principles for IM and information exchange activities in emergencies.

Ideally, such GIS management is already in place before the onset of a disaster. In brief, managing GIS in an organisation in this context denotes making sure that it can be used right away from the start of an emergency response operation. For users it involves that they should know the hardware, software and available geo-data they will use as well as having some practice in collecting, editing and sharing geo-data in the field in advance. Therefore, trainings on using GIS tools form a crucial part of disaster preparedness. Regarding the implementation strategy for GIS in an organisation (developing in-house expertise and capacity or an outsourced GIS approach through e.g. cooperation with other organisations), special trainings for IM/GIS managers or focal points in the headquarters are vital too.

In the analysed literature, documents and interviews it remains relatively unclear to what extent humanitarian organisations are ready to introduce GIS as a holistic approach rather than as an ad hoc add-on for certain activities. But several examples of GIS implementations during emergency response operations [ADA-06; CUR-01; DAV-11; JUL-08; VR-05] demonstrate that for a successful implementation, advocacy for GIS within an organisation plays a great role. Finally, there are a few underlying user related aspects in humanitarian emergency response which deserve great attention. Disaster response is characterised through high staff turnover and usually short deployment periods on short notice. The demands on the usability and practicability of GIS applications are therefore very high. Furthermore, usability and practicability also imply a certain level of standardisation of GIS tools within an organisation. In the interviews, many respondents expressed the need for what can best be described as *Standard Operating Procedures (SOPs)* for GIS – to be clear on management responsibilities, user tasks and the expected outputs of using GIS. Concluding, “GIS preparedness” can be considered the critical factor for making use of GIS tools or not, for yielding their benefits or not. What factors “preparedness” involves in terms of GIS will be explored in *Chapter 6*.

3.5 Conclusion: What is a User-friendly GIS Framework?

The definition of and view on GIS for this thesis explained in *Chapter 1* encompasses a comprehensive set of characteristics. These are framed with the terms hardware, software, data, users and management, of which several aspects have been highlighted above. The term “framework” is described in dictionaries as a *basic conceptual structure* and as a *set of processes and components which form a complex whole*. Following, as a first step it can be said that a GIS framework is an idea of how hardware, software, data, users and management fit together. Of course, how these pillars should fit together depends on the context and the purpose of a GIS framework (what it intends to deliver); i.e. for the thesis, the context of WASH emergency response and the aim of providing user-friendly GIS solutions that support WASH field work reflecting both, user needs and policies applicable to GIS that target a standardised framework covering all sectors of humanitarian emergency response.

As a second step it can be argued that for a GIS framework to be user-friendly, clearly considerations of and on the users must be the focal point. It is therefore user-centred. *Figure 4* on the next page shows the outline of a user-friendly GIS framework for humanitarian emergency response based on the considerations and findings in this chapter. In this sketch, users are embedded at the centre of the GIS framework being both influential on and influenced by the surrounding components of the adopted GIS approach. Through the use of applications and trainings in its use, GIS tools are further refined and adapted towards appropriate solutions for its users. Ideally, this is an on-going feedback loop that affects decisions regarding hardware, software and data as well as the implementation of standards (rather the way than a standard itself, e.g. there are different ways of providing metadata for geo-data), guidelines and SOPs. Primarily through trainings, the feedback loop works at the same time the other way; users are trained in the use of GIS applications (hardware, software and data), standards and guidelines for data collection/sharing and SOPs for emergency response operations. Standards, guidelines and SOPs also relate to hardware, software and data (e.g. standard hardware used within an organisation). GIS management acts as a mechanism in the background, ensuring a constant development of GIS through the feedback loops, i.e. lessons learnt in the field and changes in the environment of GIS and IM in emergency response operations.

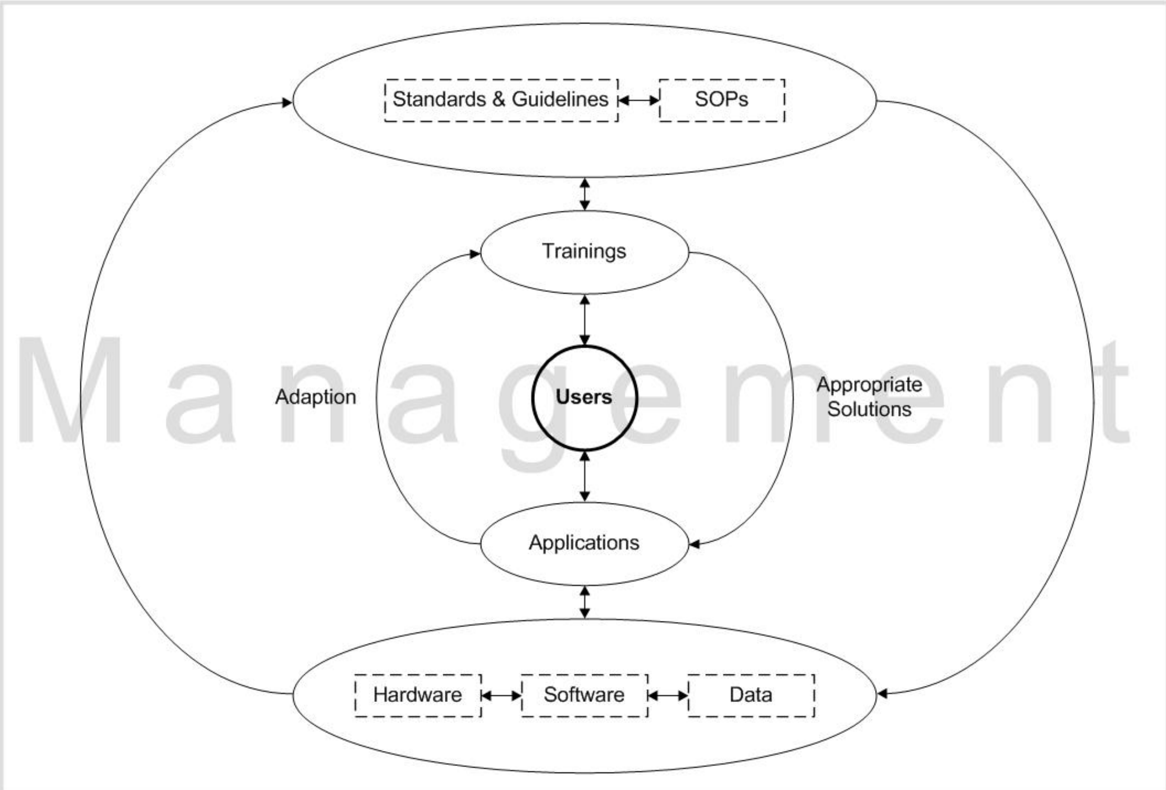


Figure 4: Outline of a user-friendly GIS framework for humanitarian emergency response

The model for a GIS framework elaborated above (*Figure 4*) however does not automatically imply a user-friendly GIS approach. Being user-centred can rather be considered a precondition for becoming user-friendly. The main characteristic for the user-friendliness of a GIS framework will be determined by the applications, as these are the direct link between users and a GIS. GIS applications include hardware, software and data, but software being the most critical GIS user interface for applications. The usability of software user interfaces will therefore have a great impact on the overall usability of GIS applications. The software section in *Chapter 4* will take a look at the criteria for user-friendly software in which user interface design is one out of several factors. Nevertheless, usability of software is still a criterion amongst others to consider. Most notably the functionalities of different software, the ability of software to handle various geo-data and the overall interoperability of hardware, software and data can make it necessary to weight e.g. functionality against usability. In adding operational requirements and demands as highlighted in the subsections above, the set-up of appropriate GIS solutions most certainly comes along with relevant limitations.

The idea conveyed here is that a GIS framework should facilitate this process of developing a user-friendly GIS for specific sector work like WASH where there are clear needs for basic GIS functionalities but the existing GIS approaches cannot be adopted because of their complexity and dependencies on the resources of specialists. The use and the meaning of the term "GIS framework" in this sense differs from what is often sought to express with it, i.e. a technical depiction of how hardware, software, data, services and processes relate to each other to provide GIS functionalities for users. *Figure 5* below shows an example of a GIS framework for DM developed after the 2004 Indian Ocean tsunami by an open source project named *Sahana* (http://sahanafoundation.org/).

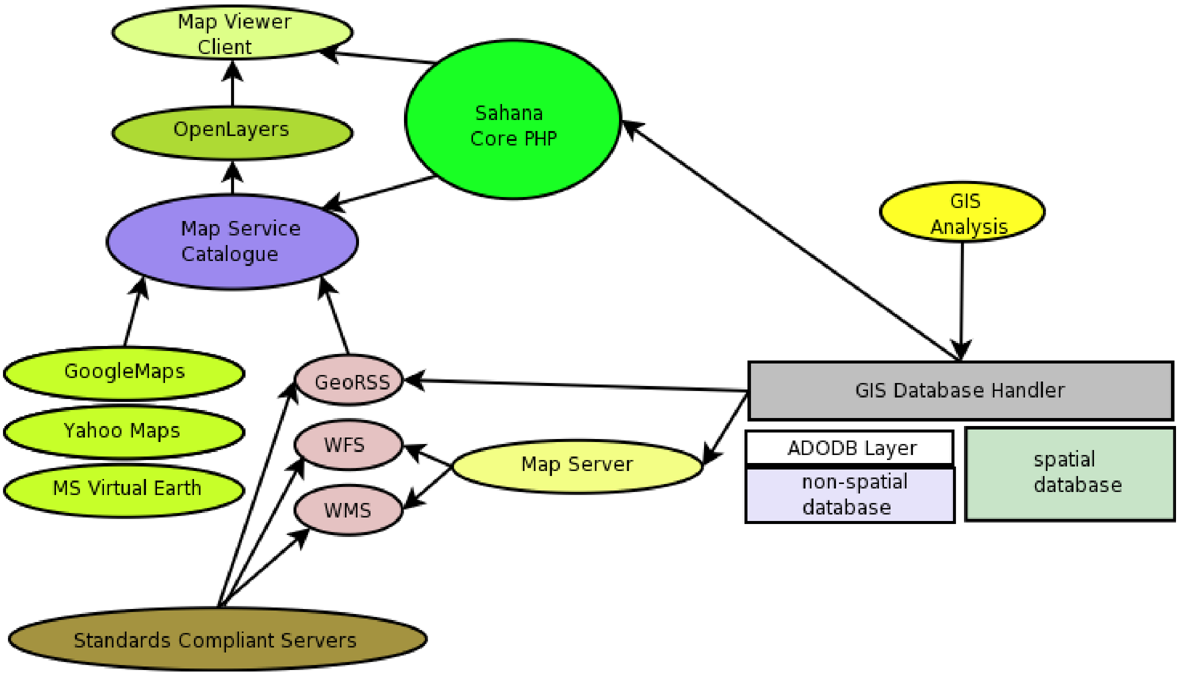


Figure 5: The GIS (prototype) framework of the Sahana DM system [CAR-07]

Since its initial development by a group of Sri Lankan volunteers in 2005, the Sahana DM system has been used around the globe and advanced to a widespread DM system with GIS integration in major disasters [CAR-07]. Although the GIS (prototype) framework of the Sahana DM system (*Figure 5*) is in its purpose and complexity (i.e. a web based platform for managing all relief activities in the aftermath of a disaster) far away from the attempt of the thesis' research, several aspects of its development provide a valuable reference and source of information for the elaboration of a user-friendly GIS framework in the WASH sector. To begin with, two practical considerations derived from lessons learnt in utilising GIS in humanitarian emergency response operations which have guided the Sahana GIS development are important with respect to the thesis' GIS approach [CAR-07]:

- Focusing on lighter GIS applications which are quicker and easier to deploy in environments characterised by resource constraints, low levels of computer literacy and weak infrastructure

- Adopt a modular approach and develop targeted applications that can support individual areas of work

4 Appropriate Technology: Hardware and Software

This chapter addresses the choices for appropriate hardware and software selection. Considering continuous technological advance on the one hand and generally predetermined hardware on the other hand, the first section is limited to discussing the use of basic required equipment and existing (quasi-)standards in the light of interoperability. The second section provides an overview of free or free and open-source GIS software tools which are used by various organisations or people involved in disaster response; both their potential applications and related shortcomings will be identified.

4.1 Hardware Equipment and Standards

Humanitarian emergency response is characterised through technology affinity and has to some extent become a playground for testing hardware innovations [COY-09]. There is an ever-growing range of consumer hardware that can be utilised for GIS applications: *laptops, netbooks, tablet computers, pocket computers or (smart)phones optionally with a built in GNSS receiver or in connection with a GNSS handheld, data logger, mouse, USB stick or a wrist-worn gadget.* Next to the criteria highlighted in *Chapter 3,* hardware selection in general should therefore also reflect which devices or which devices in combination cover the largest application area providing the most critical functionalities at the same time.

For GIS hardware the choice of having a typical consumer laptop (which is being used for communication anyway) in combination with a simple consumer GNSS handheld (for navigation, viewing base maps and mapping) has been proven to be a reliable and solid system used by the average emergency responder as well as the mapping specialists of GIS NGOs. Increasingly smartphones equipped special applications are providing mapping and GPS functionalities, but up to now they still lack some essential qualities of GNSS handhelds [MAP-11]. Most notably the battery life is reduced dramatically to a few hours if GPS is switched on. Other issues include incompatibility with coordinate specifications (formats and datum), handling for mapping, robustness in outdoor use, costs or satellite reception in general. Nevertheless, smartphones are a good alternative in the absence of a GNSS handheld and it is likely to assume that their overall capabilities will improve steadily to become more suitable for GIS integration in disaster response.

4.1.1 Personal Computers (Laptops)

Typically a computer's minimum hardware requirements will depend on the software applications which are intended be operated on it in a desired way, i.e. without long loading times and errors. GIS software applications can be very resource intensive, particularly when it comes to processing large datasets. *Table 1* provides an overview of such hardware requirements specified for and by the WASH cluster's IM which are based on the used GIS software suit *ArcGIS*, and a comparison with its latest version. Several of the criteria mentioned below (*Table 1*) – considering standard office applications and state of the art technology of average consumer computers – do not suggest special considerations for selecting computer hardware for GIS; except for *CPU speed/processor and system memory (RAM)*.

	WASH Cluster [GWC-08] min. hardware specifications (based on ArcGIS 9.3)	**ArcGIS 10.1 min. hardware specifications (according to http://www.esri.com)**
CPU Speed	2 GHz	2.2 GHz
Processor	Intel Core Duo	Intel Pentium 4/Core Duo
System Memory/RAM	3 GB	2 GB
Screen Resolution	n/a	1024 x 768
Display Size	15”	n/a
Hard Drive	100 GB	n/a
Video/Graphics Adapter	n/a	64 MB
Networking Hardware	Wireless (g), Ethernet (TCP/IP)	Ethernet (TCP/IP)
Optical Drive, Ports	DVD recorder, USB 2.0, VGA	n/a

Table 1: WASH cluster: Minimum hardware requirements based on ArcGIS versions

The software selection in the next subsection is also based on the idea that lighter, less resource intensive software is a more successful option for providing GIS tools in contexts where people simply may not have access to the latest computer technology. The suggested lighter software coincides with increased usability through less functionality or targeted applications compared to high-level GIS software (e.g. *ArcGIS*). If available, the listed software is provided with information on minimum hardware specifications (*Table 5,6,7,8,9,10 and 11*). Not for all programs this information can be determined. However, they are designed to be interoperable with a wide range of “outdated” computer hardware from a today’s perspective. But to demonstrate that the suggested software runs fine on older laptop hardware, all programs have been tested successfully on a variety of laptops running different OS (*Windows*, *Mac OS X* and *Ubuntu Linux*). To give a rough guidance on the minimum hardware requirements for the GIS software suggested in this research, key specifications of the two oldest laptop models used for testing are shown in *Table 2*.

	IBM/Lenovo ThinkPad T60 hardware specifications (model released in 2006)	**Acer Travelmate 8005 LMi hardware specifications (model released in 2004)**
CPU Speed	1.66 GHz	1.8 GHz
Processor	Intel Core Solo	Intel Pentium-M (forerunner of Intel Core)
System Memory/RAM	1 GB	1 GB
Screen Resolution	1024 x 768	1400 x 1050
Display Size	14.1”	15”
Hard Drive	80 GB	80 GB
Video/Graphics Adapter	64 MB	128 MB
Networking Hardware	Wireless (g), Ethernet (TCP/IP)	Wireless (g), Ethernet (TCP/IP)
Optical Drive, Ports	DVD recorder, USB 2.0, VGA	DVD recorder, USB 2.0, VGA

Table 2: Hardware specifications of outdated laptop models used for GIS software tests

Without going into the technical details displayed in *Table 2*, it can be followed that the main concern for GIS applications on old computers originates from the size of the processed files. Even on a computer with better and higher *CPU speed/processor and system memory (RAM)*, as displayed in *Table 1*, handling bigger datasets (from less than one GB to several GB) can be time-consuming, cause programs to crash and lead to unsatisfied users. Hence, the size of geo-data is another important factor to consider for user-friendly GIS applications.

4.1.2 GNSS Handhelds

With respect to global satellite navigation in general, four different systems with existing or planned services for civil use can be distinguished:

- **GPS** (http://www.gps.gov/)

  GPS was conceived in the early 1970's by the U.S. Government for purely military purposes. It became the first GNSS available for civil use after the systems completion in 1993 as the so called "standard positioning service". This standard service was degraded to less than 100 metres positional accuracy to prevent civilian GPS equipment from being used in military attacks on U.S. interests [VER-05]. In 2000 the distortion of the signal quality for civil use − called "selective availability" − ended, making GPS more interesting for civilian purposes. Since then, GPS offers a positional accuracy better than 15 metres (for typical consumer-grade devices) and GPS receivers became a mass-marketed product.

- **GLONASS** (http://www.glonass-ianc.rsa.ru/en/)

  The development of GLONASS (Russian acronym for GNSS) began in the former Soviet Union, short after the inception of the GPS project. The system was completed in 1995 but soon lost its operability for global use. In 2007, restrictions for civil usage were removed and full global coverage was restored in 2011. GLONASS compatible consumer GNSS handhelds are available, though the development of the user segment is still in its early stages. The first and only (as of October 2012) consumer-grade GNSS handheld featuring GPS and GLONASS capability has been launched by the end of 2011 (the latest *Garmin eTrex series*, which albeit does not work with GLONASS only; see also *Table 3* for a model of this series). Further development from GPS to GNSS handhelds can be anticipated in the consumer market segment.

- **GALILEO** (http://www.esa.int/esaNA/galileo.html)

  The European Union's GNSS named GALILEO officially started in 2003 and full completion of the system is expected by 2020.

- **COMPASS** (http://www.dragoninspace.com/navigation/compass-beidou2.aspx)

  The Chinese GNSS programme COMPASS, also known as Beidou-II, was launched in 2004 and plans to provide positioning and navigation services to the Asia-Pacific region by 2014. Expansion to global coverage is expected in 2020.

In humanitarian emergency response consumer GPS handhelds advanced to prevalent equipment. These devices have been around for more than two decades and proven to be long-lasting as well as easy to maintain and handle by users with low levels of computer literacy or education in general. Well-known manufacturers of consumer-grade GPS handhelds in a price range of 100 to 500 EUR include *Garmin, Magellan, Lowrance* or *DeLorme*. Over the course of time, several humanitarian organisations have specified series or models of GPS handhelds to be used by emergency responders in the field. It seems that for many *Garmin* brand GPS handhelds have become internal standards as they have been widely used in other areas too (e.g. recreational activities). A very popular series was and still is *Garmin eTrex* of which some models are standard equipment for instance within the IFRC and the logistics cluster lead by the World Food Programme (WFP) which typically use GPS handhelds for mapping transportation infrastructure and GIS integration [IFR-07; LOG-10]. The WASH cluster in general suggests using a specific *Garmin* wrist-worn GPS device or similar for their staff [GWC-08].

It can be considered that such standards are more important within an organisation or department for usability than across organisations for interoperability. Mainly because the bulk of GPS handhelds of different manufacturers feature industrial standards (e.g. *USB Mini-B interface* for data transfer to a computer or a *microSD card slot* for map storage extension), data transfer protocols and formats which are (or of which at least one is) supported by common software. But different models and series of handhelds have diverging user interfaces (even within one brand), which can make their handling intricate if users are familiar with one model/series but then have to learn to cope with a different one based on another philosophy. Three basic user interfaces can be distinguished: keypads (*Figure 6*), touchscreens and a mixture of both in varying degrees (*Figure 7*).

Source: Garmin, Magellan, DeLorme

Figure 6: Examples of different keypad interfaces on GNSS handhelds

Source: Garmin, Lowrance, Magellan

Figure 7: Examples of different touchscreen (first and second from left) and touchscreen plus keypad/button control (third and fourth from left) interfaces on GNSS handhelds

Which interface (keypad, touchscreen or a mixture of both) will provide the highest usability differs from one person to another and depends on individual preferences and experiences. But overall, it can be considered that the lowest level of diversity in GNSS handhelds possible within an organisation is beneficial and less complicated to maintain for both the users and the organisation. Normally, newer models within a series (e.g. *Garmin eTrex*) provide a similar user interface and object oriented controls resulting in better recognition of users. Changes of a handheld series should therefore be carefully considered when more or new devices are procured. Among the different series of GNSS handhelds, also across different manufacturers, the basic functionalities and most needed features are the same. *Table 3* shows a comparison of the configuration and functionalities of three different current GNSS handheld models/series of *Garmin*.

	 Oregon® 450 $ 329.99 USD	 eTrex® 20 $ 199.99 USD	 GPSMAP® 62sc $ 499.99 USD
Unit dimensions, WxHxD:	2.3" x 4.5" x 1.4" (5.8 x 11.4 x 3.5 cm)	2.1" x 4.0" x 1.3" (5.4 x 10.3 x 3.3 cm)	2.4" x 6.3" x 1.4" (6.1 x 16.0 x 3.6 cm)
Display size, WxH:	1.53"W x 2.55"H (3.8 x 6.3 cm); 3" diag (7.6 cm)	1.4" x 1.7" (3.5 x 4.4 cm); 2.2" diag (5.6 cm)	1.43" x 2.15" (3.6 x 5.5 cm); 2.6" diag (6.6 cm)
Display resolution, WxH:	240 x 400 pixels	176 x 220 pixels	160 x 240 pixels
Display type:	transflective color TFT touchscreen	transflective, 65-K color TFT	transflective, 65-K color TFT
Weight:	6.8 oz (192.7 g) with batteries	5 oz (141.7 g) with batteries	9.3 oz (262.1 g) with batteries

Table 3: Configurations and functionalities of selected *Garmin* GNSS handhelds

Battery:	2 AA batteries (not included); NiMH or Lithium recommended	2 AA batteries (not included); NiMH or Lithium recommended	2 AA NiMH batteries (included)
Battery life:	16 hours	25 hours	16 hours (2 AA batteries)
Waterproof:	yes (IPX7)	yes (IPX7)	yes (IPX7)
Floats:	no	no	no
High-sensitivity receiver:	yes	yes	yes
Interface:	high-speed USB and NMEA 0183 compatible	USB	high-speed USB and NMEA 0183 compatible
Basemap:	yes	yes	yes
Preloaded maps:	no	no	no
Ability to add maps:	yes	yes	yes
Built-in memory:	850 MB	1.7 GB	3.5 GB
Accepts data cards:	microSD™ card (not included)	microSD™ card (not included)	microSD™ card (not included)
Waypoints/favorites/locations:	2000	2000	2000
Routes:	200	200	200
Track log:	10,000 points, 200 saved tracks	10,000 points, 200 saved tracks	10,000 points, 200 saved tracks
Automatic routing (turn by turn routing on roads):	yes (with optional mapping for detailed roads)	yes (with optional mapping for detailed roads)	yes (with optional mapping for detailed roads)
Touchscreen:	yes	no	no
Electronic compass:	yes (tilt-compensated, 3-axis)	no	yes (tilt-compensated, 3-axis)
Barometric altimeter:	yes	no	yes
Camera:	no	no	yes (5 megapixel with autofocus; automatic geo-tagging)
Photo navigation (navigate to geotagged photos):	yes	yes	yes
Picture viewer:	yes	yes	yes
Custom maps compatible:	yes	yes	yes
Sun and moon information:	yes	yes	yes
Tide tables:	yes	yes	yes
Area calculation:	yes	yes	yes
Custom POIs (ability to add additional points of interest):	yes	yes	yes
Unit-to-unit transfer (shares data wirelessly with similar units):	yes	no	yes

Source: Garmin

Table 3 (continued): Configurations and functionalities of selected *Garmin* GNSS handhelds

The listed configurations and functionalities in *Table 3* (which is based on current *Garmin* models) provide actually more than what is usually needed for emergency response operations. GNSS handhelds of other common manufacturers have very similar features, as a look on their websites (*Magellan, Lowrance, DeLorme*) will reveal. *Garmin* handhelds however are a reasonable choice in disaster response for several practical reasons. But this shall not indicate that GNSS handhelds of other producers won't work at all with the GIS application explored in this research. Most notably, the advantages of using *Garmin* handhelds are:

- being the leading producer of GNSS handhelds with the highest worldwide availability
- offering the largest range of GNSS handhelds
- being already used and widespread in organisations involved in disaster response
- being supported primarily and best by common GIS software, related tools and applications for adding custom data and free available maps (e.g. OpenStreetMap)

Therefore, the GIS applications explored in this thesis are based on *Garmin* related products. Following *Table 3* and the requirements/demands highlighted in *Chapter 3*, the specifications and functionalities of GNSS handhelds for emergency response can be distinguished according to their importance. *Table 4* below shows which of their features and functionalities can be regarded as minimum requirements for WASH emergency response activities. These are referencing key specifications of outdated *Garmin eTrex* models which have become standard equipment within e.g. the IFRC and the LOGISTICS cluster. All other capabilities – as listed exemplarily in *Table 3* – can be categorised as less important but nice to have. This differentiation intends to provide general guidance for selecting GNSS handhelds to ensure their optimal utilisation for WASH field work, though this does not mean that it will stay the same under all circumstances.

Minimum features and functionalities (based on outdated *Garmin eTrex* models)	
Display	Medium sized (~ 3.3 x 4.3 cm) colour display with ~176 x 220 pixels
Battery life	≥ 15 hours
Case/physical	Rugged and waterproof to IPX7 standard; temperature range ~ -15ºC to 70ºC
Interface	USB (Mini B port)
Extended memory	microSD card slot for memory extension (maps, points, tracks)
Custom data	Ability to add custom maps and points data
Features	Mark and edit waypoints (including viewing, adding and editing text notes), tracking and routing

Table 4: Recommended minimum features and functionalities of GNSS handhelds for WASH emergency response

4.2 User-friendly Software

The findings in *Chapter 3* stressed the importance of a modular GIS approach which is based on light software with targeted applications. The list of software presented and analysed in the following four subsections begins with programs providing basic required functionalities for WASH emergency response (*Google Earth* and *Garmin*

BaseCamp/MapInstall) and then expands towards more sophisticated applications (*GPSBabel, Geotag, DNR GPS* and *Quantum GIS*). Increased functionality will go hand in hand with higher demands on the user which can be expressed in longer learning times and may also require more frequent trainings. The software selection attempts to provide an overview of GIS solutions for various levels of user experience and application contexts. The latter include short-term emergency response deployments as the main background of the thesis, but also long-term deployment settings in the recovery phase where time is less critical and users may opt for more advanced GIS tools, or wish to do so to explore additional benefits for their work.

The usability of software or rather its interactive graphical user interface (GUI), through which the user communicates with a program, is of general relevance. With Riedl [RIE-00] it can be argued that with respect to GIS the usability of an interface has a double meaning: on the one hand a map is an interface itself and on the other hand a (digital) map needs an interface to be used. This aspect is insofar essential, as it draws attention to the link between software and base maps/satellite imagery and software's capability to display map contents in a way that makes its essential information immediately visible and understandable. Based on Shneiderman [SHN-98], Riedl [RIE-00] accentuates five user interface design goals with which the usability of an interactive interface for cartographic applications can be measured: *time to learn, speed of performance, rate of errors by users*, *retention over time and subjective satisfaction*. With Riedl [ibid.] they can be elaborated as follows:

- **Little time needed to learn how to use an application**

  User should be able to use their skills and experience already acquired through working with common map products and software in general. This means that known interface elements – e.g. ticking a check box to activate a function, which is for instance used in Google Earth to activate/display a layer (*Figure 8*) – and symbols with familiar associations – e.g. a pointer or magnifier icon to select pointing or zooming mode with the mouse (*Figure 9*) – facilitate the learning process, if used of course in a consistent way.

- **High speed of performance**

  Interfaces should make it easy to find or use a function without substantial work steps beforehand and be based on a logical workflow which is reflected in the GUI. For instance in *Google Earth* and *Garmin BaseCamp*, if a layer is added, it gets immediately displayed, the map centres on the layer extent and by clicking a feature of the layer it is marked in a different colour, pops up and is zoomed at in the centre of the map display.

- **Low rate of errors by users**

  For users, the possibility to make essential mistakes and produce errors ought to be as limited as possible, i.e. interfaces must be error avoiding and tolerant. For instance the place/feature search function in *Google Earth* and *Garmin BaseCamp* features upper and lower case insensitivity and displays suggestions when typing. Another example provides *Garmin MapInstall* which guides the user step by step (accompanied with additional explanations) through the process of installing a map on a GNSS handheld (*Figure 10*).

- **Retention over time**

  The frequency of use and ease of learning improve user retention. Or the longer newly acquired skills are memorised, the more useful applications will be for users. Therefore, intuitive interfaces have a great impact on user retention over time. Especially considering that many trained emergency responders may not use several GIS applications regularly, how well a user can remember the interface even after months is a crucial factor.

- **Subjective satisfaction**

  Subjective satisfaction can be regarded as the most important measure. The better the previous interface design goals are implemented, the higher it will be. Assessing and evaluating it is important and should be implemented as part of trainings as well as debriefings after deployments.

Even though there is always room for improving usability, such ideas on interface usability can be said to have shaped GIS applications enormously over the years and made software interfaces more appealing to new users with no specific background in this area. The software presented below features core usability elements in varying degrees and – except for *Quantum GIS* – provides a similar workflow logic to common word processing or spread sheet programs; commands like *File open/add/import*, *File export/save as*, pointing device gestures like *drag and drop* and the *direct manipulation* interface style, which immediately visualises edits made, create a familiar environment for newcomers and already allow for using the bulk of possible applications.

User-friendly software in this work encompasses usability – in short, that software is easy to grasp without advanced computing skills right from its first use – as well as accessibility. Accessibility includes that software is available for free use, designed to be operated with average consumer hardware (even when several years old) and interoperable with various OS configurations. An overarching aspect is that software is consistently developed, updated and bug fixed. Because *Windows* being the most widely used OS in general, GIS and GNSS applications have been developed primarily on its base; therefore, it still provides the best compatibility. Although popular lighter GIS and GNSS related software is increasingly developed for multiple OS, depending on the desired applications, not using *Windows XP or later* can still mean limitations to the range of software available.

4.2.1 Geo-browser: Google Earth

Google Earth has been characterised as a digital globe based geo-browser. It is not the only one, but so far the only which can be considered appropriate for its use in emergency response (according to the criteria highlighted in *Chapter 3*). Most notably because it is a stand-alone application that works without internet access and can be easily learned [MAP-

08; MAP-11]. As has already been pointed out previously, *Google Earth* is more than just software. At the same time it is also a massive collection of archived satellite and to a lesser degree aerial imagery, a standard for exchanging spatial data (see *Chapter 5*) as well as an online community and resource for developing new applications and services [MAP-08]. Its high popularity in general – mainly due to its limited core functionality which makes it very easy to use combined with the highly immersive user experience when exploring the whole world in 3D on a digital globe – has contributed to its increased use in disaster response [ibid.]. Across all emergency response sectors *Google Earth* has become a common interface for viewing, sharing and editing spatial information.

Google Earth Fact Sheet (latest version 6.2)	
Supported OS	Windows XP or later; Mac OS X 10.5 or later; Linux and several OS for mobile devices
Minimum system requirements	*Windows* CPU: Pentium 3, 500 Mhz System Memory (RAM): 256 MB Hard Disk: 400 MB free space Network Speed: 128 Kbits/sec Graphics Card: DirectX 9 and 3D capable with 64 MB of VRAM Screen: 1024x768, "16-bit High Colour" - DirectX 9 (to run in Direct X mode) *Mac* CPU: Any Intel Mac System Memory (RAM): 256 MB Hard Disk: 400 MB free space Network Speed: 128 Kbits/sec Graphics Card: DirectX 9 and 3D capable with 64 MB of VRAM Screen: 1024x768, "Thousands of Colours"
Available languages	Arabic, Brazilian Portuguese, Bulgarian, Catalan, Chinese (simplified and traditional), Croatian, Czech, Danish, Dutch, English, Farsi, Filipino, Finnish, French, German, Greek, Hebrew, Hindi, Hungarian, Indonesian, Italian, Japanese, Korean, Latin American Spanish, Latvian, Lithuanian, Norwegian, Polish, Portuguese, Romanian, Russian, Serbian, Slovak, Slovenian, Spanish, Swedish, Thai, Turkish, Ukrainian, Vietnamese
Import data formats (relevant ones)	Google Earth (*.kml, *.kmz) GNSS (*.gpx, Garmin, Magellan) Images (*.jpg, *.bmp, *.tif, *.png, *.jpeg, *.gif, *.tiff)
Export data formats (relevant ones)	Google Earth (*.kml, *.kmz) Images (*.jpg)
Download	http://earth.google.com
Online resources, help and tutorials	Tutorials: http://www.google.com/earth/learn/ Google Earth Outreach: http://www.google.com/earth/outreach/tools/index.html MapAction's *Field Guide to Humanitarian Mapping* [MAP-11]

Table 5: *Google Earth* fact sheet

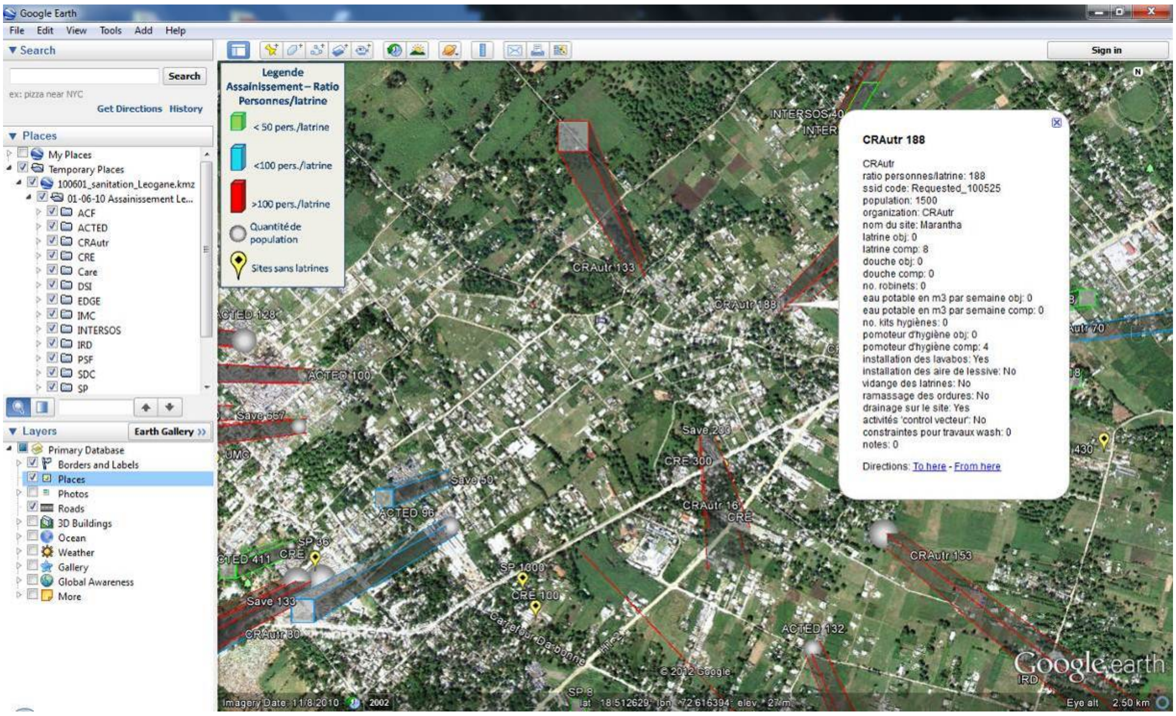


Figure 8: Screenshot of *Google Earth* showing the latrine coverage of IDP camps in Léogâne, Haiti

Google Earth applications can be considered the main entry point to GIS in disasters for new users and a hub for viewing, using and sharing geo-referenced information through which basic required GIS functionalities for emergency response can be connected with more advanced applications of professional GIS used by the WASH cluster and OCHA. Its most relevant basic features and applications are:

- Orientation (satellite imagery with layers visualising roads, places, borders, etc.)
- Situational snapshots of locations of interest if imagery is up-to-date (e.g. obtain size and structure of IDP camps)
- Search for place names and coordinates
- Offline use through a program cache for imagery and layers (up to 2 GB)
- Measure distances and obtain coordinates
- Create custom points, lines and polygons
- Edit and enhance custom data through adding text or links (e.g. to images) and by using custom icons
- Import GNSS data (as a file or direct from a connected device)
- Import, view and edit custom data layers shared by others (**.kml*/**.kmz* files)
- Export satellite images with overlays as displayed on the screen as an image file (**.jpg*) for further processing

Furthermore, *Google Earth* provides a lot more advanced features and applications which include for example:

- Create overlays with images (e.g. topographic maps) which first need to be geo-referenced manually, i.e. to be dragged in the right place and turned in the right position
- Create maps or overlays using *Google Fusion Tables* – a web service through which datasets can be visualised e.g. in the form of diagrams (*Figure 8*)

So for experienced users, and when internet access is available *Google Earth* offers many possibilities to further improve the visualisation of geo-data and the quality of information that can be retrieved from it. The most noteworthy shortcomings for its basic use are:

- The search function requires internet access
- Metadata of *Google Earth* files (**.kml, *.kmz*) are not supported (directly)
- Unreliable direct data import from a connected GNSS (e.g. with some *Garmin* GNSS handheld models it is only possible to import tracks/lines but not (way)points)
- No area measurements (requires *Google Earth Pro*)
- It is not possible to display geo-referenced raster data (photos, maps) respectively imported images are not automatically geo-located (requires *Google Earth Pro*)
- No support of other commonly used GIS vector data formats, e.g. ESRI shapefiles (**.shp*) (requires *Google Earth Pro*)
- Only what (area, resolution/zoom level, layers) has been viewed is cached for offline use
- Adding photos stored on the local hard disk to e.g. a point is still far from being easy-going (e.g. local file paths are not directly supported in **.kmz* files and require a work around or while images with the file extension **.jpg* are displayed, those with the upper case ending **.JPG* are not)
- It is not portable and can therefore not be installed on other computers in case there is no internet access available
- An internet connection is required for installation

With *Google Earth Pro*, the business-oriented and enhanced version of *Google Earth*, which provides more GIS functionalities but comes with licence costs, some of these shortcomings can be overcome. *Google Earth Pro* is licensed annually per user, in 2012 for 321 EUR per year per single user license (see also the website of *Google Earth Pro* at http://www.google.com/enterprise/earthmaps/earthpro-features.html). It is also worth mentioning that *Google* grants *Google Earth Pro* licenses at no costs to qualifying organisations who demonstrate a need for its advanced features. However, applying for a grant is a lengthy bureaucratic process and the eligibility criteria (which can be found at http://www.google.com/earth/outreach/grants/software/earthpro.html) are not in favour of the capacities of most organisations involved in disaster response. But in general, the imagery and relevant data layers are the same across both versions of *Google Earth*.

4.2.2 Vector map viewer and data editor: Garmin BaseCamp

Garmin BaseCamp is the successor of *Garmin MapSource* – a popular mapping software whose development has been discontinued in 2010 but is still available for free download. *Garmin's* software distribution policy changed just a few years ago (2009/2010), making its mapping software freely available for download, whilst before, software was only distributed together with purchased devices. Already in 2006, in the early days of *Garmin MapSource* Adams [ADA-06] argued in a journal designed for humanitarian practice exchange that there is no reason why organisations cannot adopt such software tools for emergency response as its capability is exactly what is needed, and quicker and easier to use than professional GIS applications. *Garmin's* software improved substantially over the years and additionally (since only a few years) supported third party maps like e.g. *OpenStreetMap* have increased its application range and decreased the dependency on maps of commercial providers; the latter often a reason for not using this kind of software.

Garmin BaseCamp Fact Sheet (latest version 4.0.2)	
Supported OS	Windows XP Service Pack 3 or later; Mac OS X 10.6 or later
Minimum system requirements	*Windows* IBM-compatible computer System Memory (RAM): 1 GB Hard Disk: 85 MB free space OS Components: .NET framework 3.5 SP1 *Mac* Intel-based Mac System Memory (RAM): 1 GB Hard Disk: 85 MB free space
Available languages	Chinese (simplified and traditional), Croatian, Czech, Danish, Dutch, English, Finnish, French, German, Hungarian, Italian, Japanese, Korean, Norwegian, Polish, Portuguese, Russian, Slovak, Slovenian, Spanish, Swedish, Thai
Import data formats (relevant ones)	Google Earth (*.kml, *.kmz) GNSS (*.gpx, Garmin) Images (*.jpg, *.jpeg)
Export data formats (relevant ones)	GNSS (*.gpx, Garmin)
Download	http://www8.garmin.com/support/mappingsw.jsp
Online resources, help and tutorials	Tutorials: http://www8.garmin.com/learningcenter/training/basecamp/ User guide and documentation: http://static.garmincdn.com/basecamp/en/Default.htm

Table 6: *Garmin BaseCamp* fact sheet

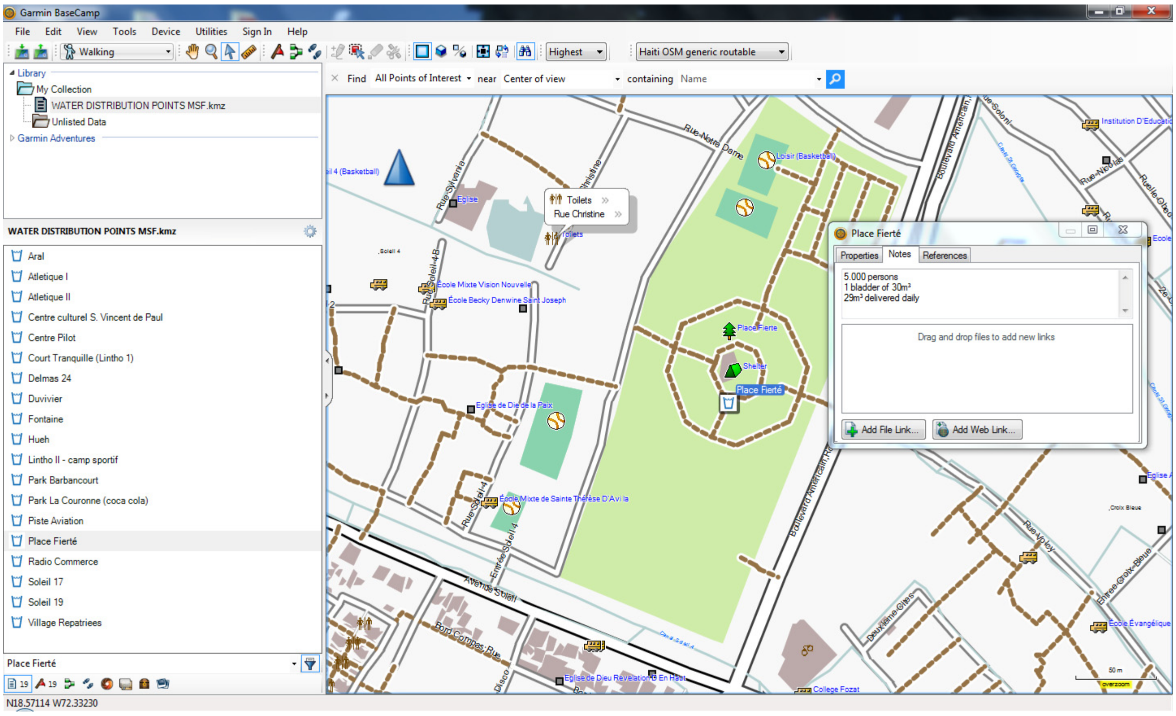


Figure 9: Screenshot of *Garmin BaseCamp* showing a water distribution point layer on *OpenStreetMap* in Port-au-Prince, Haiti

The main purpose of *Garmin BaseCamp* is to view vector maps together with custom geo-data and to handle GNSS data, i.e. it provides the connection between a GNSS and a computer. Its functionality complements *Google Earth* in several important ways. Most notably because the software provides the ability to view vector maps (e.g. *OpenStreeMap* data) stored on the computer as well as a reliable transfer of data between a computer and a GNSS receiver. Likewise, the software provides a similar interface and working logic as *Google Earth* making its first use a familiar experience. Increased usability is provide through e.g. an *undo/redo function* for any change made, or the possibility to *customise the GUI with activating/deactivating and moving toolbars or resizing the different sections of the work window*. *Garmin BaseCamp's* most relevant basic features and applications are:

- No internet access is required at all
- Data transfer between computer and GNSS receivers (points, tracks, photos or raster data like satellite imagery or topographic maps)
- Editing GNSS data (tracks/lines and waypoints/points including adding text notes and changing icons which can also be viewed on the GNSS handheld)
- Direct export of GNSS data to *Google Earth* (which then opens and displays the exported layers)
- Display custom maps installed on the computer with varying map details to visualise the information desired to retrieve (which is often better to provide overviews than satellite imagery with custom layers)

- Print maps (automatically north oriented) as **.pdf* files in various sizes with respect to the area covered including custom map elements (coordinate grid, scale, overview map, displayed layer name)
- Measure distances and areas
- Search any points of interest/places which are featured in the map
- Geo-locate (also called geo-tag or geo-code) photos with GNSS data
- View all custom geo-data (photos, points, tracks, routes) on maps for situational overviews or to present such to others
- It is portable and can therefore be operated on flash drives or be installed on other computers in case there is no internet access available (this works e.g. across *Windows XP or later*)

The most noteworthy shortcomings for its basic use are:

- Works only with *Garmin* brand devices
- No support of other commonly used GIS vector data formats, e.g. ESRI shapefiles (**.shp*)
- Does not provide access to free available satellite/aerial imagery like e.g. *Google Earth*
- Only supports points and line data respectively polygons are displayed as lines and not filled

4.2.3 GNSS and GIS enhancements

4.2.3.1 Garmin MapInstall

Google Earth, Garmin BaseCamp and *MapInstall* cover the basic needed capabilities for WASH emergency response. The main purpose of *Garmin MapInstall* is its only application, i.e. to install or uninstall maps on a GNSS handheld. A precondition for this is that GNSS handhelds have a memory where maps can be saved. Newer GNSS handheld models usually have already a larger built-in memory (several GB), but its extension through a memory card (*microSD* card, at least in the range of 2 - 4 GB) can be considered a recommended capability to provide flexibility with the kind of data to be uploaded, also in the future. To use this software, *BaseCamp* compatible maps (see *Chapter 5*) need to be installed on a computer first, and can then be transferred. Like *Garmin BaseCamp*, *MapInstall* is a portable software and can be operated on flash drives or be installed on other computers in case there is no internet access available (this works e.g. across *Windows XP or later*).

Actually, there are quite a few different ways and tools for transferring maps to a GNSS device, which also depend on the data format (*BaseCamp* map installer or maps as **.img* file) of the available maps, but *Garmin MapInstall* is regarded as the easiest way to do it. Alternative ways for *Garmin* brand devices are explained in several online resources such as forums, blogs and wikis (see for instance http://wiki.openstreetmap.org/wiki/OSM_Map_On_Garmin#What_if_I_have_an_existing_gmapsupp.img_file.3F). However, these are prone to errors and should only be suggested for experienced users. Overall, there might just be very few occasions where *Garmin MapInstall* cannot be used since e.g. *BaseCamp* map installers with *OpenStreetMap* data are available at a worldwide coverage for *Windows XP or later* and *Mac OS X 10.6 or later* (*Chapter 5*). The fact that *Garmin MapSource* already included *MapInstall* in its interface, but *BaseCamp* so far does not, appears as a weakness. It remains to be seen if future releases of *Garmin BaseCamp* will solve this issue.

Garmin MapInstall Fact Sheet (latest version 4.0.1)	
Supported OS	Windows XP Service Pack 3 or later; Mac OS X 10.6 or later
Minimum system requirements	*Windows* Hard Disk: 40 MB free space OS Components: .NET framework 3.5 SP1 *Mac* Intel-based Mac System Memory (RAM): 512 MB Hard Disk: 40 MB free space
Available languages	Chinese (simplified and traditional), Croatian, Czech, Danish, Dutch, English, Finnish, French, German, Hungarian, Italian, Japanese, Korean, Norwegian, Polish, Portuguese, Russian, Slovak, Slovenian, Spanish, Swedish, Thai
Import data formats (relevant ones)	Not selectable (requires BaseCamp compatible maps installed on a hard or flash drive)
Export data formats (relevant ones)	Not selectable (installs BaseCamp compatible maps as a *.img file in the “Garmin” folder on the GNSS handheld or rather the built-in memory/microSD memory card)
Download	http://www8.garmin.com/support/mappingsw.jsp

Table 7: *Garmin MapInstall* fact sheet

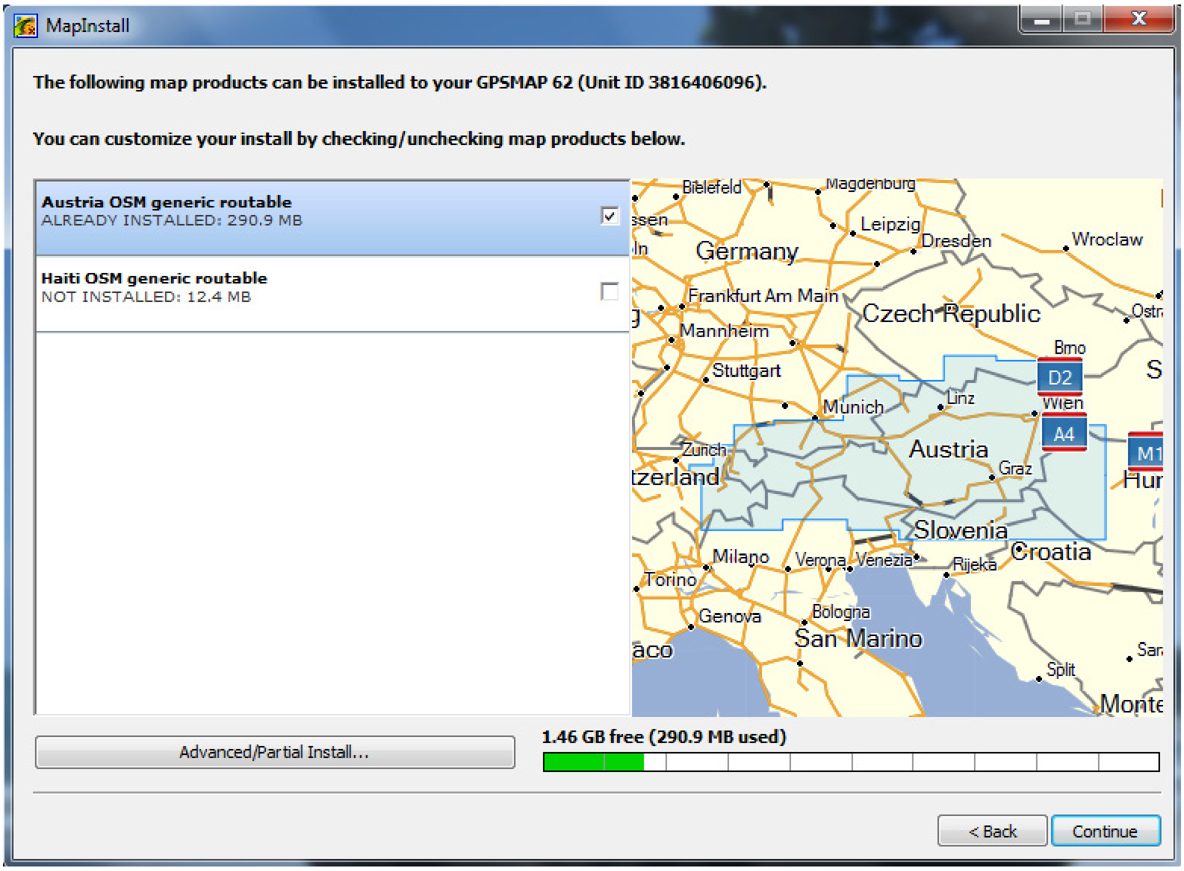


Figure 10: Screenshot of *Garmin MapInstall* showing the selection of maps to be installed or uninstalled on the GNSS handheld

4.2.3.2 GPSBabel

GPSBabel is just one out of an immense variety of GPS/GNSS software tools. Its main capabilities are that it interfaces with a large number of GNSS types/models/brands and allows the conversion of many data formats (see *Table 8*). It is e.g. listed in MapAction's *Field Guide to Humanitarian Mapping* [MAP-11] as a suggested tool, and because of its specific and comprehensive functionalities popular throughout the GNSS community for amateur use. Although the software's interface seems self-explanatory (*Figure 11*), its proper use requires an understanding of the used data formats and their limitations. The basic features and applications of *GPSBabel* in emergency response include:

- Downloading and uploading data from/to a GNSS device in case it is not supported by or this does not work with *Google Earth* and *Garmin BaseCamp*
- Converting vector geo-data (points, lines and polygons) that is not supported by *Google Earth* and *Garmin BaseCamp* into compatible file formats
- Converting especially point data and their description/notes like e.g. water distribution points (*Figure 9 and 11*) into tables (**.csv* or **.txt*) that can be visualised in common spread sheet programs and printed for instance to be used as hard copies during assessment or monitoring trips

- It is portable and can therefore be operated on flash drives or be installed on other computers in case there is no internet access available (this works e.g. across *Windows XP or later*)

The most noteworthy shortcomings for these basic uses are:

- No direct support of other commonly used GIS vector data formats, e.g. ESRI shapefiles (**.shp*)
- Geo-data might require to be pre-processed (e.g. to split and save a single layer from a file containing several layers or to reformat points with coordinates stored in tabular form) in order to be converted with the desired output

GPSBabel Fact Sheet (latest version 1.4.4)	
Supported OS	Windows XP or later; Mac OS X 10.6 or later; Linux
Minimum system requirements	None specified Hard Disk: 40 MB free space
Available languages	English; additional languages are available but need a separate installation (see also http://www.gpsbabel.org/tips/translate.html)
Import data formats (relevant ones)	Over 100 (including e.g. *.kml, *.kmz, *.gpx, *.csv, *.txt)
Export data formats (relevant ones)	Over 100 (including e.g. *.kml, *.kmz, *.gpx, *.csv, *.txt)
Download	http://www.gpsbabel.org/download.html
Online resources, help and tutorials	User guide and documentation: http://www.gpsbabel.org/readme.html

Table 8: *GPSBabel* fact sheet

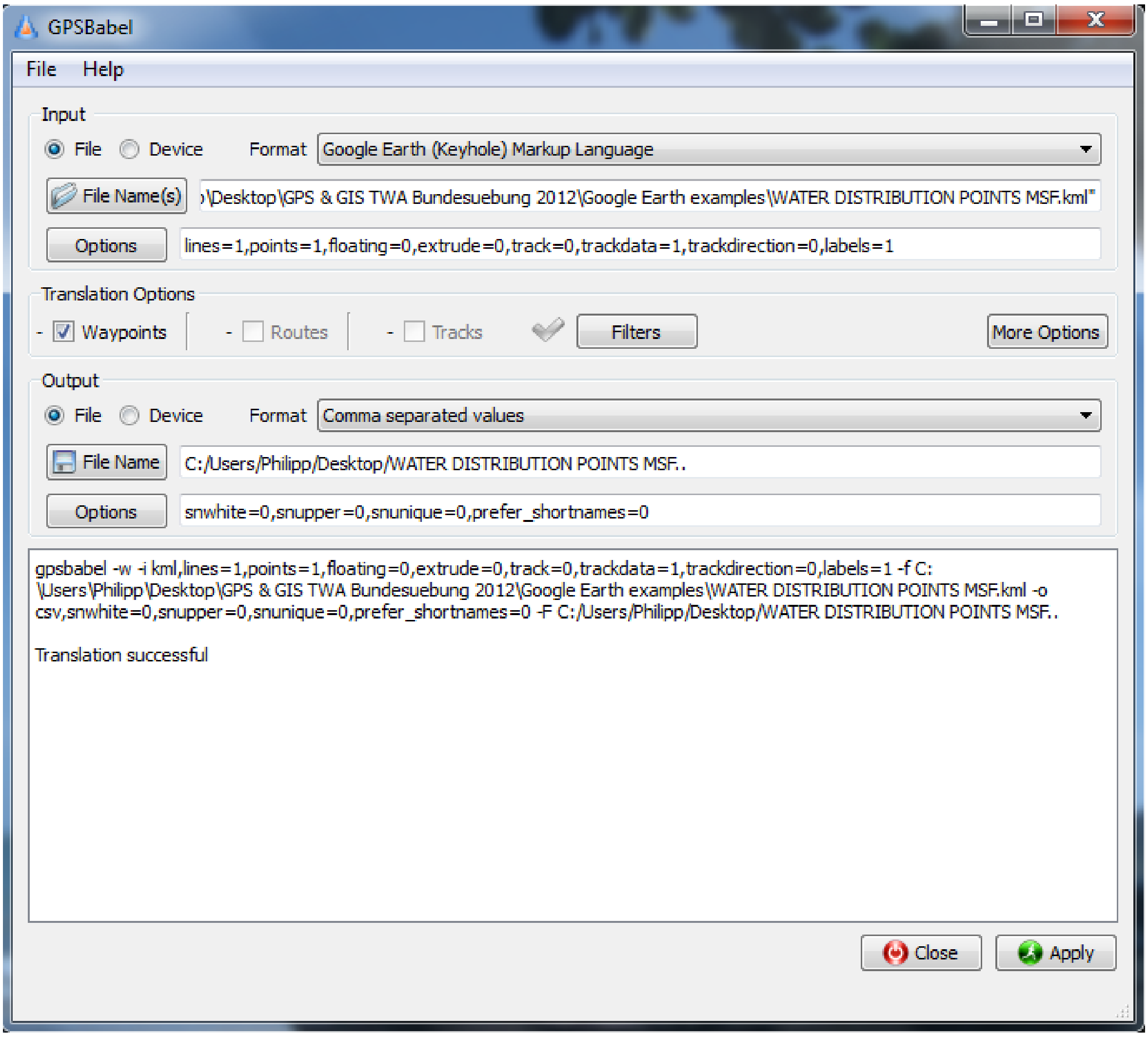


Figure 11: Screenshot of *GPSBabel* showing the conversion of a *Google Earth* layer with water distribution points to a spread sheet file for print or further processing

4.2.3.3 Geotag

As indicated by its name, *Geotag* is a photo geo-tagging tool; one of the few which is available for free, portable, OS independent and supporting multiple languages. The software provides additional functionalities which are not supported by *Garmin BaseCamp* or the other software listed. These are:

- Adding coordinates plus information on the administrative units of the position (country, province, city and location) into the metadata of an image through the built-in *GeoNames* web service (http://www.geonames.org/) – a worldwide geographical database of geographical names and unique features (*Figure 12*); like the coordinates, this data is embedded within the image file itself and can be retrieved quickly and easily for further purposes with image viewers

- Export geo-tagged photos in a custom size embedded in *Google Earth *.kmz* files, so they can be shared and viewed with software which does not support automatic geo-location of images, like *Google Earth* itself

The most noteworthy shortcomings for using *Geotag* are:

- The software requires external programs which are not included (*Table 9*) and therefore the settings need to be adjusted before its first use
- The *GeoNames* tagging service only works when connected to the internet

Geotag Fact Sheet (latest version 0.082)	
Supported OS	Any OS for which Java SE 6 or later is available (e.g. Windows XP or later, Mac OS X 10.5 or later, Linux)
Minimum system requirements	*Windows and Mac* Hard Disk: 3 MB free space OS Components: Java SE 6 (http://www.java.com/en/) External Programs: GPSBabel (*Table 8*) and ExifTool (3.3 MB) (http://www.sno.phy.queensu.ca/~phil/exiftool/) *Mac* 64-bit Intel-based Mac
Available languages	Brazilian Portuguese, Czech, Danish, Dutch, English, French, German
Import data formats (relevant ones)	GNSS (*.gpx) Images (*.jpg, *.jpeg, *.tif, *.tiff)
Export data formats (relevant ones)	Google Earth (*.kmz)
Download	http://geotag.sourceforge.net/?q=node/4
Online resources, help and tutorials	Documentation: http://geotag.sourceforge.net/?q=node/11 User forum: http://sourceforge.net/projects/geotag/forums

Table 9: *Geotag* fact sheet

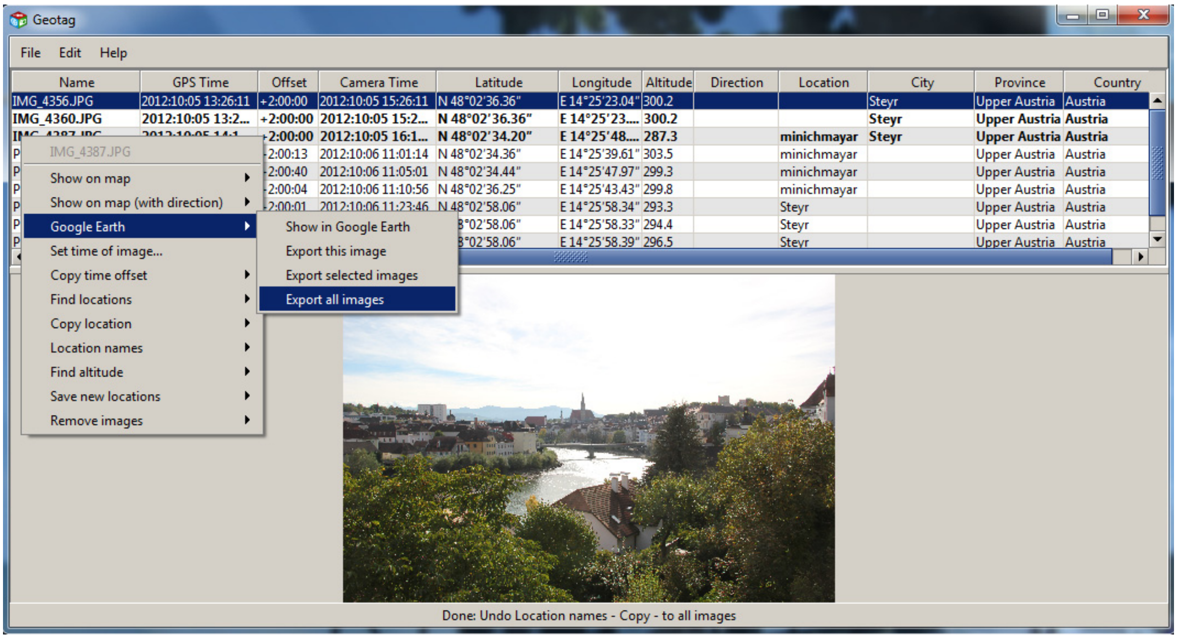


Figure 12: Screenshot of *Geotag* showing geo-tagged photos with added location information and export function for *Google Earth*

4.2.3.4 DNR GPS

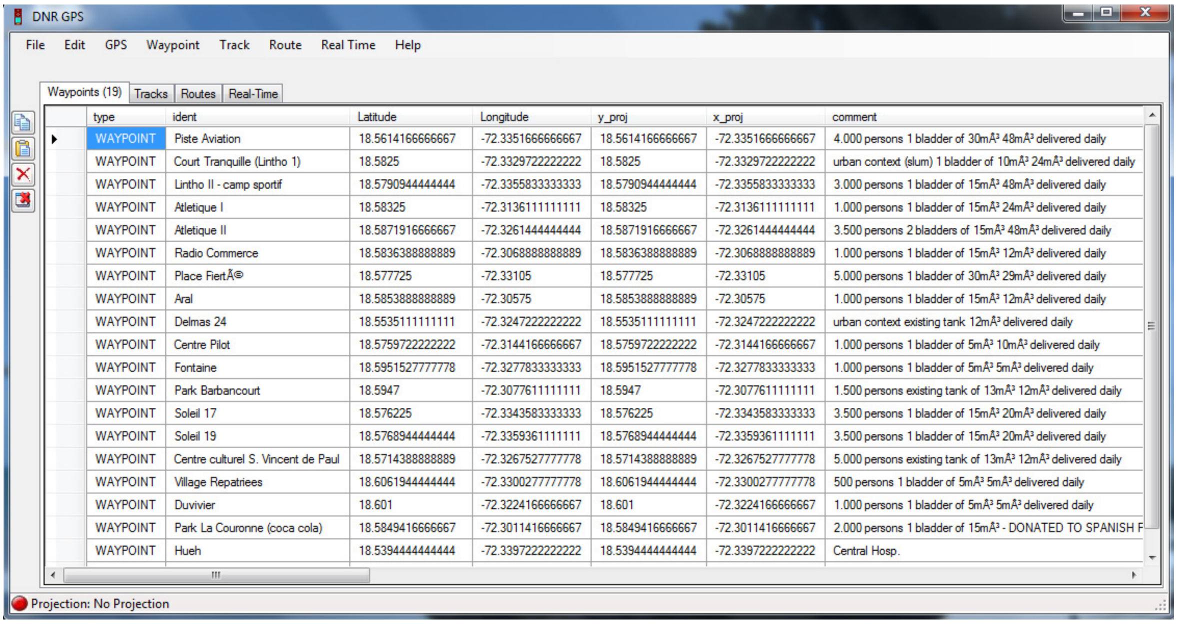
DNR GPS was originally developed to transfer data between *Garmin* handheld GPS receivers and professional GIS software like *ESRI's ArcGIS*. Out of the free and light software tools designed to make specific data created with GIS software compatible with geo-browsers, map viewers and GNSS receivers, for the still widely used ESRI shapefiles (**.shp*), *DNR GPS* offers the best results and least errors. It has become a standard software tool of UN GIS units and the logistics cluster [LOG-10]. The main interface consists of a spread sheet in which data can be loaded or manually entered and directly manipulated (*Figure 13*). Depending on the kind of attributes of e.g. water distribution points needed, the columns can be renamed and adjusted individually to include additional information, descriptions or comments. The basic features and applications of *DNR GPS* for emergency response include:

- Downloading and uploading data from/to a GNSS device
- To geo-locate photos (only coordinates) with GNSS data
- Converting commonly used GIS vector data formats, e.g. ESRI shapefiles (**.shp*), to be used e.g. with *Google Earth, Garmin BaseCamp,* spread sheet programs and GNSS handhelds (and vice versa)
- To create in particular point layers from coordinates which are only available in digital or printed spread sheets, or any other format which cannot be directly used with *Google Earth* or *Garmin BaseCamp* and transferred to a GNSS device
- It is portable and can therefore be operated on flash drives or be installed on other computers in case there is no internet access available

The most noteworthy shortcomings are, that *DNR GPS* is only available for *Windows XP or later* and in English.

DNR GPS Fact Sheet (latest version 6.0.0.15)	
Supported OS	Windows XP or later
Minimum system requirements	*Windows* Hard Disk: 74 MB free space OS Components: .NET framework 4
Available languages	English
Import data formats (relevant ones)	GIS (*.shp, *.map, *.gml, *.txt) Google Earth (*.kml) GNSS (*.gpx, Garmin)
Export data formats (relevant ones)	GIS (*.shp, *.map, *.gml, *.txt) Google Earth (*.kml) GNSS (*.gpx, Garmin)
Download	http://www.dnr.state.mn.us/mis/gis/DNRGPS/DNRGPS.html
Online resources, help and tutorials	User guide and documentation (also included in download as pdf): http://maps1.dnr.state.mn.us/dnrgps/index.html

Table 10: *DNR GPS* fact sheet



type	ident	Latitude	Longitude	y_proj	x_proj	comment
WAYPOINT	Piste Aviation	18.5614166666667	-72.3351666666667	18.5614166666667	-72.3351666666667	4.000 persons 1 bladder of 30mÂ³ 48mÂ³ delivered daily
WAYPOINT	Court Tranquille (Lintho 1)	18.5825	-72.3329722222222	18.5825	-72.3329722222222	urban context (slum) 1 bladder of 10mÂ³ 24mÂ³ delivered daily
WAYPOINT	Lintho II - camp sportif	18.5790944444444	-72.3355833333333	18.5790944444444	-72.3355833333333	3.000 persons 1 bladder of 15mÂ³ 48mÂ³ delivered daily
WAYPOINT	Atletique I	18.58325	-72.3136111111111	18.58325	-72.3136111111111	1.000 persons 1 bladder of 15mÂ³ 24mÂ³ delivered daily
WAYPOINT	Atletique II	18.5871916666667	-72.3261444444444	18.5871916666667	-72.3261444444444	3.500 persons 2 bladders of 15mÂ³ 48mÂ³ delivered daily
WAYPOINT	Radio Commerce	18.5836388888889	-72.3068888888889	18.5836388888889	-72.3068888888889	1.000 persons 1 bladder of 15mÂ³ 12mÂ³ delivered daily
WAYPOINT	Place FiertÃ©	18.577725	-72.33105	18.577725	-72.33105	5.000 persons 1 bladder of 30mÂ³ 29mÂ³ delivered daily
WAYPOINT	Aral	18.5853888888889	-72.30575	18.5853888888889	-72.30575	1.000 persons 1 bladder of 15mÂ³ 12mÂ³ delivered daily
WAYPOINT	Delmas 24	18.5535111111111	-72.3247222222222	18.5535111111111	-72.3247222222222	urban context existing tank 12mÂ³ delivered daily
WAYPOINT	Centre Pilot	18.5759722222222	-72.3144166666667	18.5759722222222	-72.3144166666667	1.000 persons 1 bladder of 5mÂ³ 10mÂ³ delivered daily
WAYPOINT	Fontaine	18.5951527777778	-72.3277833333333	18.5951527777778	-72.3277833333333	1.000 persons 1 bladder of 5mÂ³ 5mÂ³ delivered daily
WAYPOINT	Park Barbancourt	18.5947	-72.3077611111111	18.5947	-72.3077611111111	1.500 persons existing tank of 13mÂ³ 12mÂ³ delivered daily
WAYPOINT	Soleil 17	18.576225	-72.3343583333333	18.576225	-72.3343583333333	3.500 persons 1 bladder of 15mÂ³ 20mÂ³ delivered daily
WAYPOINT	Soleil 19	18.5768944444444	-72.3359361111111	18.5768944444444	-72.3359361111111	3.500 persons 1 bladder of 15mÂ³ 20mÂ³ delivered daily
WAYPOINT	Centre culturel S. Vincent de Paul	18.5714388888889	-72.3267527777778	18.5714388888889	-72.3267527777778	5.000 persons existing tank of 13mÂ³ 12mÂ³ delivered daily
WAYPOINT	Village Repatriees	18.6061944444444	-72.3300277777778	18.6061944444444	-72.3300277777778	500 persons 1 bladder of 5mÂ³ 5mÂ³ delivered daily
WAYPOINT	Duvivier	18.601	-72.3224166666667	18.601	-72.3224166666667	1.000 persons 1 bladder of 5mÂ³ 5mÂ³ delivered daily
WAYPOINT	Park La Couronne (coca cola)	18.5849416666667	-72.3011416666667	18.5849416666667	-72.3011416666667	2.000 persons 1 bladder of 15mÂ³ - DONATED TO SPANISH F
WAYPOINT	Hueh	18.5394444444444	-72.3397222222222	18.5394444444444	-72.3397222222222	Central Hosp.

Figure 13: Screenshot of *DNR GPS* showing a loaded layer with water distribution points in an editable spread sheet form for further processing

4.2.4 Alternative to Proprietary Software for the WASH Cluster GIS: Quantum GIS

As has been already revealed earlier, GIS in humanitarian emergency response in general still relies on what can be called conventional, but sophisticated and powerful desktop GIS software such as the *ESRI ArcGIS* software suit which is used by the WASH cluster [MAP-11]. Many organisations lack the resources to acquire and deploy such solutions which require significant investment in money and trainings [ibid.]. In terms of functionality, *Quantum GIS (QGIS)* is no different than other professional GIS programs, but it is free and open-source portable software. In addition to that, MapAction [ibid.] points out that it has fast access to most standard raster and vector formats (*Table 11*) and a user-friendly interface; it is argued that *QGIS* allows users with a basic understanding of GIS and its applications to work with it in a productive way. The trainings of MapAction in disaster settings suggest that *QGIS* even allows for ad hoc sessions for already experienced users to learn and refresh the most needed capabilities. However, trainings in its use are still far more time-consuming than for the software and applications mentioned so far and more importantly, they require more previous knowledge of users.

Quantum GIS Fact Sheet (latest version 1.8.0)	
Supported OS	Cross-platform (e.g. Windows XP or later, Mac OS X 10.6 or later, Linux)
Minimum system requirements	None specified Hard Disk: 600 MB free space
Available languages	47 languages
Import data formats (relevant ones)	All listed so far in *Table 5,6,8,9 and 10* Spatially-enabled tables using PostGIS and SpatiaLite, vector formats supported by the installed OGR library, including ESRI shapefiles, MapInfo, SDTS, GML and many more Raster and imagery formats supported by the installed GDAL (Geospatial Data Abstraction Library) library, such as GeoTiff, Erdas Img., ArcInfo Ascii Grid, JPEG, PNG and many more Databases (e.g. *Microsoft Access, ESRI ArcGIS*) GRASS raster and vector data from GRASS databases Online spatial data served as OGC-compliant Web Map Service (WMS) or Web Feature Service (WFS) OpenStreetMap data
Export data formats (relevant ones)	See import data formats
Download	http://www.qgis.org/index.php
Online resources, help and tutorials	Multilingual user guide: http://www.qgis.org/en/documentation/manuals.html Wiki with tutorials: http://hub.qgis.org/projects/quantum-gis/wiki/How_do_I_do_that_in_QGIS Asking questions: http://gis.stackexchange.com/questions/tagged/qgis MapAction's *Field Guide to Humanitarian Mapping* [MAP-11]

Table 11: *Quantum GIS* fact sheet

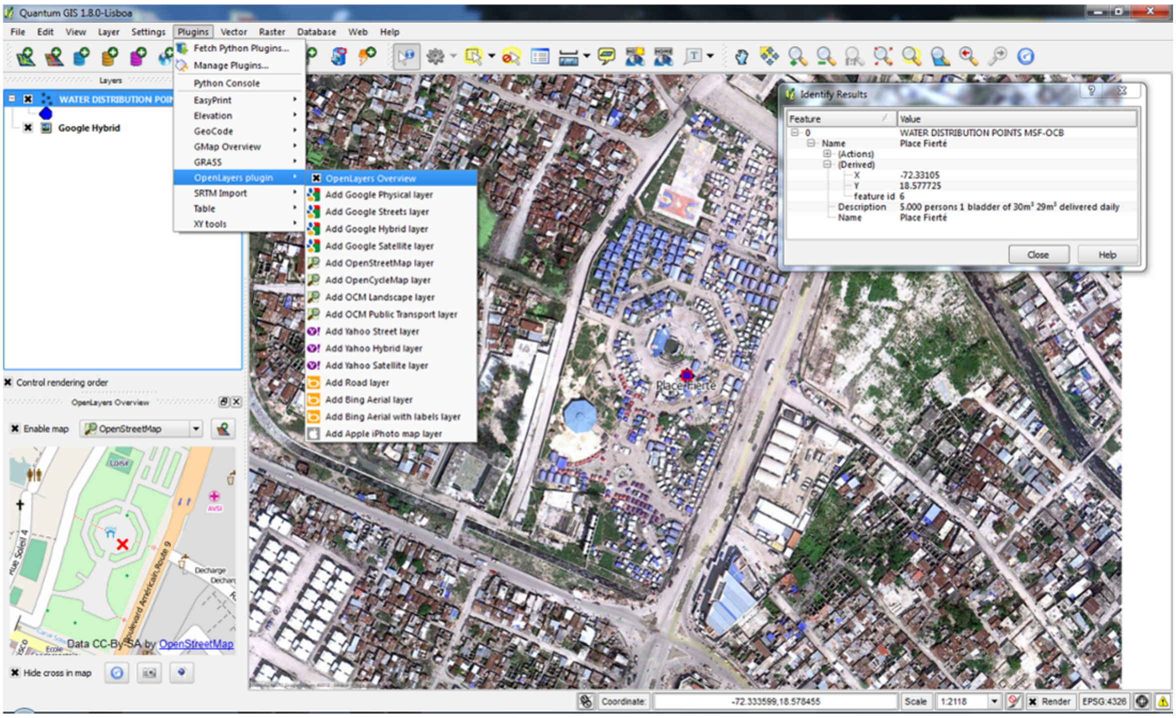


Figure 14: Screenshot of *Quantum GIS* showing the *OpenLayers plugin* in combination with a water distribution point layer

QGIS provides great flexibility in terms of functionality and GUI design and can be adapted more easily to users' needs than most other commercially available GIS software. The basic pre-installed functions are available as toolbars/icons and can be turned on/off and placed anywhere in the main window so that only the tools needed and regularly worked with are displayed, making the whole interface less complex to navigate. Additionally, over 100 plugins with specific functionalities and/or usability features are available, which can be installed individually through the software's main interface. Some plugins also provide access to data which are otherwise only accessible with other software or web browser based applications; an example of this kind is the *OpenLayers plugin* which has also been provided by e.g. the Sahana DM system (*Figure 5*) mentioned in the previous chapter. When connected to the internet, this plugin provides access to maps and satellite/aerial imagery of different providers (*Figure 14*). As the data quality of different providers varies from area to area this can be regarded a valuable benefit, not just for emergency response.

With respect to the use of GIS within the WASH cluster, the WASH IM tools and their related outputs (e.g. overview maps) described in *Chapter 2*, *QGIS* provides all technical capabilities needed and is fully interoperable with the developed tools. In general, a recurrent aspect of GIS approaches in emergency response which foresee to put GIS in the sole responsibility of hired short-term specialist is, that it takes a considerable amount of time until the geographic information outputs match the demands [JUL-08]. Moreover, as indicated earlier, several times the WASH clusters GIS services could not be set up (in time) as GIS specialists were simply hard to find [ibid.]. Therefore it is argued, that the way ahead with GIS of the WASH cluster should reflect on the idea of providing a pool of

WASH staff with the needed GIS software skills. GIS practitioners do not become obsolete, just their role shifts – from providing rather basic GIS services to facilitating trainings, refresher crash courses, technical support and equipping others with the needed skills as well as adapting the tools and applications for users. Using free GIS software that can be adjusted to various degrees of functionality like e.g. *QGIS* can aid such an approach.

5 Data Standards, Sources and Applications

Reliable and up-to-date data form a crucial part in any disaster response operation. Available and accessible base maps or satellite imagery are as essential as data standards, the latter especially for sharing geo-data. The first section begins with outlining the latest approach towards standardised geo-data and their benefits for emergency response. The second section then reviews sources for base maps and core geo-data which can be used with *Google Earth*, *Garmin BaseCamp* and GNSS handhelds. The third section concludes with identifying relevant (quasi-)standards for WASH field work and introduces to easy to use/implement tools as well as guidelines for geo-browser based information sharing. Considerations on basic GIS applications for collecting, processing and sharing geo-referenced data are illustrated with respect to interoperability and data quality.

5.1 Approaches towards Standardised Datasets

Efforts to provide standards for managing and sharing spatial data in humanitarian emergency response have increased significantly over the past few years. The beginning made standards in the form of *metadata* to describe what the data is about, *file formats* for data exchange and a *common vocabulary* for spatial features [KEM-06b]. Several initiatives from different backgrounds (UN agencies, academia, GIS NGOs and mapping communities) have also been working on ambitious and more detailed standardisation concepts – e.g. the *Humanitarian Spatial Data Model* [KEM-06b] – which brought further attention to the importance of standards for the organisation and exchange of geographic information. But so far, the most progressive approach towards standardised datasets for GIS constitutes the implementation of *Common and Fundamental Operational Datasets* in disaster response which have been endorsed by the IASC in 2010 [IAS-10]. These datasets developed out of OCHA's mandated responsibility within the UN system for developing and improving baseline data on regions and countries affected by humanitarian crisis [IAS-08a]. *Figure 15* on the next page shows the outline of their structure and contents. The datasets can be accessed and downloaded by everyone through the web based *COD/FOD Registry* (http://cod.humanitarianresponse.info/). Likewise, individuals and organisations can submit their datasets through this registry to be considered for being included in the CODs/FODs after review.

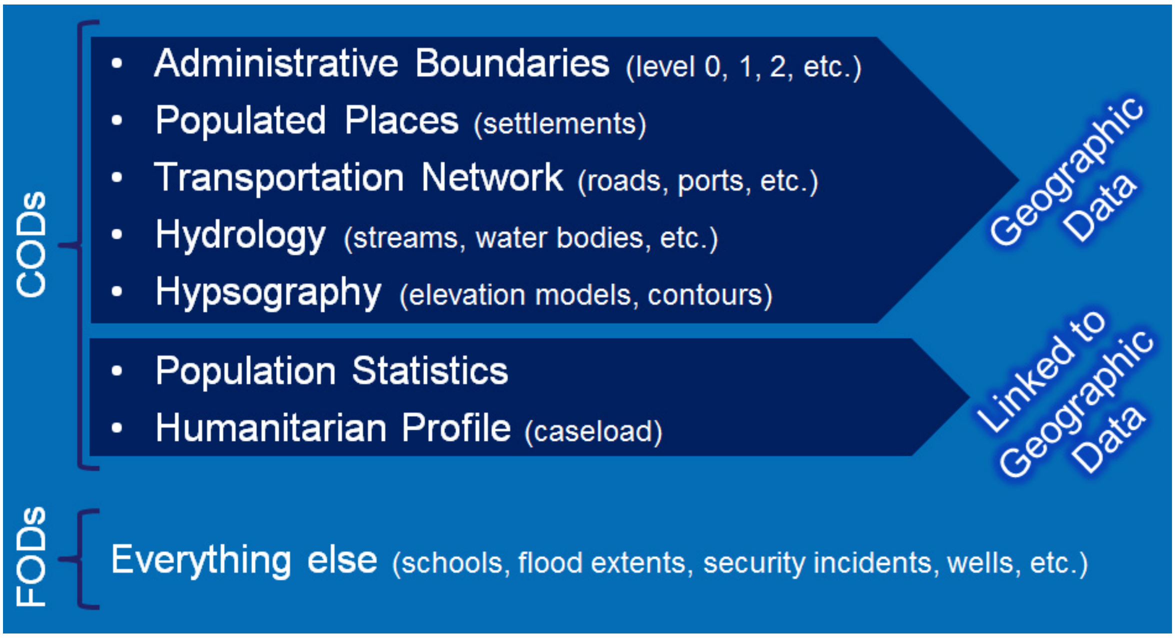
The IASC has developed *Guidelines on Common Operational Datasets in Disaster Preparedness and Response* to help national authorities and humanitarian organisations exchange data, thereby improving the effectiveness of humanitarian response [IAS-10]. These state, that the primary audience for these guidelines are the humanitarian country teams, UN agencies and other international organisations, the IFRC and national societies and NGO representatives, who are engaged in disaster risk management actions (particularly inter-agency contingency planning in order to increase their level of preparedness and enhance their ability to respond to emergencies). According to them, the datasets are defined as follows [ibid.]:

- **Common Operational Datasets (CODs)**

  Common operational datasets are predictable, core sets of data needed to support operations and decision making for all actors in a humanitarian response. Some of the CODs, such as data on the affected population and damage to infrastructure, will change during the different phases of the response and therefore will need to be frequently updated and maintained. Other CODs, such as rivers and village locations, are likely to remain the same throughout the response. The CODs are proactively identified and maintained prior to an emergency as part of data preparedness measures and made available by OCHA (or pre-agreed in-country alternate) within 48 hours of a given humanitarian emergency. All CODs must meet minimum criteria for format and attribute information in accordance with national standards.

- **Fundamental Operational Datasets (FODs)**

  Fundamental operational datasets are datasets required to support multiple cluster/sector operations and complement the common operational datasets. These datasets are characterised by thematic areas (such as health facilities) and are made available as soon as possible after the onset of an emergency, given availability.



Source: COD/FOD Registry

Figure 15: *Common and Fundamental Operational Datasets* scheme

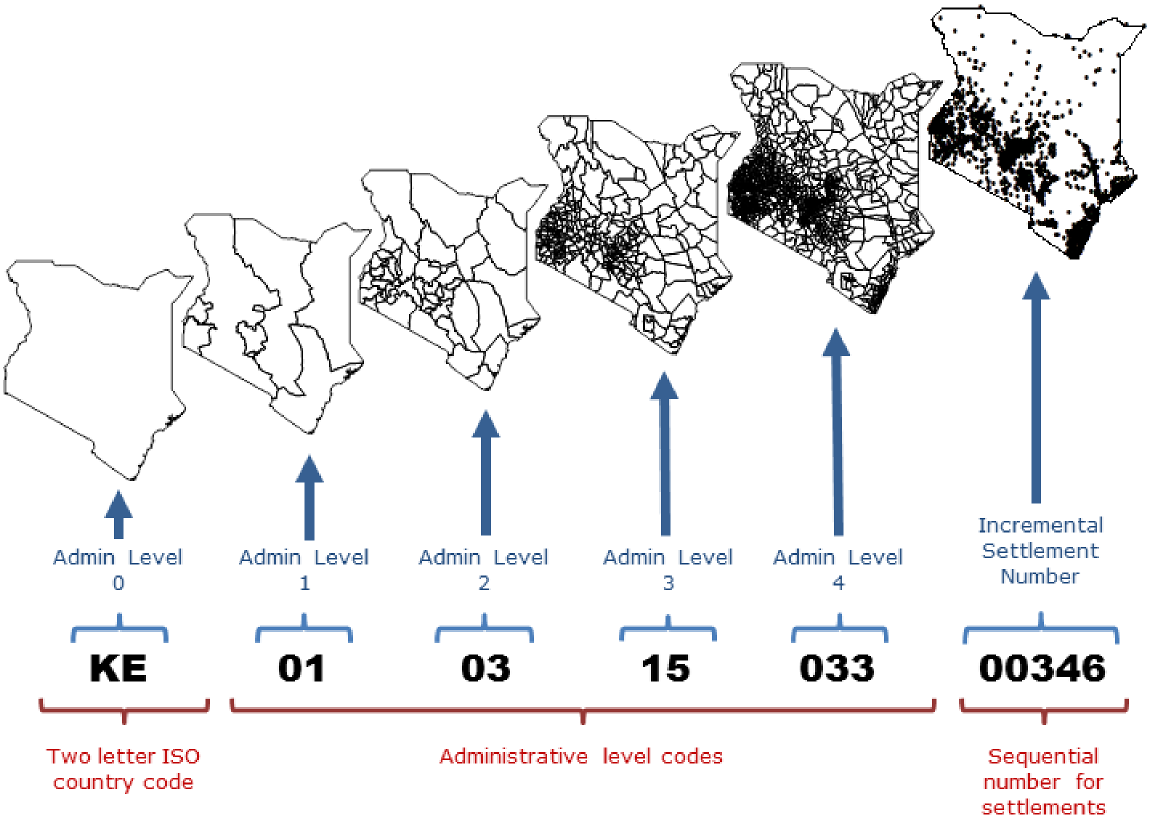
The CODs are conceived as datasets from which various analytical products (e.g. reports, maps) can be made, not the product themselves. Hence, their typical users are considered to be information managers or reporting staff [IAS-11]. Within the CODs, the *humanitarian profile* dataset (*Figure 15, Table 12*) is unique in its operational importance (e.g. for humanitarian planning and needs assessment) and unlike the other CODs, it cannot be compiled before the onset of an emergency [ibid.]. *Table 12* below shows the minimum list of datasets and their features to be included in the CODs as well as the recommended governance arrangements.

Dataset	Recommended Governance	Mandatory Data Characteristics
Humanitarian Profile (disaggregated by admin level and populated place)	- Guardian: OCHA - Sponsor: OCHA - Source: Government, Assessments, UNHCR, IOM	- Internally Displaced - Non-displaced affected - Host family/resident community affected - Refugee - Dead - Injured - Missing
Population Statistics	- Guardian: OCHA - Sponsor: OCHA,UNFPA (Other potential sponsors could include UNDP, Government agencies or INGOs) - Source: Government	- Total population by admin level (individuals) - Total population by admin level (number of households) - Age - Sex - Average family size by admin level - Unique identifier
Administrative Boundaries (Geographic) admin level 1 admin level 2 admin level 3 admin level 4	- Guardian: OCHA - Sponsor: OCHA (Other potential sponsors could include UNDP, Government agencies or INGOs) - Source: Government	- Unique identifier (P-Code) - Name
Populated Places (Geographic)	- Guardian: OCHA - Sponsor: OCHA, (other potential sponsors could include UNDP, government agencies or INGOs) - Source: Government	- Unique identifier (P-Code) - Names - Size classification - Population statistics - Status if capital of administrative division - Type (village, spontaneous settlement, collective center, planned settlement)
Transportation Network (Geographic)	- Guardian: OCHA - Sponsor: Logistic Cluster - Source: Government	- Roads (classified by size) - Railways - Airports/helipads - Seaports
Hydrology (Geographic)	- Guardian: OCHA - Sponsor: OCHA (other potential sponsors could include UNDP, Government agencies or INGOs) - Source: Government	- Rivers (classified by size) - Water bodies
Hypsography (Geographic)	- Guardian: OCHA - Sponsor: UNOSAT - Source: Remote sensing, Government	- Elevation - Resolution

Table 12: Minimum list of datasets for CODs [IAS-10]

Each COD and FOD has a *guardian*, a designated *sponso*r and *source* whose roles and responsibilities are outlined in the respective IASC guidelines [IAS-10]: The *guardian* (usually OCHA) takes responsibility for facilitating the distribution of the “best” available CODs and FODs in emergencies while managing forums for updates and distribution communication. The *sponsor* of a dataset is responsible for identifying and liaising with relevant sources to analyse, collate, clean and achieve consensus around a specific operational dataset. Finally, each dataset will have designated *source(s)* (or owner(s)), such as: a national authority/agency, cluster, NGO, UN agency, the IFRC that agrees to be fully responsible for the development, maintenance and metadata associated with a dataset and control distribution restrictions.

Another important standard, which is also part of the CODs and FODs are unique geographic identification codes to identify a specific location or feature on a map or within a database. If no national coding scheme is already available and no informal coding scheme that has been adopted by some national or international organisations, then a *Place code (P-code)* system is created. P-codes address the recurring problem in humanitarian field work of confusion over places (towns, villages) known by differing names [MAP-11]. *Figure 16* below shows the basic structure of the P-code system with the example of Kenya, a country with four administrative boundary levels.



Source: OCHA IM WIKI

Figure 16: P-Code scheme

Standards for P-codes have been derived from a variety of international organisations and can be accessed through the *OCHA IM WIKI* (https://sites.google.com/site/ochaimwiki/). In addition to the P-code system, which can cover administrative units down to the level of single settlements, there are also unique numeric identifiers for populated places in relation to exact geographic positions. These are called *Stable Site Identifiers (SSIDs)* and are used when referring to post-disaster spontaneous settlement sites where the P-code system reaches its limits (e.g. after the earthquake in Haiti in 2010, where numerous spontaneous settlement sites were located closely to each other and only temporary). While P-codes refer to administrative units, SSIDs refer to single geographic coordinates within an administrative unit. A brief summary of frequently asked questions regarding P-Codes and SSIDs with examples from Haiti prepared by OCHA can be found through *OneResponse* (http://oneresponse.info/resources/imtoolbox/publicdocuments/What_Are_PCodes_and_SSIDs_ver3_Current.pdf).

When P-codes and/or SSIDs are created for an emergency response operation, all humanitarian organisations are admonished to use them when providing data to promote cooperation and information sharing. Using the P-codes and SSIDs for data management enables organisations to combine their own information with datasets from other organisations. Thus, duplication of efforts (e.g. assessments of the same site) can be avoided and the planning of resources can be improved (e.g. when data from the shelter cluster on construction activities is combined with sanitation data from the WASH cluster). P-Codes and SSIDs are distributed through OCHA and can be obtained from the disaster response operation's web platform through *OneResponse*. Usually they are made available in different file formats including spread sheets (*Microsoft Excel *.xls*), *Google Earth* files (**.kml/kmz*) and common GIS software formats (*ESRI shapefile *.shp*).

For WASH emergency response, datasets featuring P-codes/SSIDs and the CODs/FODs can be a highly valuable source of spatially referenced information. The CODs can offer base map features (such as roads, populated places or administrative boundaries) and baseline data (such as population figures or number of affected people); and the FODs may provide geo-data even more relevant to WASH interventions such as contact details and locations of cholera treatment centres or updated IDP locations. However, as of now the quantity and quality of the datasets provided through the *COD/FOD registry* differs greatly depending on the country. Also, it can be considered that the high number of smaller disasters with less numbers of affected may not be covered through the CODs and FODs.

Another issue is the file formats in which the datasets are provided. According to the *OCHA IM WIKI* they should be provided for download at least as GIS software formats (ESRI shapefiles **.shp* or Geography Markup Language files **.gml*); an *Microsoft Excel* (**.xls*) version of the tabular data formatted for easy use by reports officers and others is highly recommended, and other formats such as *Google Earth* files (**.kml/kmz*) can be included if desired. Following, many CODs and FODs are only available in data formats which cannot be viewed and used with light and user-friendly GIS software tools such as *Google Earth* and *Garmin BaseCamp*. From a technical standpoint there is no reason why these datasets cannot be converted to files compatible with *Google Earth*, even when providing the same quality of data and information.

5.2 Availability and Accessibility of Geographical Data

The CODs and FODs can improve the content of core geo-data (e.g. populated places). Overall, as mentioned earlier in *Chapter 3*, there are relatively few options for/to geo-data available and accessible with *Google Earth* and *Garmin BaseCamp* – keeping in mind a user-friendly approach at the same time. *Google Earth*, as a geo-browser, includes the access to satellite imagery and several data layers which are downloaded and saved automatically in its cache for offline use when viewed. *Google Earth's* most relevant data layers for emergency response include: *Borders and Labels, Places* and *Roads* which can be extended through e.g. *Local Place Names, Place Categories* and *Transportation* symbols (see the selected check boxes in *Figure 17*).

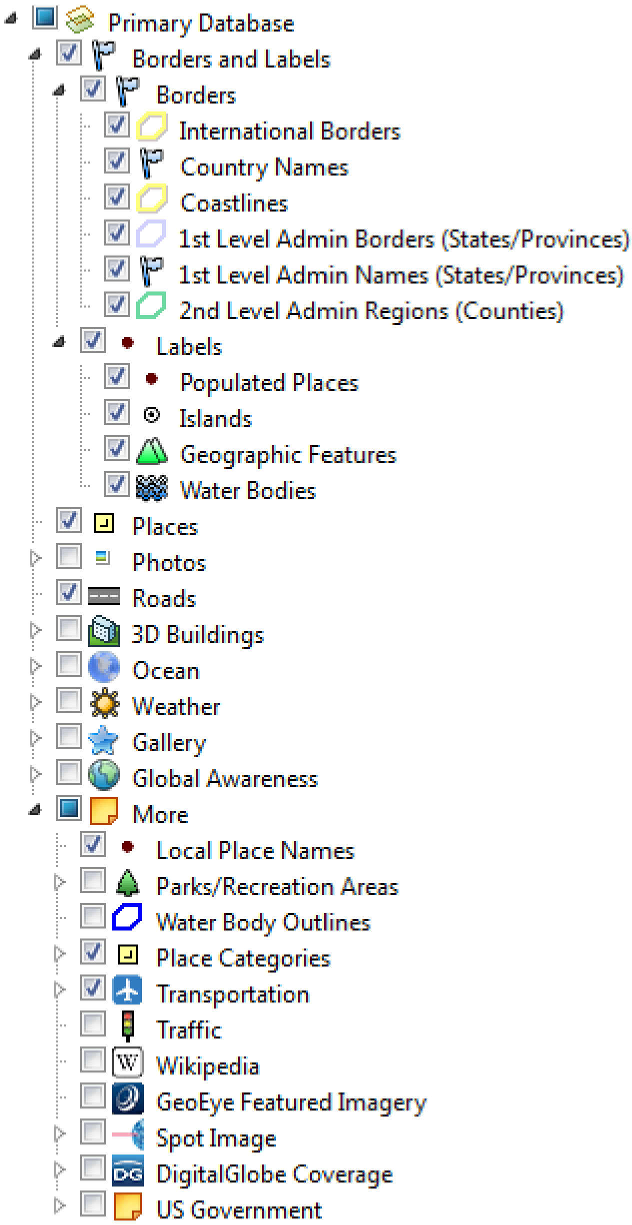


Figure 17: *Google Earth* data layers

Anyhow, for remote and less densely populated areas outside a countries centre the information provided through the *Google Earth* data layers is often scarce. Through network links (embedded in a *.*kml/kmz* file) additional data layers as well as map overlays can be loaded into *Google Earth*, intersected and viewed together with the *Google Earth* data layers, thereby enriching the contents displayed with additional information. Such applications are being developed by *Google Earth* communities and are constantly enhanced. Two popular applications that can be regarded to provide added value in disasters are presented below: *GeoNames Features* and *Google Earth Map Overlays*. These network-linked *kml/kmz* files appear as a regular *kml/kmz* file with layers which can be turned on/off. The big difference (or disadvantage) however is that the data of such layers is not cached and therefore not available for offline use.

- **GeoNames Features**

  The *GeoNames Features* network link exhibits features available through the *GeoNames* database (http://www.geonames.org/). It can be downloaded as a *kml* file (http://www.geonames.org/kml/feature-networklink.kml) and provides the following set of relevant layers with point data:

  - Administrative Boundary Features (e.g. country, state, region)
  - Hydrographic Features (e.g. stream, lake)
  - Area Features (e.g. locality, area)
  - Populated Place Features (e.g. city, village)
  - Road/Railroad Features (e.g. road, railroad)
  - Spot Features (e.g. spot, facility)
  - Hypsographic Features (e.g. mountain, hill, rock)

- **Google Earth Map Overlays**

  The *Google Earth Map Overlays* (overview, overlay description and download (requires a *Google* account) at http://ge-map-overlays.appspot.com/) network link displays a variety of road maps, terrain maps and alternative satellite image sets for the area currently viewed in *Google Earth*. It includes overlays of various providers with the following being the most relevant to emergencies:

  - OpenStreetMap
  - Cloudmade (i.e. OSM map rendered in a different style)
  - Google Maps (Road, Terrain)
  - Bing Maps (Road, Aerial, Hybrid)

The following figures on the next three pages show the differences regarding data quality in comparing only *Google Earth* imagery and data layers (*Figure 18*) and diverse *Google Earth Map Overlays* with the populated places layer of *GeoNames Features* and the *Google Earth* data layers for the Sudan/South Sudan border region along the White Nile (*Figure 19* to *Figure 23*).

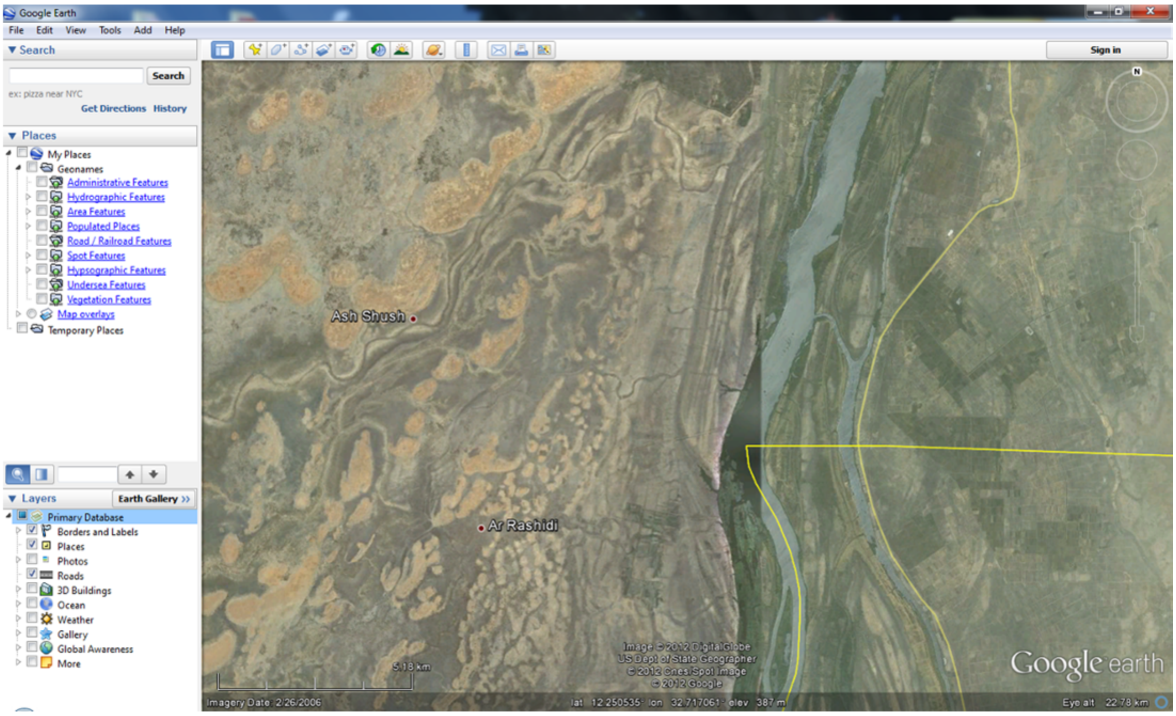


Figure 18: *Google Earth* data for Sudan/South Sudan White Nile border region

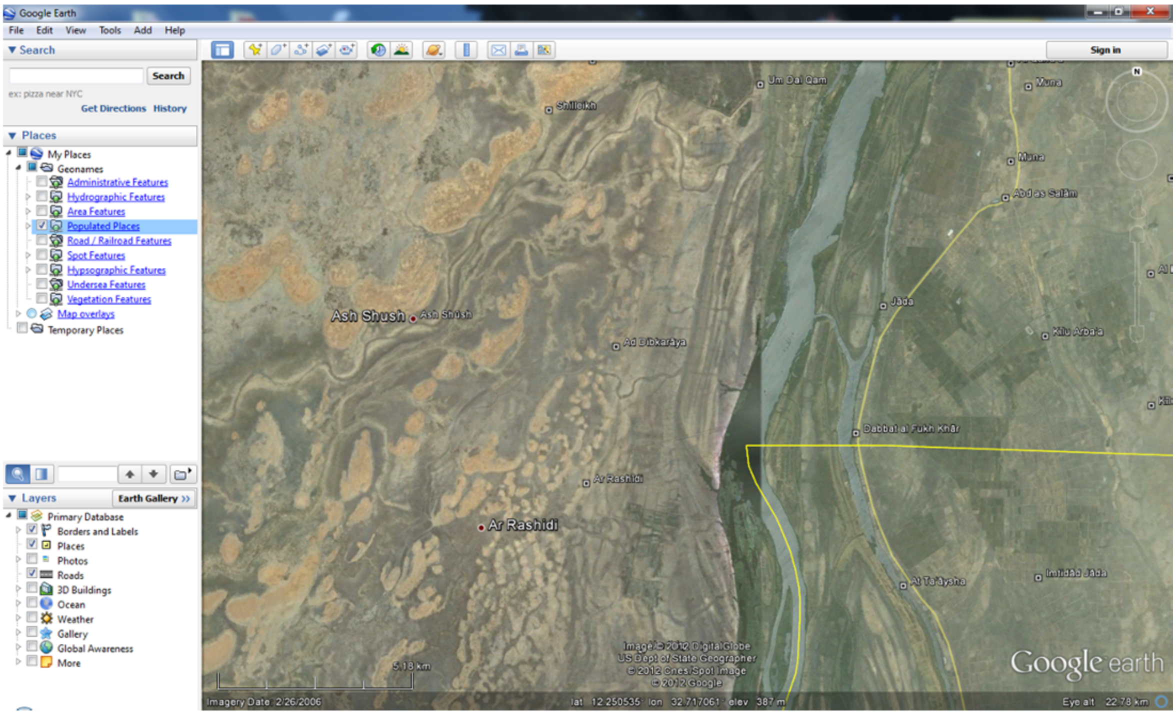


Figure 19: *Google Earth* data and *GeoNames* populated places layer for Sudan/South Sudan White Nile border region

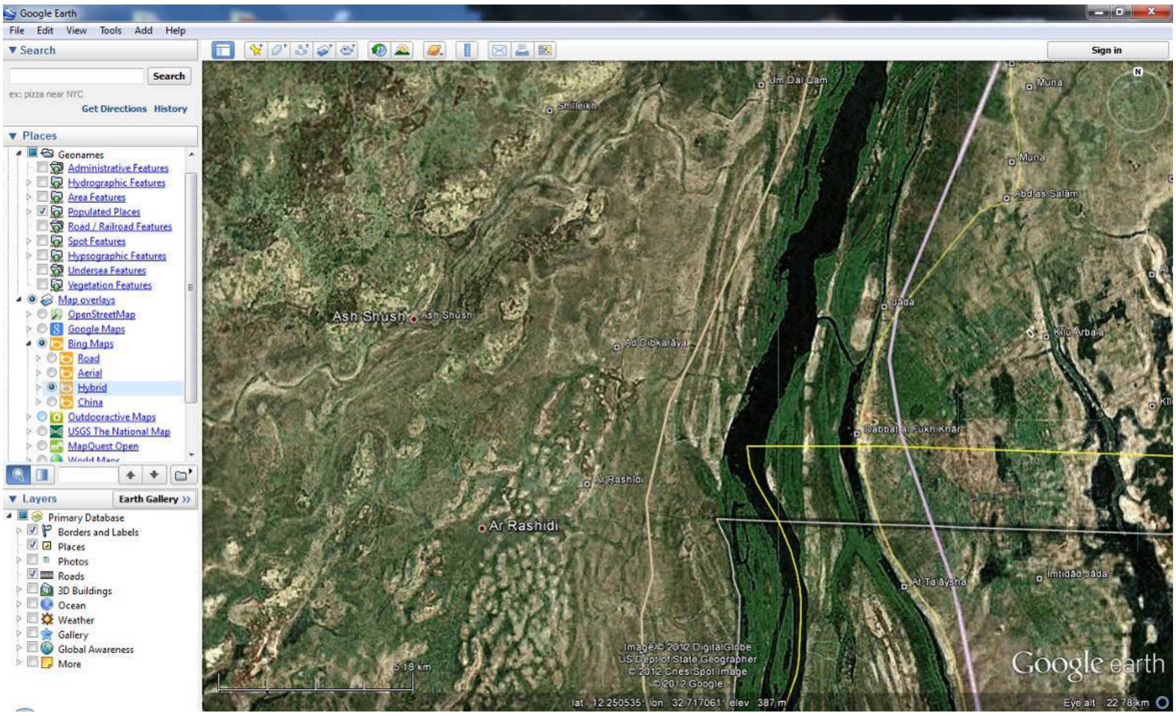


Figure 20: *Bing Maps hybrid* data with *Google Earth* layers and *GeoNames* populated places layer for Sudan/South Sudan White Nile border region

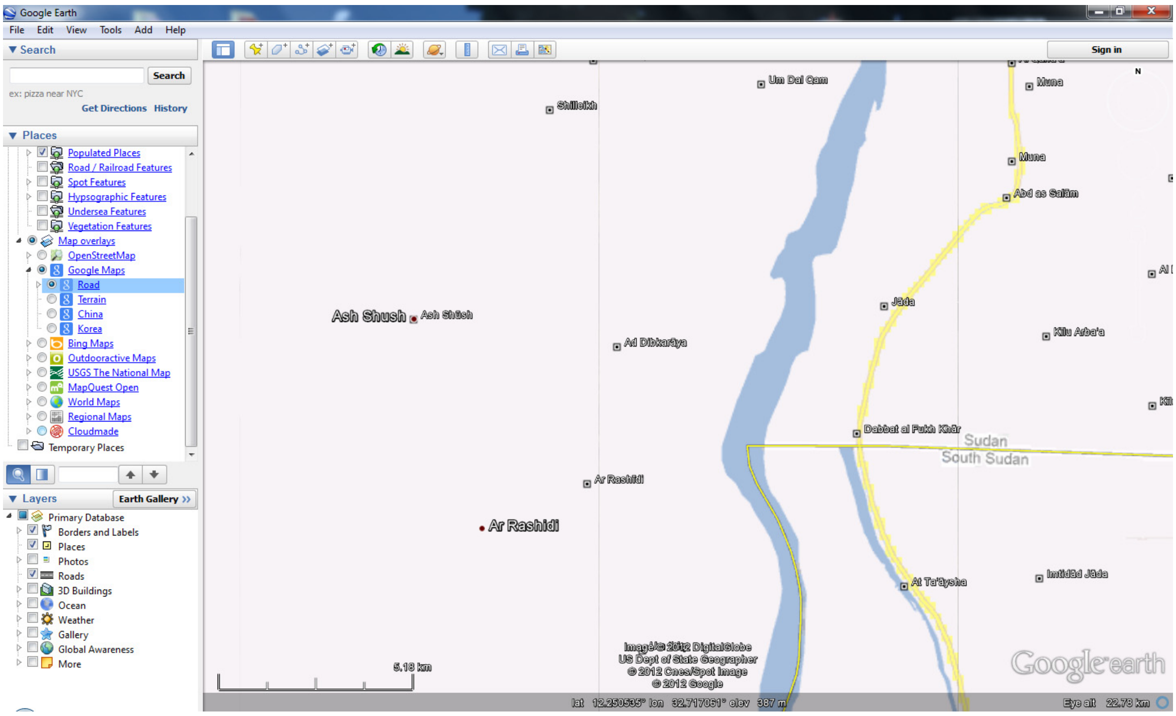


Figure 21: *Google Maps* data with *Google Earth* layers and *GeoNames* populated places layer for Sudan/South Sudan White Nile border region

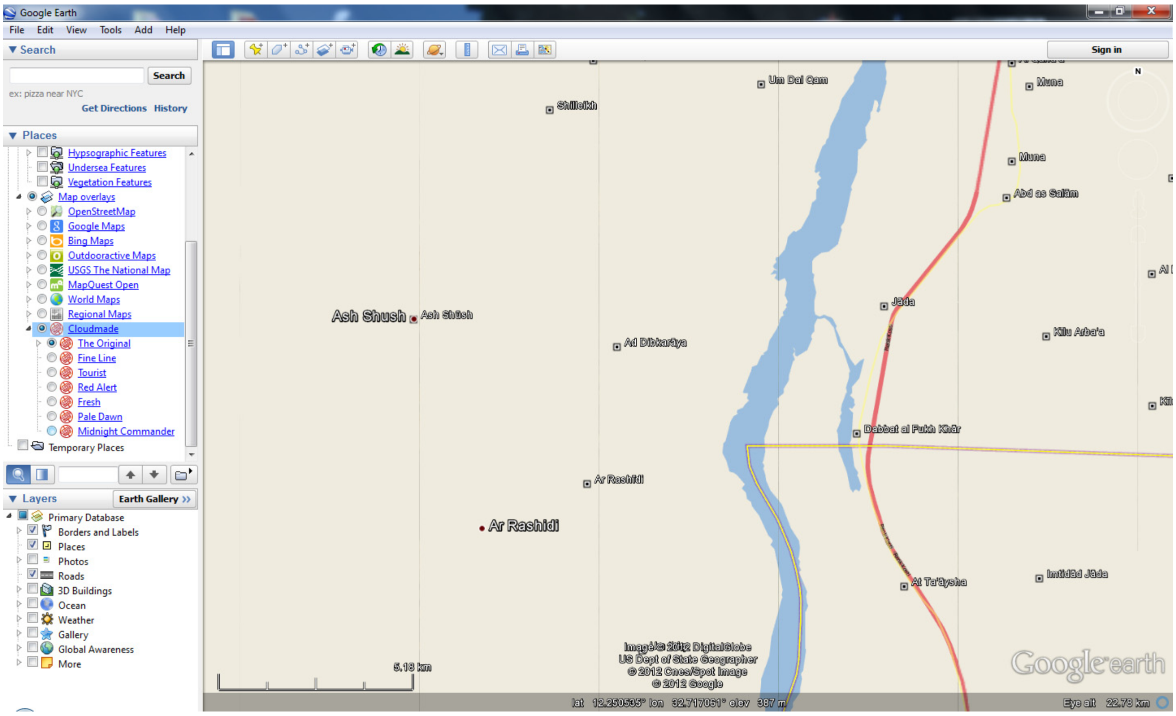


Figure 22: *Cloudmade OSM* data with *Google Earth* layers and *GeoNames* populated places layer for Sudan/South Sudan White Nile border region

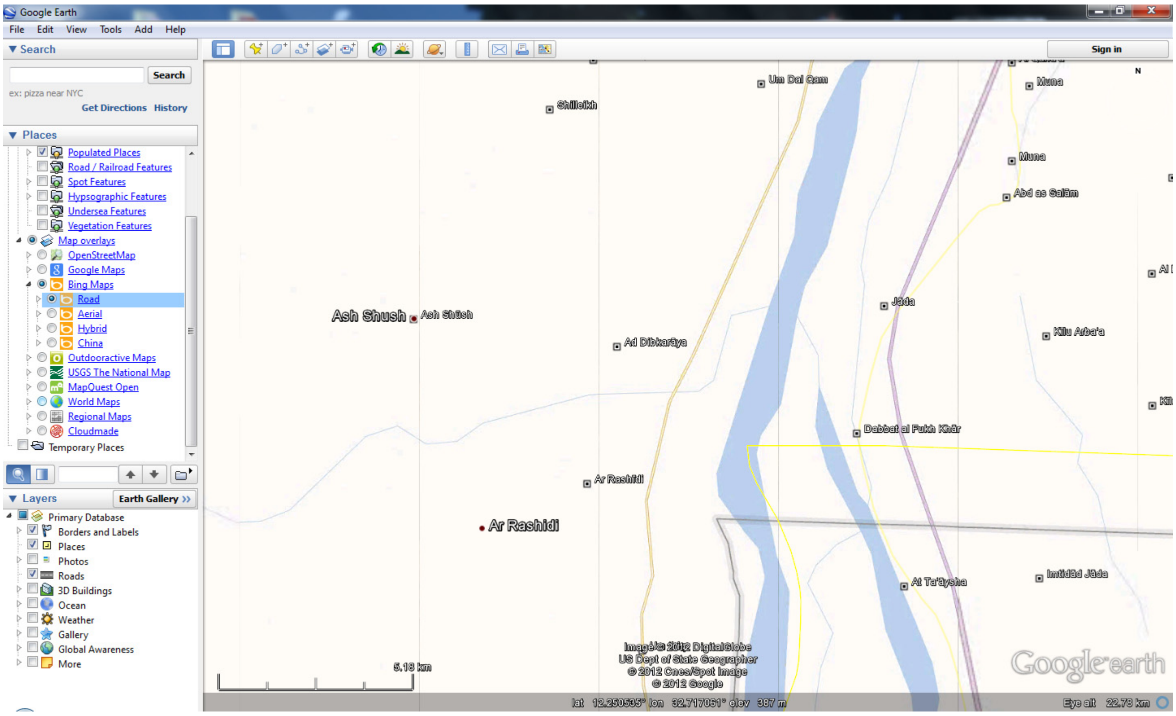


Figure 23: *Bing Maps* data with *Google Earth* layers and *GeoNames* populated places layer for Sudan/South Sudan White Nile border region

The examples of viewing different data layers and map/imagery overlays with *Google*

Earth for the border region of Sudan/South Sudan along the White Nile do not suggest that there is something like one "best" source for geo-data in general; rather that depending on the location, data sources may differ in the amount and quality of geographic contents they offer, and depending on the application and its scale level some sources of geo-data will be more useful than others. Another important aspect highlighted in this comparison is the simple possibility to cross-check the information provided or not provided in different sources, i.e. the existence and location of features. For instance as illustrated in *Figure 23*, the location of the place "Ar Rashidi" might be not where indicated in the *Google Earth* layer but where indicated in the *GeoNames* layer, whereas the location of the place "Ash Shush" is indicated at the same position in both layers and therefore appears to be less disputable; and the *Bing Maps* overlay shows additional map contents (streams, a road west of the river) but with less accuracy (roads, international border, streams). Low accuracy levels typically indicate that map features have been digitised from small-scale maps or have been produced with the primary purpose of visualising heavily generalised contents as needed for small-scale country maps.

It can be concluded that free available and accessible geo-data sources (e.g. *Google Earth/Maps, Bing Maps/Imagery, OSM, GeoNames*) provide information relevant from quick orientation to mapping. But the reliability of the information retrieved from single features should always be critically reflected. Ultimately for critical applications which depend on accuracy, ground-truthing with GNSS, i.e. to verify the existence and position of a map feature of interest in the real world, remains the only way to achieve reliability.

For both online and offline use as well as its use on GNSS handhelds, OSM has been more and more developing towards a unique geo-data source for humanitarian work which addresses core needs of emergency responders. Since 2004, the OSM project has been a pioneer in crisis mapping where base map data is often scarce, out of date or rapidly changing and continues to drive new innovative concepts in providing base map data to the humanitarian community. E.g. in 2009, humanitarian OSM teams (http://hot.openstreetmap.org/) have been launched who act as a link between the grassroots OSM community and emergency responders and facilitate the creation and distribution of free geo-data through OSM. OSM is built entirely by volunteers from all over the world from three main sources: GPS data from field surveys, digitised features from aerial imagery, and existing public sources of geo-data to improve the map and add features [VAN-12]. When humanitarian relief efforts are supported with mapping capacities of the OSM community (remotely and/or physically in countries), OSM data quality can unsurprisingly be significantly better than those of commercial data providers (e.g. *Google, Bing*). A list of past and current humanitarian mapping activities with additional information can be found through the respective section on the *OSM Wiki* (http://wiki.openstreetmap.org/wiki/Humanitarian_OSM_Team).

OSM data is released through a free and open licence and can be downloaded from different sources in a variety of data formats for GIS/mapping software and GNSS devices:

- Overview of download portals for OSM data

  (http://wiki.openstreetmap.org/wiki/Planet.osm)

- Overview of download portals for OSM data to be used on *Garmin* GNSS receivers (http://wiki.openstreetmap.org/wiki/OSM_Map_On_Garmin/Download)

One of the best maintained sources for worldwide and routable OSM data, which can be used with *Garmin BaseCamp* and on *Garmin* brand GNSS devices, is the provider *Lambertus* (http://garmin.openstreetmap.nl/). The website offers an easy to use download selection interface for selection by country or manual selection for custom areas (*Figure 24*) with regularly updated OSM data in different map file formats to be used with the designated software on *Windows, Mac OS X* or *Linux* (*Figure 25*). *Garmin BaseCamp* map installers are available for *Windows* and *Mac OS X* and once downloaded and installed the OSM map can be viewed with *BaseCamp* (*Figure 9*) and uploaded on a GNSS handheld through *MapInstall* (*Figure 10*). The file sizes of the OSM data on a country level varies between a few megabytes (e.g. Haiti: 12.4 MB) and gigabytes (e.g. Germany: 1.1 GB).

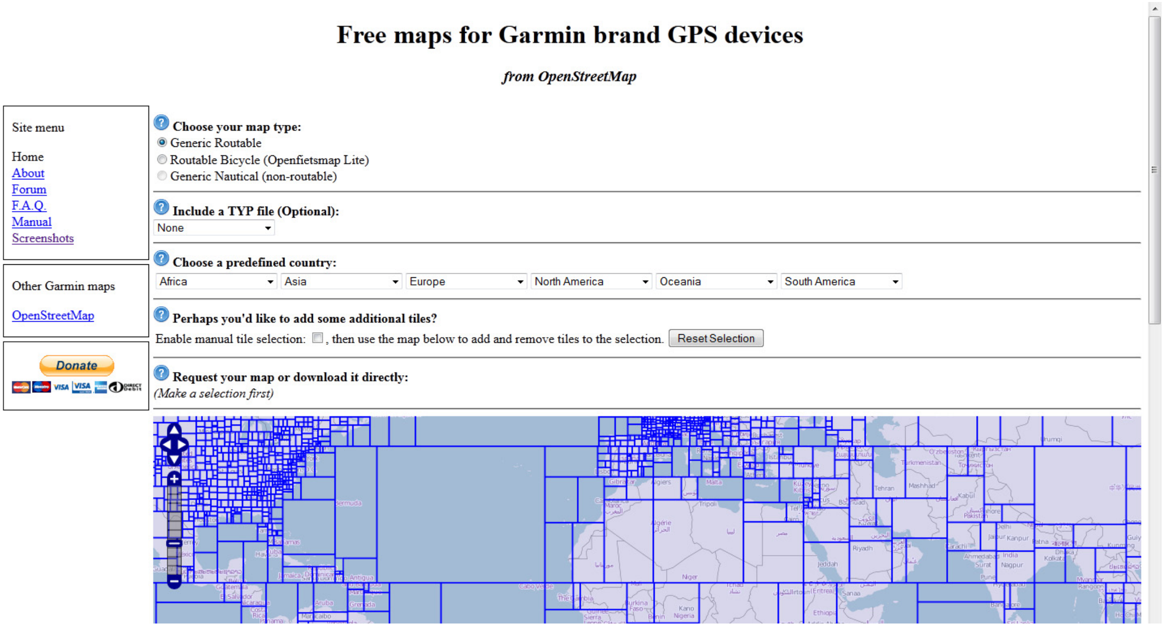


Figure 24: Screenshot of *http://garmin.openstreetmap.nl/* (selection of OSM data for download)

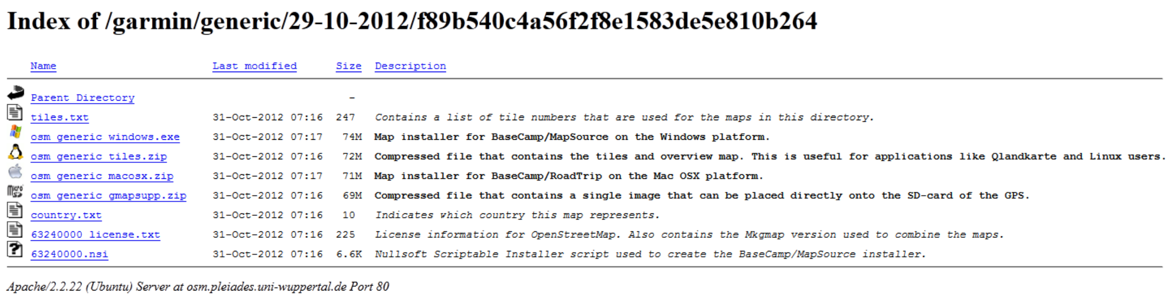


Figure 25: Screenshot of *http://garmin.openstreetmap.nl/* (map files for download)

5.3 Collecting, Processing and Sharing of Geo-referenced Information

Collecting, processing and sharing geo-data are critical IM activities in the field, helping to make emergency interventions more effective in reaching its objectives. One of the designated aims of the WASH cluster is to not just create a culture of information sharing, but to reach a level of information exchange characterised by joint assessments and monitoring of multiple agencies using agreed tools keeping all stakeholders up-to-date [GWC-09]. A common language and understanding of how geo-data should be gathered and shared based on standards play an important role in this regard, and will also foster interoperability. Interoperability has so far been mainly discussed with respect to hardware and software. The technical side is however just one aspect of interoperability. Bjorgo [BJO-04] remarks that in humanitarian disasters and response "an even more important aspect of interoperability is the various institutional conditions that allow for, or obstruct, information sharing within the whole environment that constitutes the disaster relief community". The author [ibid.] suggests perceiving interoperability as a "common culture of communication" and points out three key issues for disaster response and management:

- Communication must be continuous and flow in all directions. Lessons learnt point out the need for communication within organisations, between organisations (bilaterally), among organisations (multilaterally), with local leaders, with and between decision makers, with the media and among the parties.
- Information structures need to be flexible and mainstreamed in the coordination of the humanitarian assistance. Mechanisms for sharing information, including collected field data, must be in place prior to the actual intervention.
- The international community, both donors, coordinators and implementing agencies, need to actually learn from the lessons learnt. In too many cases, the international community does not draw sufficiently on past experiences and experiments with which model should be applied.

With respect to handling geo-data within the WASH sector or between clusters, such a common culture of communication does not exist explicitly nor is it yet clear how it should look like in practice. But the essential components can be derived from policy documents of the cluster system (mainly prepared by and for OCHA), tools or concepts which are being used by the WASH cluster and OCHA as well as the principles for IM (*Chapter 2*) respectively open data standards. The GIS applications explored in this work involve at least the following set of standards: file formats, geo-data properties (i.e. geodetic datum, coordinate formats, metadata, file naming and structure) and symbols/colour labels. These are discussed in the following on the basis of minimum requirements for geo-data collected and shared in the field, and for applications with *Google Earth* and *Garmin BaseCamp*.

- **File formats**

  For different purposes, different file formats are being used or required. The two file formats described below are based on the *Extensible Markup Language (XML)*, which is an open standard widely used in all kinds of web or office applications.

- *GPS eXchange Format *.gpx* (http://www.topografix.com/gpx.asp)

  GPX is used for the interchange of GPS/GNSS data (waypoints, routes, and tracks) between software applications and GNSS receivers and a de facto standard. E.g. *Garmin* GNSS devices store data in this format by default. It is also capable of storing textual descriptions of any feature, which can be retrieved on GNSS handhelds. Because of its limitations, *GPX* is no alternative to *Google Earth's* data format (*.kml/*.kmz*); *GPX* rather provides raw point and line data for further processing.

- *Keyhole Markup Language *.kml/*.kmz* (http://www.opengeospatial.org/standards/kml/)

  KML specifies a set of features (points, lines, polygons, textual descriptions, images, etc.) for display in e.g. *Google Earth*. *KMZ* is a zipped *KML* file and capable of containing overlays, images, icons, etc. together with the **.kml* file. Therefore, after geo-data is edited (e.g. icons are changed or images are included) *KMZ* is used for sharing, so the data is displayed as it has been edited when others view it. This however works for the bulk of contents only across *Google Earth*, unfortunately not with *Garmin BaseCamp*. *KML* can only store textual descriptions of points, lines and polygons (as *GPX*) and network links to images, icons, etc.

- **Geodetic datum**

  The geodetic datum (often just called "datum", sometimes also referred to as "spheroid") is a mathematical description of the Earth's shape and affects the position of a coordinate. Depending on the used geodetic datum a unique coordinate (e.g. a latitude/longitude fix retrieved with a GNSS receiver) can be interpreted as slightly different positions on the ground in the range of up to several hundreds of metres. The standard geodetic datum used is the *WGS 84* (the "World Geodetic System" first defined in 1984) [UNO-09a]. It is not just a standard in humanitarian emergency response, but in many other applications too. E.g. *Google Earth* is based on it and it is the default setting of commercial GNSS handhelds (although this should be always checked).

- **Coordinate formats**

  Based on the geodetic datum *WGS 84*, coordinates can be used, reported and shared in different formats. This is what typically happens in disasters, creates confusion and can lead to misunderstandings or mistaken ideas over the location/position of coordinates with severe consequences. For OCHA, the standard coordinate format (also called "position format") used should be the *Decimal Degrees Latitude/Longitude* format [UNO-9a]. The main purpose for using this specific format is to ease computer processing. Latitude should be reported first, then longitude (in a spread sheet the two values should be stored in separate columns) using six decimal places because of accuracy [ibid.].

Software typically displays latitudes south of the Equator and longitudes west of Greenwich designated by a preceding minus sign (-); thus, latitude is a number between -90 and (+)90 and longitude between -180 and (+)180. This format is recommended by OCHA [UNO-09a] for spread sheets but for all other purposes using hemispheric labels (E/W, N/S) instead is obvious; also GNSS receivers will show coordinates this way. Examples of the recommended decimal degrees format are illustrated below:

	Latitude	Longitude
Spread sheet format	48.033333	14.416667
GNSS/reporting format	N 48.033333	E 014.416667

For relief workers it is still important to know how to handle other common or used coordinate formats (e.g. *Degrees and Minutes* and *Degrees, Minutes and Seconds*).

- **Metadata and file naming**

A key finding for IM in emergency response operations is that information will not be used unless it is trusted, and only be helpful if it is accurate and authenticated [COY-09]. Considering just geo-data, these challenges can best be addressed through advocating metadata and metadata standards. Metadata, the data about data, are seen as a fundamental concept of IM [UNO-06]. Adding to the disaster context, against the backdrop of geo-browser based information sharing and with the popularity of *Google Earth*, metadata usage and related standards have turned out to be especially difficult to maintain as metadata are not supported (directly) by such applications. The OCHA IM WIKI states that during times of disasters, there is likely to be no metadata as production and sharing of datasets is happening too quickly to allow for formal metadata. Hence, the approach suggested is the concept of *emergency metadata* which is to make sure that the dataset is (to the extent possible) self-explanatory. OCHA's emergency metadata approach requires the following elements and can be looked up in the respective IM WIKI section (https://sites.google.com/site/ochaimwiki/geodata-preparation-manual/metadata):

- Dataset filenames follow a naming convention
- Unnecessary data attributes are removed
- Attribute names are clear
- If some attributes are too complex to be easily understood from the attribute name, a simple text file should be added to the dataset distribution explaining the attribute names (this file should have the exact same name as the dataset with *_METADATA.txt* added at the end)

Although this approach is intended for geo-data created with professional GIS software its core aspects and ideas can be used for geo-data created with *Google Earth*. An example of what attributes and attribute names can look like provides the pop-up/balloon window in *Figure 8*. It is evident that any metadata approach for WASH geo-data needs to provide a large degree of flexibility so it can be applied to any relevant data (which will depend on the intervention respectively the impacts of a disaster and the needs). But there are some core categories of metadata which will remain relevant in any event to provide the most needed information for organisations and individuals with whom a dataset is shared. The following categories are suggested and based on a selection out of 13 metadata categories of the basic metadata template (see the OCHA IM WIKI section https://sites.google.com/site/ochaimwiki/geodata-preparation-manual/metadata):

- *Place keyword* (A keyword that describes the geographical extent of the dataset; in addition, it can be suggested to include the P-code or SSID too if applicable)
- *Title* (Title of the dataset describing the contents)
- *Source* (The organisation that provides the source of the dataset)
- *Dataset reference date* (The date (YYYYMMDD) on which the dataset was created as an indication for its timeliness)
- *Distribution information* (Description of distribution rights, to the extent it is known)

Contrary to the first four categories, depending on the context, *distribution information* can be essential (e.g. because of security or confidentiality reasons) or rather obsolete. If there is a clear need to include this category in the metadata, a similar approach to indicate the intended audience as used by OCHA for field map dissemination can be used. This approach defines the audience according to four aspects [UNO-09b]:

- *Unclassified* – public distribution of the product
- *Embargoed* – internal only until specified date
- *Internal only* – not for dissemination
- *Exclusive* – dissemination to specific partner(s)

Coming back to the idea of OCHA's emergency metadata approach of making a dataset self-explanatory to the largest possible extent and the problem that the software used cannot enhance **.kml/*.kmz* files with metadata, two options remain. Either metadata of a dataset is provided in a separate, simple text file or the four/five relevant metadata categories identified above (*Place keyword, Title, Source, Dataset reference date* and optionally *Distribution information*) are implemented with a file naming convention. The latter is already to a certain extent part of OCHA's file naming convention for geo-data. Based on it, the metadata elements to the naming convention could be arranged in the following order (each separated by an underscore: _ and optional elements are denoted by brackets: []):

Place keyword_[P-code/SSID]_Title_Source_Dataset reference date_[Distribution information]

A fictitious **.kmz* file example (of the location of community latrines built by the Austrian Red Cross in Léogâne, Haiti) could then look like this:

Haiti Leogane P-code112_ Finished community latrines built by AutRC at camp sites_Source-AutRC_as of 2010-06-08_for public distribution.kmz

The point being made here, is not to suggest a very strict naming convention or a naming convention capable of covering all imaginable eventualities as it is extremely unlikely that these would prevail in daily routine, but to provide an outline of how the most important metadata information can be included in file naming, a matter of just seconds. Of course this possibility is limited to only a small set of metadata categories as otherwise the filenames would become too long and unpractical. But still the advantage is that metadata cannot get lost when geo-data is exchanged as it could happen when provided in a separate file and this file is not forwarded together with the dataset.

- **Geo-data structure**

  Very closely linked to metadata is the structure of geo-data, i.e. what features are included in a dataset and how they are organised in it (according to what logic). *Google Earth* offers the possibility to pack all kinds of data and information in a single **.kml/*.kmz* file with numerous subfolders for divisions. Such files may reach the content extent comparable to large databases covering base maps and data on all emergency response activities in an affected country. Two problems, challenges or risks are apparent for user-friendly GIS applications in the WASH sector: First of all, there are no official guidelines or standardised templates for geo-browser based data sharing; and secondly, because of that, people organise and structure the geo-data gathered and collected reflecting their needs and/or experiences. These individual geo-data structures may not be directly interoperable with other GIS (of the clusters, OCHA and other organisations), accordingly can limit the use of this data when not substantially pre-processed and rearranged before being imported.

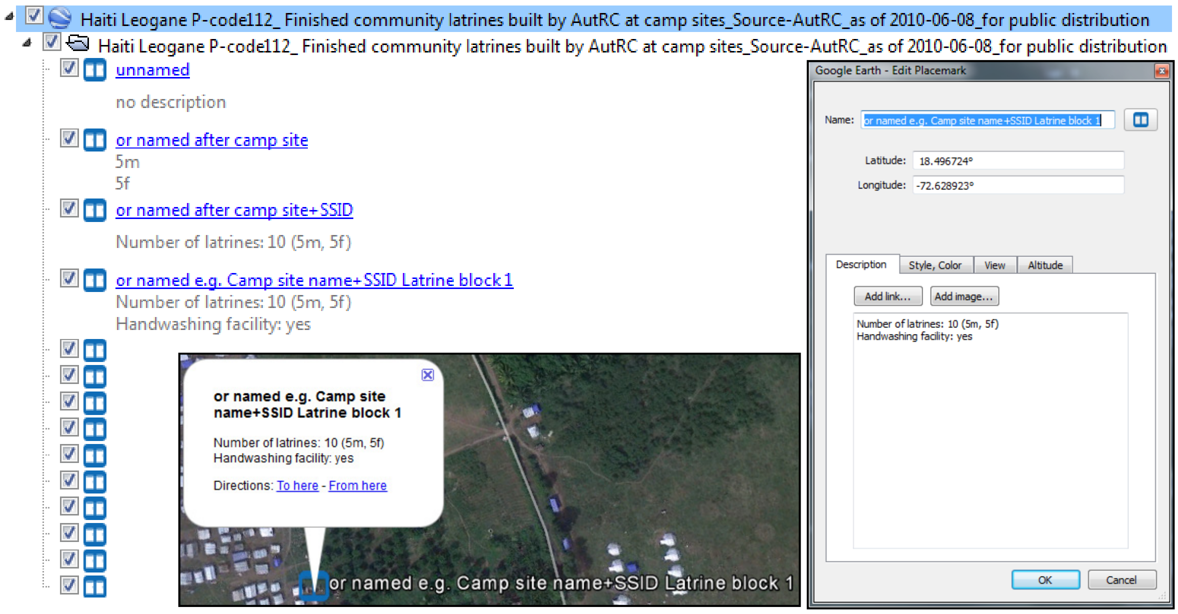


Figure 26: Data structure example of a *kml/kmz* file in *Google Earth*

To make **.kml/*.kmz* files created with *Google Earth* and their structure immediately compatible with professional GIS software of e.g. the WASH cluster on the one hand, and to increase/ease their use for multiple purposes on the other hand, they must reflect the basics of common GIS database structures – which is a hierarchic structure based on single/distinguishable features separated in single files at its lowest level. This means that different feature types like IDP camps, water distributions points, water supply lines, wells, latrines, field offices, etc. should be stored separately, and additionally each feature class (points, lines and polygons) is stored in a separate file. So as a first step, a single **.kml/*.kmz* file will be prepared to only contain one feature type consisting of one feature class with any arbitrary number of features, e.g. points. *Figure 26* illustrates an example (the metadata example used previously) of a **.kml/*.kmz* file data structure prepared according to this with *Google Earth*. The figure also shows how the metadata included in the file name and added textual descriptions are displayed as well as how certain metadata elements can be used to enhance the information of single features.

	Name	Description
0	unnamed	no description
1	or named after camp site	5m 5f
2	or named after camp site+SSID	Number of latrines: 10 (5m, 5f)
3	or named e.g. Camp site name+SSID Latrine block 1	Number of latrines: 10 (5m, 5f) Handwashing facility: yes
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		

Figure 27: Attribute table view of the *kml/kmz* data structure in *Figure 26* with professional GIS software (*QGIS*)

Figure 27 depicts how the file (structure and textual descriptions) shown in *Figure 26* is translated when imported in professional GIS software; the attribute table of the **.kml/*.kmz* file lists each feature with its (given) name and the attribute “Description” containing the text added in *Google Earth*. In short, this structure sets the base for immediate further processing of such data by GIS specialist of e.g. the WASH cluster. As a second step, again in the light of basic geo-browser based applications, the files containing separate features can be viewed together as layers in *Google Earth* and then if needed single features and/or their information can be merged together through *copy and paste* in any favoured form or structure. For example, to provide situational overviews it might be desired to have all available WASH information as textual descriptions of point locations of camp sites rather than having numerous files and each containing parts of the information sought after. Concluding, again important is to remain flexible to different needs and circumstances and not to elaborate a detailed geo-data structure. However, the basics of common GIS database structures explained above can serve as guidance for processing and exchanging geo-data in the field aiding a greater variety of applications and making better use of collected information.

- **Symbols and colour labels**

  Geo-data enhanced with meaningful symbols and labels provide ways for communicating complex concepts and situations independent of different languages and promote quick and simple transmission of important information in disasters. When geo-data is prepared for sharing or presented to others with *Google Earth* or *Garmin BaseCamp*, the software's built-in symbols may be used initially, though the selection is rather limited and many symbols do not have a distinctive meaning. Many features of interest during disasters are rather special and so far various agencies have developed their own symbol sets, often expressing the very same feature with different symbols. Therefore, and because still many features were not covered, OCHA has created a set of 500 freely available humanitarian icons, published in 2012. The first set was released in 2008 and since then the set of symbols has expanded covering now a wider range of activities and features in humanitarian emergency response. The full humanitarian symbol set is included in the *Appendix 8.2.2* (including the download link). *Figure 28* below lists the icons designed for WASH.

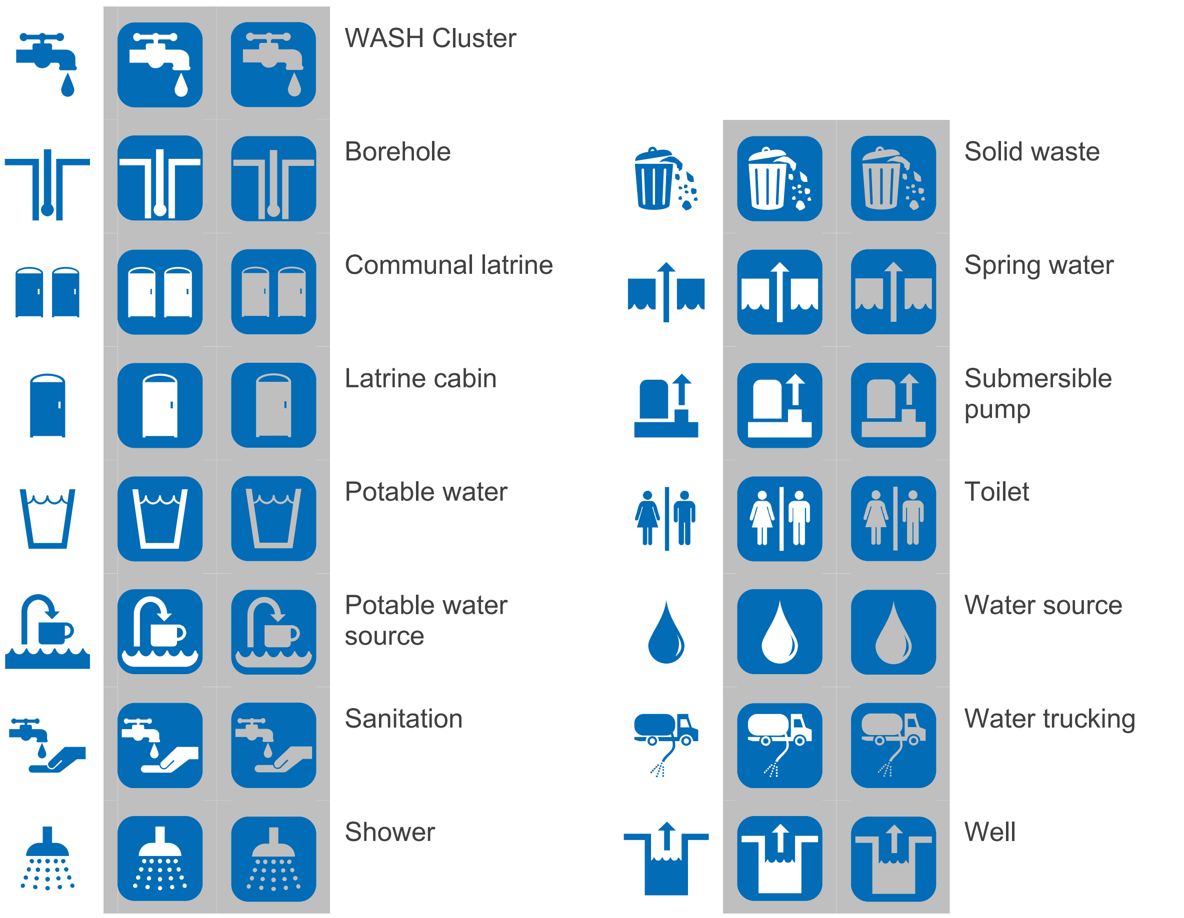


Figure 28: OCHA Humanitarian Symbol Set for WASH

Google Earth and *Garmin BaseCamp* allow for using custom symbols, though the central shortcoming is that both programs do not have a built-in legend or any function with which the name, i.e. meaning of symbol, can be viewed. While *Google Earth* makes it very easy to use custom icons once stored locally (also it is possible via public links to e.g. a file hosting service), *Garmin BaseCamp* requires a few steps to be done in advance (see http://garminoregon.wikispaces.com/Custom+Symbols). The only way to provide geo-data with a legend is to include one in a **.kmz* file; however, with the current ways to achieve this, it cannot be seen as user-friendly in the light of the thesis. The icons listed in *Figure 28* demonstrate that not all of them are what can be considered self-explanatory.

In addition to symbols, common colour labels can be used. *Figure 29* explains the colour key for severity ranking which is already being used in emergency assessment forms across all sectors, representing an analogy to traffic lights. *Figure 8* provides an example of a more sophisticated application in *Google Earth* using this colour labels. A more simple use of colour codes is to just use icons in the desired colour, change the colour of icons or of its transparent background (when icons are available as **.png/*.gif* files). The latter can be done with any graphics editing program. Although *Google Earth* offers the possibility to change the colour of icons, for the design of the humanitarian symbol set it does not provide satisfying results as the colours get mixed when changed. An example to highlight unsafe water sources for urgent intervention using the humanitarian symbol set (available in **.png* format) could look like one of the following three icons:

Ideally for such use the meaning of symbols is explained through the file name in the absence of any other simple means. But generally, when numerous layers are viewed at the same time in *Google Earth*, they allow for a better distinction of different feature types (provided they are marked with different symbols). Furthermore, several of the non-WASH symbols included in the humanitarian symbol set can be relevant for WASH field work too. As these icons are relatively new, it remains to be seen how they perform in practice, if and how different organisations adopt them and how creatively they are used.

Key for severity ranking	Red	Severe situation: urgent intervention required
	Orange	Situation of concern: surveillance required
	Yellow	Lack of/unreliable data: further assessment required
	Green	Relatively normal situation or local population able to cope with crisis: no further action required

Figure 29: Severity ranking with colour labels used in IASC assessment forms [IAS-09]

If developed and implemented properly, geo-data standards and guidelines can create the shared frame of reference necessary to manage large amounts of data effectively among a group of actors – saving time and money, and ensuring quality and completeness [UNO-06]. But they are only useful to the extent to which they are mutually accepted [ibid.]. It seems that this remains to be found out only during emergency operations. However, the aspects of a common culture of communication explored in the last part of this chapter underline the need for procedures and tools already in place beforehand. Procedures will ultimately have to be defined by organisations themselves, communicated to their staff, and tools require in particular to be tested before being applied in the field. Both require covering all relevant WASH activities ranging from assessments, implementation, monitoring to handover, and reflecting the steps from data collection with GNSS handhelds (see for example the template for recording waypoints in *Appendix 8.2.1*) to processing and finally sharing (as illustrated exemplary above).

With Cai et al. [CAI-06] the demanding requirements for GIS in disaster response can be framed with *immediacy, relevance and sharing* – meaning having direct access to relevant data which explains itself to facilitate collaboration and a shared understanding. To proof itself as a mainstream tool that can be applied immediately as needed, GIS obliges to be rooted in DM and organisational practices. Overall, the use of GIS in all its facets will lastly always be influenced by to what extent and for what kind of work specifically agencies want to include GIS functionalities for their personnel's tasks.

6 User and Management Issues

The closing chapter of the thesis' main part draws attention to the human and organisational side of GIS. Compared to the preceding chapters, it is kept more compendious as most issues in this regard are even more specific to organisational contexts and generalised statements are difficult to accomplish; in addition only very limited research has been done on mainstreaming or institutionalising GIS in the humanitarian sector. Hence, findings are scarce (even for high-level GIS solutions). The first section deals with the different aspects to be taken into consideration when GIS is introduced in an organisation. Based on the analysis of the main part and Austrian Red Cross experience, critical factors for implementing, managing and developing GIS are presented and discussed. The second section focusses on the critical role of GIS trainings for prospective users. Related challenges and opportunities are reviewed in the light of disaster preparedness as well as lessons learnt from WASH trainings conducted by the Austrian Red Cross.

6.1 Introducing GIS in an Organisation

One of the few practical research examples (although very brief) provides Adams [ADA-06], who published the GIS experience of the organisation GOAL in Uganda for humanitarian operations, and was seeking similar GIS applications (with the combined use of GNSS and basic mapping software) as dealt within this research. His concluding thoughts are: "Our experience of using mapping and GIS for humanitarian assessments and planning is in its early stages and has been mixed. We have glimpsed some of the potential, and we believe that GIS could serve a wide range of purposes […] We have also encountered many of the problems that are or can be involved in using this technology. The experience suggest that there is great potential and that GOAL needs to develop its own mapping/GIS capability as a humanitarian organisation." [ibid.]. Six years later, a diagnosis very much alike can be made for e.g. the Austrian Red Cross, probably for numerous other humanitarian actors too.

How can this gap be explained? Several factors can help to answer this question. One factor is that – except for UN GIS units – in humanitarian organisations GIS dependens on a few specialist or experienced users which prepare GNSS data with e.g. *Google Earth* for distribution to the community; if applications and experience in using them are shared, it usually happens in informal ways. The reason for that, or another factor is, that there is no clear GIS mandate and operating procedure in place; GIS is for the most part not institutionalised, its outcomes are left open and usage is not documented, so organisations and individuals can draw from past experiences and build on already developed applications. A third factor, common in many other areas of humanitarian work too, constitutes the high staff turnover with the effect that non-institutionalised GIS use is often lost and others start from the scratch again, investing lots of time to figure out appropriate solutions for desired applications. Communities of practice for using GIS in humanitarian relief, connected through the web (e.g. blogs, learning networks), are still in its early stages, but denote great potentials for exchanging information on applications and their lessons learnt (especially for current user-friendly GIS applications).

A final report of a workshop held in Kenya titled *Envisioning the Future of International Humanitarian Service Activity and a Research Agenda to Help Get Us There* [NSF-08] has put a strong emphasis on the background issues of GIS and IM. It states that the biggest challenge to technology integration and information sharing is differing organisational missions, policies, practices, environments and cultures. This once more suggests that GIS practices can only be properly developed and managed within/through organisations, even for rather simple applications as highlighted in this research. The report also includes some key findings from a GIS project implemented in El Salvador (*Table 13*). In this case, digital field mapping and survey tools have been tested, a GIS database for emergency planning has been developed and solutions for provisioning data through the internet have been worked on. Although GIS applications are highly context specific, several general issues and problem areas can be identified which all refer to GIS management tasks. Such findings, highlighted in *Table 13* and identified in the thesis, would be the lack of/quality of core geo-data, maintenance/updating of data, agreeing and enforcing standards, proper ways to share data and thorough testing of literally everything before being deployed to the field.

Area	Findings
Issues/Problem Areas	- Lack of base maps - Ownership of software and data - Ownership of handheld devices - Web hosting
Data Standardisation	Difficulty in: - Agreeing on standardisation - Using standardised terminology - Country-to-country and regional sharing
Data Integration	- Data sharing saves resources, but what is the best way to do it? One possibility is a clearinghouse with open access. - Data integration presents trust issues between the actors.
Data Updating	Issues in data updating include: - Maintenance - The rapidity of situation changes - The different ways that data can be updated - Questions about who should support the updates
Lessons Learned	- Survey mods are needed - Technology costs must be considered - Everything must be tested

Table 13: GIS and GPS findings from a project in El Salvador [NSF-08]

Not contrary, but more recent and elaborated research findings on the introduction of GIS in organisations are available through Cavric [CAV-11], who analysed the human and organisational aspects of GIS development in Gambia. Cavric [ibid.] argues that technologies evolve faster than the institutional and organisational capacities of different GIS users are able to absorb them. Implementation of GIS technology, he deduces, is under threat in the absence of suitable organisational settings and a critical user mass. For this reason, the author calls for drawing attention to the human and organisational factors to improve GIS diffusion. A crucial precondition for introducing GIS is that organisations must have a strong commitment to implement GIS, which does not necessarily go hand in hand with interest in and desire for specific GIS applications. It may require substantial and steady advocacy for GIS in advance to create such interest and commitment which is hard to achieve within a short period of time. The approach assumed here is a project in itself, a process that requires time and preparation, and is opposite to a more or less spontaneous activity. As a first step then organisations need to find out and define what they want. With Cavric it can be claimed, that the following set of questions related to GIS generally require special attention in this process [ibid.]:

- *Who is going to use it?*

  (Many people or a few, specialist or non-specialist, technical or administrative staff, etc.)

- *What will it be used for?*

  (Research or management, retrieval or processing, screen displays or printer output, etc.)

- *Where it will be used?*

  (Only at headquarters or in the regions (districts) as well, only at fixed office sites or out in the field or even mobile locations, etc.)

- *When will it be used?*

  (Occasionally or frequently, for short periods or long periods at a time, etc.)

- *How will it be used?*

  (In stand-alone use or in connection with other equipment and (if in connection) whether it needs to be online or offline and in real time or not, etc.)

- *Why should it be used in the first place?*

  (Is it in order to achieve greater speed, or more accuracy, or better service to the public; or is it for something else like helping to promote regional development, etc.)

These questions have (slightly modified) been used in the interviews with WASH and DM focal points (see *Appendix 8.1*). The interviews (largely reflecting a Red Cross/Red Crescent DM and WASH context) revealed the following results which are summarised below for each question:

- *Who is going to use it?*

  Basically everybody out in the field who has to gather information, find target locations where to implement tasks and has to share gathered data with others (WASH delegates, DM/coordination staff, personnel responsible for security, technicians, fleet managers, etc.) and administrative staff in the headquarters

- *What will it be used for?*

  Data collection and sharing, processing assessments data, management and coordination tasks (e.g. for preparing coordination meetings), security (e.g. escape and evacuation routes), (de-)briefings, handover to others, on screens and for printouts

- *Where it will be used?*

  On all levels ranging from headquarters, fixed field offices to mobile field locations

- *When will it be used?*

  On a regular basis with simple ways for users to integrate data for assessments, reports as well as for preparatory task and post-processing of trainings and emergency response operations

- *How will it be used?*

  In stand-alone use with the possibility to work, collaborate and share data offline, but as soon as online data can be updated

- *Why should it be used in the first place?*

  For the coordination of all actors in the same area at the same time, to get a picture of the size and scale of a disaster, to have an overview of emergency response interventions and to share but not duplicate information

The next logical (or second) step then would be to develop a realistic mission statement, i.e. to provide answers to the questions *Where are we?* and *What do we want to achieve?* as an organisation. One of the tools that can be used for answering such strategic planning questions, and which is commonly used in the initial start-up phase of (GIS implementation) projects, is an analysis of the *Strengths, Weaknesses, Opportunities and Threats (SWOT)* involved in achieving GIS objectives as e.g. provided through the answers to the six questions above. With a SWOT analysis *Strengths* and *Weaknesses* are viewed as internal factors (attributes of an organisation which can be influenced), and *Opportunities* and *Threats* are viewed as external factors (attributes of an organisation's environment with no means of control). The next steps ahead include the development of a strategy (the preparation of strategic plan) identifying the tasks to reach the goals and vision identified, followed by its implementation. Which relevant general tasks the introduction of GIS in an organisation at least involve in the light of a user-friendly GIS framework (*Figure 4*) are listed below – based on conclusions drawn from the research's analysis:

- Identify (and if necessary purchase) the hardware to be used considering requirements (*Chapter 3*) and appropriateness (*Chapter 4*)
- Decide on software tools and applications to be used referencing standards (*Chapter 5*)
- Develop templates, symbols and labels to be used for data collection, sharing and dissemination

- Find procedures to provide users with a ready to use GIS package (e.g. an organisation's IT department could be tasked with it) including:
    - GNSS handhelds with pre-installed maps and updated firmware
    - Laptops with the latest software versions and OS specific requirements already installed on it as well as available and updated geo-data
    - User guides, instruction notes, templates and symbol sets
    - It might also include a portable GIS package which can be shared with others in the field when needed
- Develop SOPs for GIS (i.e. detailed and written instructions especially on when and how GIS is implemented and operated, what it involves and which tasks, outcomes and services are expected from whom) including structured feedback procedures (e.g. as part of mission debriefings)
- Provide GIS trainings for users based on elaborated training curriculums and materials
- Designate a GIS focal point within DM departments for coordination and support on all levels, and as a hub for GIS development (e.g. exchange of best practices and experienced on new technologies with GIS environments of other organisations)
- Testing of hardware, software and agreed standard applications

It is clear that organisations will require expertise for the envisioned GIS approach and its applications, and this might be the only asset related to costs beside trainings. Great potential to seek needed expertise (if not available within an organisation through the for international WASH actors large pool of human resources) lies in developing partnerships with GIS NGOs and other organisations or to use already established partnerships. Especially within global humanitarian networks such as the IFRC and its currently 187 national societies, the possibilities for making better use of existing resources and sharing of grown GIS expertise are enormous. Additionally, the increased awareness of the benefits and relevance of GIS and geospatial technologies in general for disaster response, together with the stronger focus of donors on disaster preparedness, are likely to make donor funding of projects in this area more attractive than previously [HHI-09; HHI-11].

6.2 GIS Trainings

The tasks of GIS management pointed out in the preceding section emphasise what has been framed with the term "GIS preparedness" in *Chapter 3*. A critical factor for preparing GIS to be deployed successfully is trainings. Moreover, trainings imply skilled trainers too. Studies and research findings on GIS trainings as part of a comprehensive implementation process in humanitarian organisations are notably rare or seldom made available to the public. At least three key findings can be discovered in conclusions and recommendations of GIS implementation projects in organisational settings [UNS-07]:

- The personnel involved in GIS requires frequent training to keep up with the advances in technology (insufficient training of staff and shortage of skilled users are frequent problems)
- Trainings are an important aspect for the successful implementation and operation of a GIS and needed at various levels, with differing goals and durations
- Any efforts to establish a GIS must include funds for on-going staff training as part of the annual operating budget

Regular trainings are particularly important as the use of GIS in emergency response refers to humanitarian technologies and practices still being in formative phases [HHI-09]. Broadly three different types of GIS trainings for achieving diverging goals (awareness, in-house trainer pool and user skills) can be distinguished, and of which the last one will be given attention in the remaining part:

- Awareness trainings for senior-level DM staff to seek and ensure their support
- Training of trainers (ToT) for selected staff with experience in GIS tools to achieve a more self-sustaining implementation and greater sustainability of GIS diffusion within an organisation
- Trainings for operational staff respectively the prospective users

The outline of a user-friendly GIS framework (*Figure 4*) describes mutually influencing circles in which SOPs and certain standards specific to organisational contexts (e.g. used software) affect trainings and vice versa. In the best of cases, expectations of DM and line managers in emergency response operations on the outcomes of GIS applications are defined prior to any training event. Otherwise, uncertainty or confusion is likely to be caused at a user level over what is expected from them (e.g. at Austrian Red Cross WASH trainings participants would ask for answers to question like *What should be handed over how to others in the field and after debriefings?*, *What geo-data should be included in reports?* or *Which geo-data should be saved with which structure and in which file formats?*). The latter is not an untypical situation, particularly when GIS use in an organisation is only existent through individual field applications and experiences, and is not consequently translated into consistency at higher levels and matched by implications for DM.

Trainings for users can be arranged in a couple of different ways, depending on the applications and information needs of different user groups. User can be grouped according to their tasks during disaster response operations; e.g. in operational staff at the headquarters and operational staff in the field. Short-term training courses for headquarter staff may be arranged as an in-house activity and combined with on-the-job training [UNS-07]. GIS trainings for field staff may be included as sessions being part of generic emergency response trainings, workshops or exercises in the context of disaster preparedness. While on-the-job trainings may be arranged in very flexible ways, lasting from a few days to sessions split over weeks depending on individual staff's workload, GIS sessions as part of disaster preparedness trainings will usually require being condensed to fit with a specific training curriculum. Such sessions might last for only a few hours. An example of a training curriculum outline focussing on the use of GPS and GIS software tools for WASH in emergencies, lasting for 4 hours, is attached in *Appendix 8.3*.

This curriculum example reflects GIS training sessions which have been implemented during Austrian Red Cross WASH trainings lasting for a week, and refresher exercises lasting for 3 days. For an organisation there is a need to develop (a) standard training curriculum(s) for multiple purposes or training situations referencing the relevant standards for emergency response set through OCHA and the cluster system as well as organisation specific SOPs. This involves the composition of standardised training and learning materials such as training handbooks (i.e. a detailed elaboration of curriculums), flipcharts, slideshow presentations, scripts, handouts or instruction notes for users.

GIS trainings require time-consuming preparation ahead, but also need to be post-processed as they offer the best opportunity to get direct user feedback on applications before those are being used in the case of an emergency. A user-friendly GIS should be captured as a work in progress. This does not suggest an inconsistent implementation or operation of GIS, but rather that user needs and demands are taken seriously, certain tools which allow or it are adapted and applications are being refined along with technological advancements. Therefore, trainings on a regular basis are essential, to keep users up-to-date and provide them with the possibility to practice and improve their skills. Moreover, several potential GIS applications pointed towards in the research offer opportunities for being integrated as information and support tools into other areas of work within an organisation. The past experiences of the Austrian Red Cross with GIS trainings in the use of basic tools and applications (as mentioned in the training curriculum in *Appendix 8.3*) suggest:

- Experienced users can train others, no GIS professionals are needed
- Trainings are best done hands-on (participants have its own GNSS handheld and laptop), in small groups (4-5 persons) and when embedded in a wider WASH training context, relating to e.g. case studies and scenarios with outdoor exercises where GIS tools are then applied
- The basic use of GNSS handhelds, *Google Earth* and *Garmin BaseCamp/MapInstall* including data collection, processing and sharing can be trained within four hours with productive results even with beginners (provided a suitable training context as mentioned above)
- To show, not to tell – as the guiding principle for any training activity

7 Summary and Conclusions

7.1 Summary of Research Findings

The thesis examined the requirements of a GIS framework for the WASH sector that can be deployed from small to large scale disaster response operations and integrated into other GIS, as well as the available technological options for setting up a GIS in the field meeting both demands on and of the user. Several factors point out the relevance of the guiding research questions. First of all, disasters create a unique situation and the focus, duration and operational support of WASH emergency response can vary extensively. The WASH cluster and OCHA have developed standardised IM tools and provide valuable GIS services to the field. These are based on overarching principles, standards and guidelines for humanitarian work and serve as the main frame for any GIS approach. Additionally, GIS NGOs are supporting emergency responders through mapping services. However, all these resources are hardly sufficient and do not imply that GIS services are provided right from the start of an emergency response operation or provided at all – particularly for the majority of small and medium scale disasters. Secondly, the GIS approach of the WASH cluster is designed primarily for high-level coordination and not for solutions to mapping single objects relevant to WASH interventions and suitable for non-GIS professionals. Thirdly and even more important, WASH field workers have access to crucial operational information and demand simple, easy to use means to map data, make it accessible to others and visualise it together with other geo-data to aid their work.

As people are already using simple GIS functionalities in the field through e.g. *Google Earth*, and there are clear needs for basic GIS tools, but the existing GIS approaches cannot be adopted, a GIS framework should facilitate the process of developing user-friendly applications for specific sector work like WASH. The essential requirements for such a framework are on the one hand to implement (geo-data) standards set by the cluster system – especially for data sharing – and on the other hand to adopt a modular approach with lighter and targeted GIS applications to support individual areas of work, and which are quicker and easier to deploy in environments characterised by resource constraints, low levels of computer literacy and weak infrastructure. The latter includes especially free software and its interoperability with a reasonable range of OS and hardware configurations, and freely accessible geo-data which can be used offline and without pre-processing (e.g. base maps and satellite imagery). Furthermore, GIS management rooted in an organisation's DM – including SOPs and trainings at various levels – is considered a critical factor for the overall success of any GIS implementation and operation during disasters. This also entails thorough testing of all GIS tools before being deployed.

Laptops and GNSS handhelds provide the main hardware components of a portable and flexible GIS. *Google Earth* and *Garmin BaseCamp/MapInstall* can be regarded as a basic, user-friendly software module for WASH emergency response. The software covers basic required functionalities such as viewing base maps and satellite imagery for reference and navigation, mapping field data, data and map transfer between GNSS receivers and computers, editing and sharing of field data, visualising up-to-date relevant situation data gathered by others or creating and printing simple maps. The application range of the tested software demonstrates that many more tools are freely and easily available, and expandable to (more) sophisticated GIS solutions, if desired or needed at different levels in other contexts.

Free available core geo-data at a worldwide coverage is made available through *Google Earth* (satellite imagery and e.g. *Borders and Labels, Places* and *Roads* layers) and *OpenStreetMap* (base maps for e.g. *Garmin BaseCamp*) and can be used offline as well as on GNSS handhelds (*OpenStreetMap*). Additionally, the CODs and FODs may include critical geo-data for viewing with *Google Earth* or *Garmin BaseCamp*, provided it is made available in compatible file formats. If internet access is available, *Google Earth* offers further options to view/intersect geo-data from different sources (with global coverage) and retrieve additional information through network links featuring e.g. layers with populated places or various map overlays. However, the relevance and timeliness of available core geo-data might be limited depending on the location and/or the size respectively the publicity of a disaster.

With respect to coordination and information exchange, a common culture of communication is essential. For geo-data collected and shared in the field, this means the implementation and mainstreaming of a minimum set of standards regarding file formats, geo-data properties (geodetic datum, coordinate formats, metadata, file naming and structure) and symbols/colour labels. The exchange of critical spatial information should be based on relevant and self-explanatory data to aid emergency response efforts. At the same time, this underlines the need in particular for user adapted GIS tools already in place beforehand, and translates further into the importance of GIS management and accordingly its institutionalisation.

GIS requires a long-term commitment to its preparation and development to proof itself as a valuable and sustainable mainstream tool which can be applied immediately as needed – while benefiting relief workers, headquarters and all other stakeholders in disasters. A critical factor for preparing GIS to be deployed successfully is frequent trainings, to keep users up with the advances in technology and to practise a culture of open information sharing. But most importantly, GIS approaches need to be refined and improved through lessons learnt and experiences gained during emergency deployments.

7.2 Conclusions

Once, someone described the relevance of GIS and geospatial technologies for humanitarian emergency response as being like having a pair of shoes. It’s good to have them, and this sums up many aspects of user-friendly GIS applications. These are not absolutely needed, but they can be quite useful; and not taking them into account would be a step backwards. GPS handhelds, easy to use mapping software and geo-browser based applications have been used regularly in disasters for years and their benefits are clearly seen for the most part. But all of this did not lead to a corresponding set of guidelines for collecting, processing and sharing geographic information in the field of WASH. Technology alone or technology first does not suggest a way ahead. To be implemented in a useful way and to aid a better culture of information sharing, technology in this case needs to be subsequently matched by standards for its applications, and requires to be embedded within organisational settings as well as the wider requirements for IM.

The thesis concludes that the outlined concept of a user-friendly GIS framework is appropriate to translate user demands and technological means/innovations into workable and sustainable humanitarian solutions at different levels. The documented GIS experience in relief operations revealed that many organisations and individuals struggle with similar challenges, in particular related to sharing of mapped data. Moreover, the very same problems and impediments for using data of others happen all over again at different times and places in different emergencies. So firstly, there is a clear need to document GIS operation in the field in a structured way; secondly, documented experience must be shared; and thirdly, conclusions drawn from that information require to be incorporated into existing GIS applications. This cannot be expected to be done by individuals, but by organisational resources, a GIS management.

However, the success will very much depend on an organisation itself, to what extent it is willing and/or able to invest resources. GIS diffusion is at the same time a challenge as well as an opportunity. For organisations, investments in GIS may not return immediately as benefits and are to be conceived long-term. The user-friendly GIS applications explored in this thesis have been related primarily to their use for emergency response in the WASH sector. But actually, most of them provide capabilities relevant to other sectors and levels of work too, and can be used throughout the DM cycle ranging to a long-term, development context. This can suggest more GIS benefits for humanitarian actors, once an approach is adopted and institutionalised. Also, it can be considered, that when operational geo-data is collectively gathered, archived and stored for retrieval when needed, not just organisations, but emergency responders and the humanitarian community in general will benefit from it. Most notably in areas affected by recurrent disasters or prolonged crisis, available information on already existing settings and infrastructure created by the various actors can definitely contribute to a more effective response, saving time and resources needed elsewhere. The *COD/FOD Registry* would already provide an established platform for dissemination.

Aspects related to storing operational geo-data, which has been shared in the field after emergency response operations, have not been dealt with in this research. Most certainly, it will involve some form of post-processing of geo-data for archiving, mainly because such activities contain the inherent risk of creating another source of unstructured datasets leading to information overload when not done properly. Archiving of geo-data created with GNSS receivers and software such as *Google Earth* point out prospects for further research together with the overall field of GIS institutionalisation in (humanitarian) organisation. In addition, further research should consider user-friendly solutions for proper editing and working on the same geo-data across multiple actors that can be applied in any disaster context. This may be one logical next step in the application range of basic humanitarian GIS.

8 Appendix

8.1 Interviews

Alongside many informal talks with Red Cross/Red Crescent delegates and DM staff at various occasions, the persons listed below have been contacted for personal or e-mail interviews.

Name	Organisation	Function
Ahmed Abbas	Hope 87, Pakistan	Operations Director
Sara Andersson	Swedish Red Cross	WASH Delegate
Mariyam Asifa	IFRC	WASH Officer
Don Atkinson	Australian Red Cross/IFRC	WASH Delegate
Martin Binder	Austrian Red Cross	Deputy head of WASH Unit Vienna
Julia Dissl	Austrian Red Cross	Deputy head of WASH Unit Vienna
Lidwina Dox	Austrian Red Cross	WASH Delegate
Georg Ecker	Austrian Red Cross	WASH Service Center Advisor
Hemma Hammann	Austrian Red Cross	WASH Delegate
Juergen Hoegl	Austrian Red Cross	Head of National Disaster Management
Edith Huemer	Austrian Red Cross	WASH Delegate
Cristopher Jahn	Austrian Red Cross	International Disaster Management Officer
Werner Lechner	Austrian Red Cross/IFRC	WASH Delegate
Katrin Melischnig	Austrian Red Cross	WASH Delegate
John Muathe	Kenyan Red Cross/IFRC	WASH Delegate
Carlota Muianga	UNICEF, Mozambique	WASH Officer
Mohamed Nosier	Egyptian Red Crescent	WASH Officer
Rudolf Ortner	Austrian Red Cross	Deputy head of WASH Unit Upper Austria
Marianne Pecnik	Austrian Red Cross	WASH Delegate/Service Center Advisor
Martina Schloffer	Austrian Red Cross	International Disaster Management Officer
Wolfgang Stoeckl	Austrian Red Cross/IFRC	WASH Service Center Advisor
Tihomir Strekelj	Croatian Red Cross	WASH Delegate
Michael Wolf	Austrian Red Cross	WASH Delegate

The question asked was:

If you would attend a workshop on "User-friendly GIS (Geographic Information System) tools for WASH emergency response operations", which questions would you like to have answered in that workshop regarding the following four central aspects of GIS? (Please list your questions for each point)

- *Hardware*
- *Software*
- *Data*
- *Users and management*

Additionally WASH/DM focal points of the Austrian Red Cross/IFRC have been asked the following questions based on Cavric's research on human and organisational aspects of GIS development [CAV-11]:

- *Who is going to or is expected to use GIS in WASH related disaster management and emergency response? (many people or a few, specialist or non-specialist, technical or administrative staff, etc.)*
- *What will it be used for? (research or management, retrieval or processing, screen displays or printer output, etc.)*
- *Where it will be used? (only at headquarters or in the regions (districts) as well, only at fixed office sites or out in the field or even mobile locations, etc.)*
- *When will it be used? (occasionally or frequently, for short periods or long periods at a time, etc.)*
- *How will it be used? (in stand-alone use or in connection with other equipment and (if in connection) whether it needs to be online or offline and in real time or not, etc.)*
- *Why should it be used in the first place?*

8.2 Templates and Symbols

8.2.1 Assessment/Monitoring: Waypoint records

This template is based on MapAction's guide *GPS for Emergencies v1.* [MAP-07] and has been adapted with feedback from participants at Austrian Red Cross WASH trainings.

Assessment/Monitoring: Waypoint records

Location:

Organisation (Contact)	

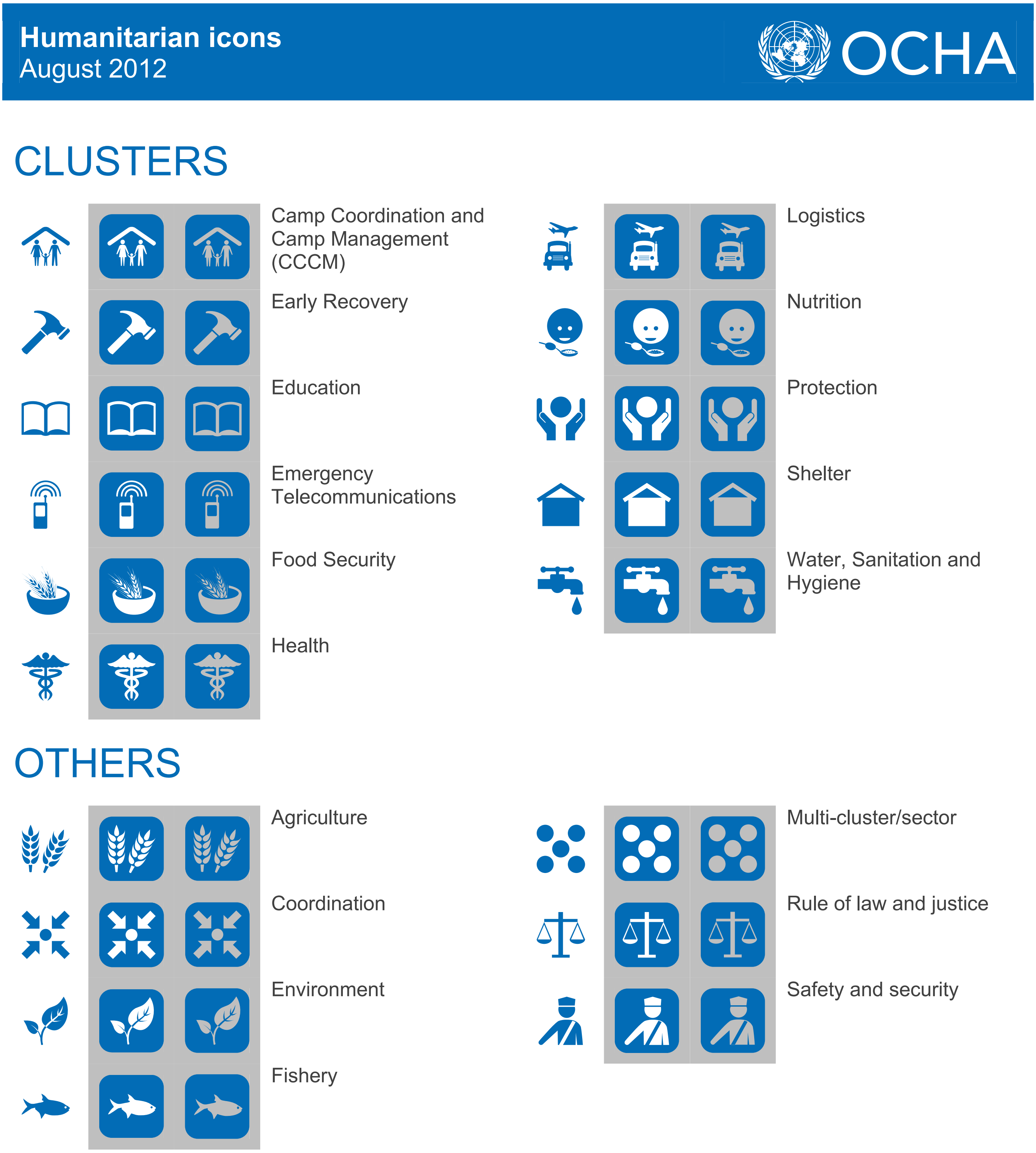
Date	
Name	

Datum	WGS 84
Coordinate format	hddd.dddddd°

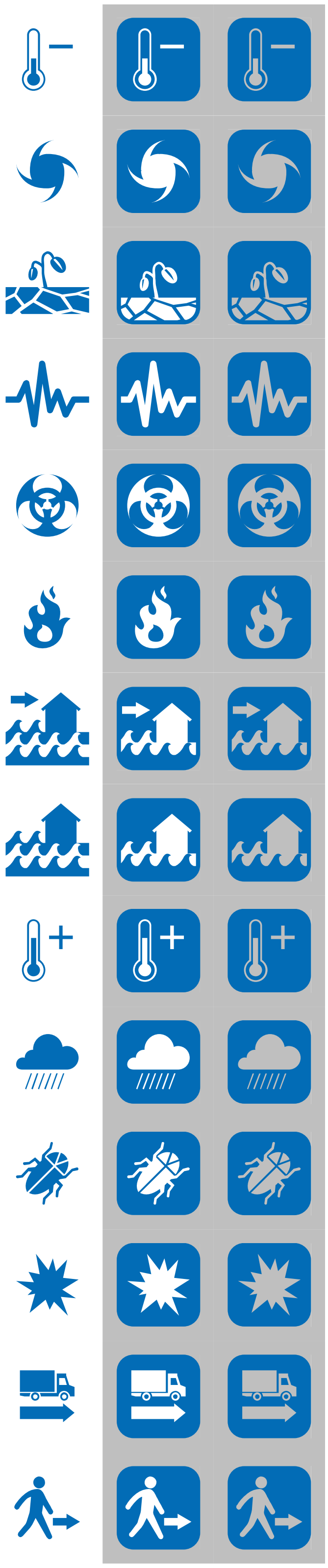
WAYPOINT	COORDINATES		DETAILS											
wpt num	**Latitude**	**Longitude**	**Feature**											**Notes**
from GPS 001, 002, etc. or name	N, S (e.g. N 48.033333)	E, W (e.g. E 014.416667)											functional (Y/N)?	

8.2.2 OCHA Humanitarian Symbol Set

The OCHA humanitarian symbol set can be downloaded for free on *ReliefWeb* (http://reliefweb.int/map/world/world-humanitarian-and-country-icons-2012).



DISASTERS/HAZARDS AND CRISES



Cold wave

Cyclone

Drought

Earthquake

Epidemic

Fire

Flash flood

Flood

Heatwave

Heavy rain

Insect infestation

Conflict

Humanitarian access

Population displacement

Landslide/mudslide

Locust infestation

Snow avalanche

Snowfall

Storm

Storm surge

Technological disaster

Tornado

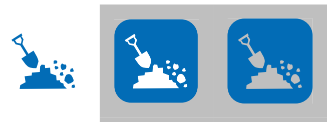
Tsunami

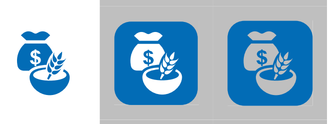
Violent wind

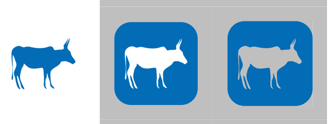
Volcano

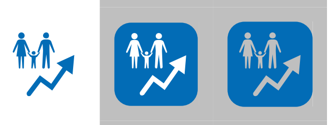

Population return

SOCIOECONOMIC AND DEVELOPMENT


Debris management

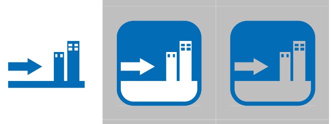

Livelihood

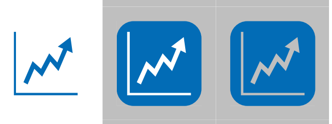

Livestock


Population growth


Reconstruction


Rural


Rural exodus


Trade and market


Urban

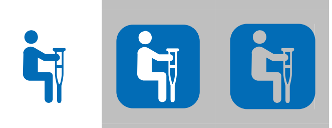

Urban/rural

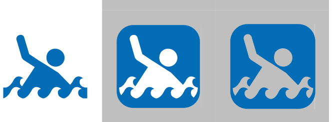
PEOPLE

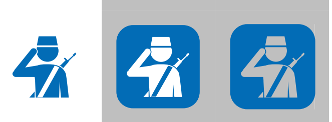

Affected population

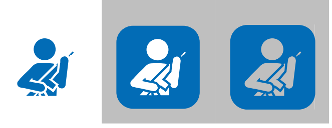

Missing

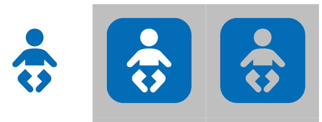

Dead

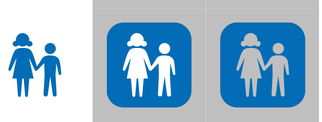

Injured

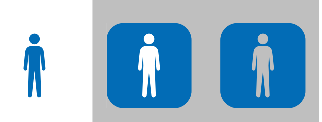

Drowned

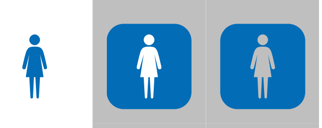

National army

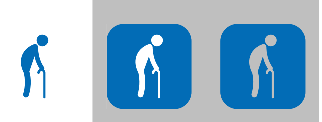

Rebel

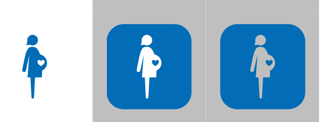

Infant


Children

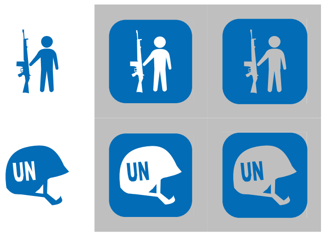

Man


Woman


Elderly


Pregnant

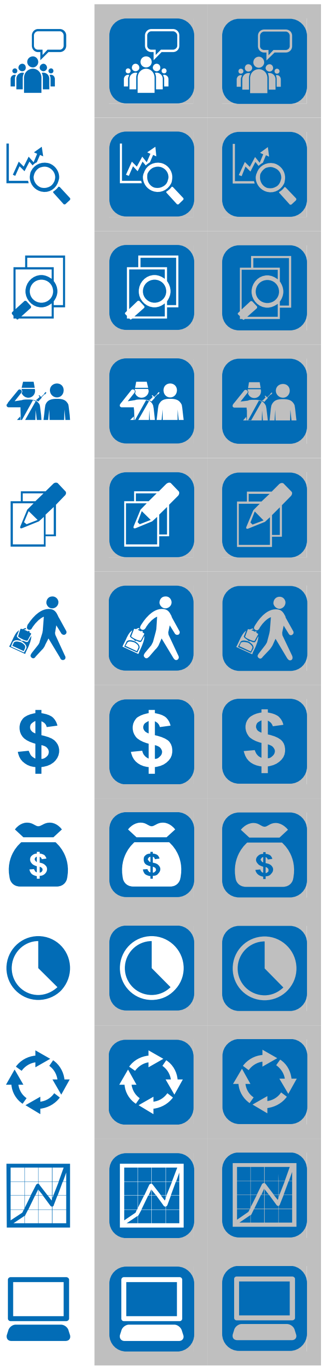

People with physical impairments



Child combatant

Peacekeeping force

ACTIVITIES/STRATEGY



Advocacy

Analysis

Assessment

Civil-military coordination

Coordinated assessment

Deployment

Financing

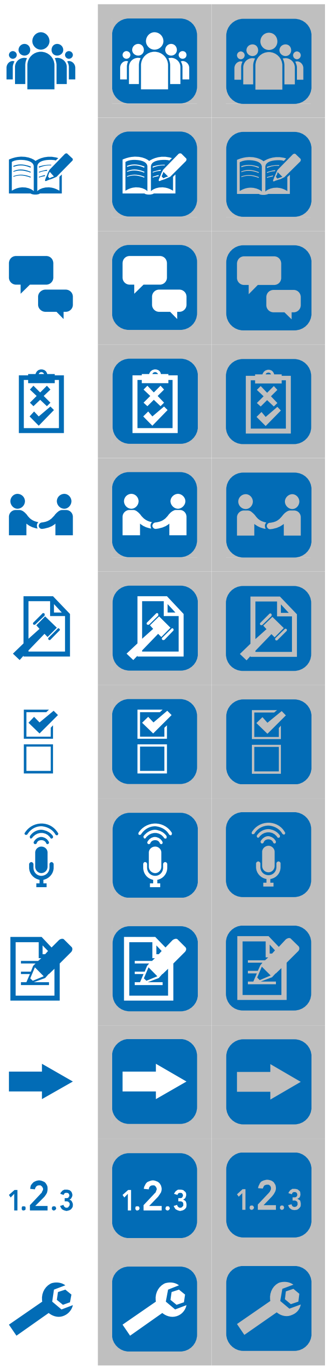
Fund

Gap analysis

Humanitarian programme cycle

Information management

Information technology



Leadership

Learning

Meeting

Needs assessment

Partnership

Policy

Preparedness

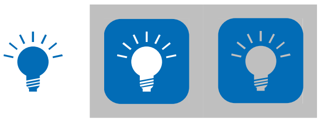
Public information

Reporting

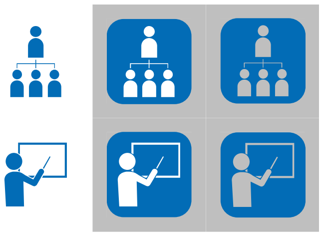
Response

Scale up/down operation

Services and tools



Innovation



Staff management

Training

PRODUCT TYPE

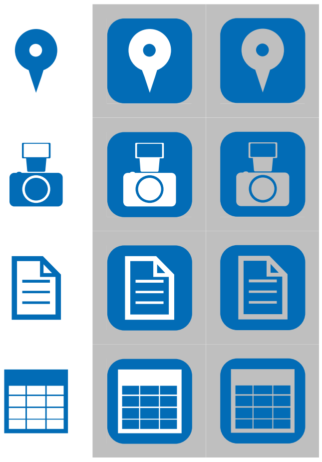
Calendar

Chart

Data

Document

Film



Map

Photo

Report

Table

FOOD AND NON-FOOD ITEMS

Blanket

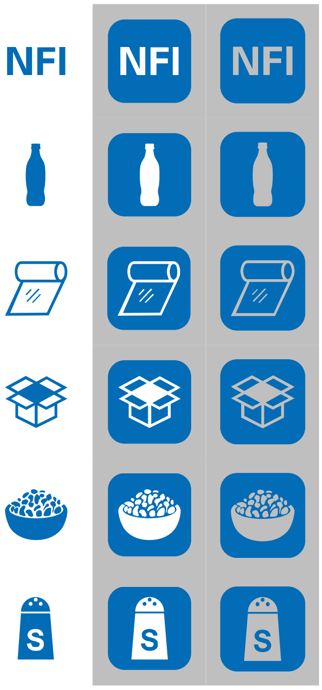
Bottled water

Bucket/jerry can

Clothing

Detergent

Flour



Non-food items

Oil

Plastic sheeting

Relief goods

Rice

Salt

Food

Infant formula

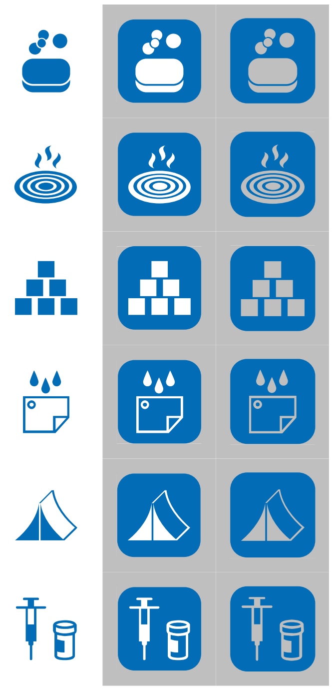
Kitchen set

Mattress

Medicine

Medical supply

Mosquito net



Soap

Stove

Sugar

Tarpaulin

Tent

Vaccine

WATER, SANITATION AND HYGIENE

Borehole

Communal latrine

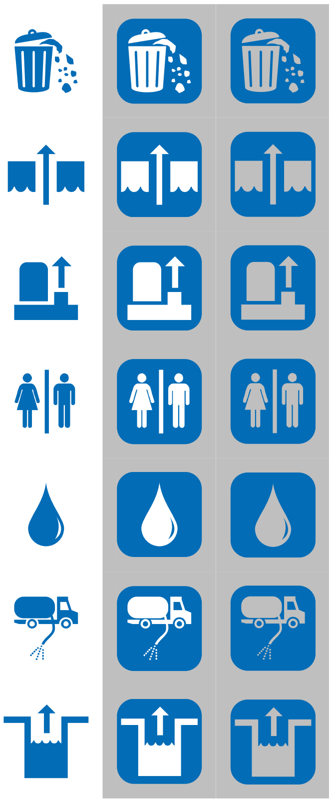
Latrine cabin

Potable water

Potable water source

Sanitation

Shower



Solid waste

Spring water

Submersible pump

Toilet

Water source

Water trucking

Well

CAMP

IDP/refugee camp

Permanent camp

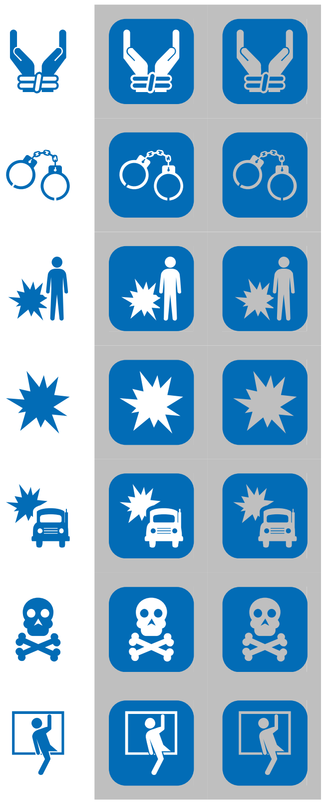
Temporary camp

Registration

Spontaneous site

Transition site

SECURITY AND INCIDENT



Abduction/kidnapping

Arrest/detention

Assault

Attack

Carjacking

Dangerous area

Forced entry

Forced recruitment

Harassment/intimidation

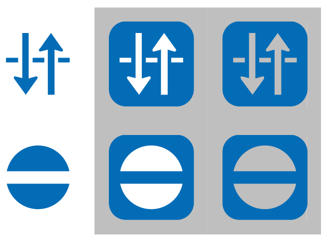
House burned

Mine

Murder

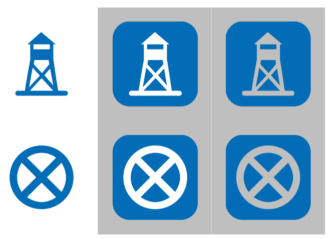
Robbery

PHYSICAL BARRIER



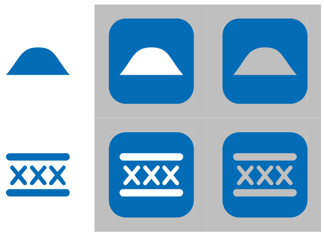
Border crossing

Checkpoint



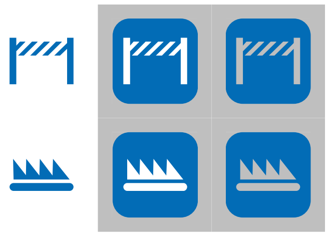
Observation tower

Physical closure



Earthmound

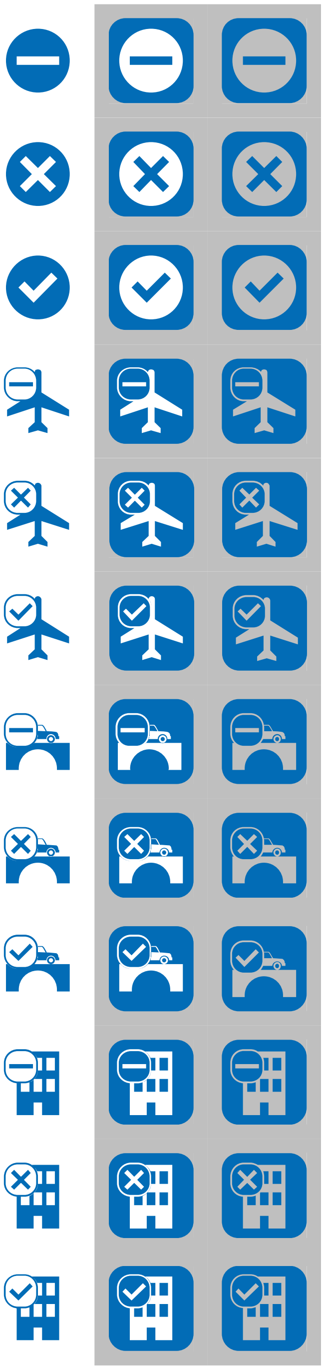
Military gate



Road barrier

Roadblock

DAMAGE



Damaged/affected

Destroyed

Not affected

Airport affected

Airport destroyed

Airport not affected

Bridge affected

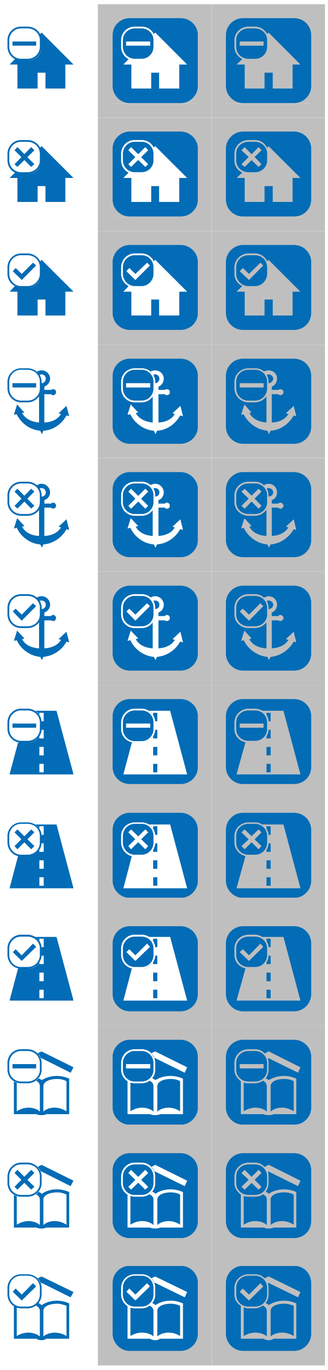
Bridge destroyed

Bridge not affected

Building affected

Building damaged

Building not affected



House affected

House destroyed

House not affected

Port affected

Port destroyed

Port not affected

Road affected

Road destroyed

Road not affected

School affected

School destroyed

School not affected

GENERAL INFRASTRUCTURE

Assembly point

Buddhist temple

Building

Church

Clinic

Community building

Diplomatic mission

Distribution site

Food warehouse

Government office

Health facility

Health post

Hindu temple

Hospital

House

Infrastructure

Mobile clinic

Mosque

NGO office

Police station

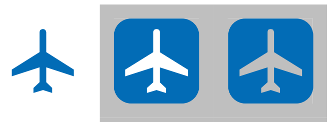
School

UN compound/office

University


Hotel

LOGISTICS


Airport


Airport military

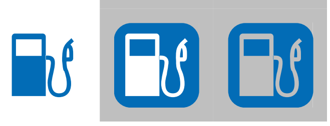

Boat

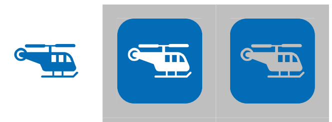

Bridge

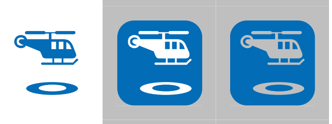

Bus


Car


Ferry


Gas station


Helicopter


Helipad

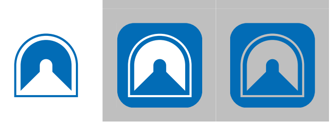

Port


Road


Ship


Train


Truck


Tunnel

TELECOMMUNICATIONS


Computer

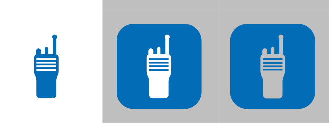

E-mail


Fax


Internet


Mobile phone


Radio


Walkie Talkie

8.3 Training Curriculum Example

The following outline of a half-day training on GPS and mapping in emergencies in the WASH sector is based on the idea, that this training should be part of a several days lasting WASH training. As the aim of this training is to enable people in the WASH sector to make use of GPS technology and GIS software tools for their work in emergencies, it is assumed that this is best done when such a training is connected with other parts/activities of the overarching training (e.g. case studies). The training curriculum is worked out in a manner that focuses on basic elements of WASH work, rather than on a very specific WASH training context, so it can be adapted to various training situations, which includes for example refresher trainings or field exercises.

Core content	Training in the use of GPS and GIS software tools for WASH in emergencies.	4 Learning units[2] / 4 hours incl. breaks
Target	Enabling people in the WASH sector to make use of GPS technology and GIS software tools for collecting, processing and sharing geo-referenced information in emergencies	
Requirement profile for trainers	Knowledge of WASH field work in emergencies; Knowledge of GPS technology and the use of GPS handhelds; Familiarity with the functionalities of GIS software tools like *Google Earth, Garmin BaseCamp/MapInstall, GPSBabel, Geotag, DNRGPS* or similar and related data formats like *gpx* and *kml/kmz*; Average computer skills including standard office applications	
Target group	People who work in the WASH sector or are trained to do so (e.g. Red Cross volunteers)	
Language	English	
Content	1) Introduction to GPS and GIS for WASH 2) GPS basics 3) Data processing and sharing 4) Feedback/Wrap-up	
Teaching and learning methods	Visual, auditory and tactile: Flipcharts, individual working with hardware and software, outdoor exercise, involving experiences and knowledge of participants	
Specific content		

[2] 1 learning unit equals 50 minutes

1) Introduction to GPS and GIS for WASH	Experiences/knowledge of participants; Explanation of the terms GPS and GIS including required hardware, free/open-source software and free available data; Examples from WASH emergency response operations for using GPS and GIS to highlighting reasons for making use of these tools;	**15 minutes**
2) GPS basics	Technical background of GPS technology; Conditions for proper working of GPS receivers; Functionality of GPS handhelds; Working with coordinates and different position formats; Geodetic datum (WGS 84); GPS exercise (mark waypoints, go to x y; tracking)	**60 minutes**
3) Data processing and sharing	Downloading OSM maps for GPS handhelds; Uploading maps to GPS handhelds; Explanation of purpose and use of different data formats (*gpx, kml/kmz*); Transferring data between GPS and software; Editing GPS data with *Google Earth* (add text/links to images; change icons); Saving and sharing *kmz* files via e-mail; Geo-tagging photos	**120 minutes**
4) Feedback/Wrap-up	Feedback from participants on training content and usability of presented applications	**5 minutes**

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DeLorme	http://www.delorme.com/default.aspx Consumer GNSS handheld manufacturer
Garmin	http://www.garmin.com/ Consumer GNSS handheld manufacturer
Lowrance	http://www.lowrance.com/ Consumer GNSS handheld manufacturer
Magellan	http://www.magellangps.com/ Consumer GNSS handheld manufacturer
OCHA	http://www.unocha.org/ OCHA’s official website
OCHA IM WIKI	https://sites.google.com/site/ochaimwiki/ Guidance and resources on information management in OCHA
OneResponse	http://oneresponse.info/Pages/default.aspx Inter-agency website with information, resources and links on humanitarian coordination and the clusters
ReliefWeb	http://reliefweb.int/ Source for humanitarian information created and maintained by OCHA

Curriculum Vitae

Philipp Polanski
(*1985, Steyr, Austria)

Contact
philipp.polanski@gmx.at

Work experience

03/2012 – 04/2012	Water and Sanitation Delegate/Trainer (WASH Training in Kosti and Al Salam, Sudan) ECHO Disaster Preparedness Project in Sudan by SRCS/AutRC
03/2011 – 03/2011	Water and Sanitation Delegate/Trainer (WASH Disaster Response Kit Trainings in Khartoum, Sudan) ECHO Disaster Preparedness Project in Sudan by SRCS/AutRC
08/2010 – 10/2010	Internship at the 'National Housing Strategy Project for the Kingdom of Saudi Arabia' of the General Housing Authority (GIZ International Services in Riyadh, Saudi Arabia) Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH
02/2010 – 03/2010	Water and Sanitation Delegate (IFRC Floods Operation in Dodoma/Morogoro Region, Tanzania) IFRC/AutRC
10/2009 – 01/2010	Part-time Worker Wholesale distribution business
09/2003 – 09/2004	Paramedic (community service) at the Austrian Red Cross' local branch Town of Steyr
Summer 2000 – 2009	Vacation Worker Sawmill (2000 – 2002); Contracting Business (2003); Truck Manufacturer (2005 – 2008); Glass Producer (2009)

Education

since 10/2004	University of Vienna: **Geography** with focus on spatial research and planning, regional development and geographic information systems; **Development Studies** with focus on services of general interest in the context of sustainable rural and urban development, natural resources management, and social/economic security policies
09/1995 – 06/2003	Secondary school for general education (Bundesgymnasium Werndlpark in Steyr)

Languages German (mother tongue), English and Spanish

Miscellaneous

since 04/2006	Volunteer of the Austrian Red Cross' Emergency Response Unit 'Water and Sanitation'
10/2004 – 12/2009	Volunteer of the Austrian Red Cross as paramedic

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