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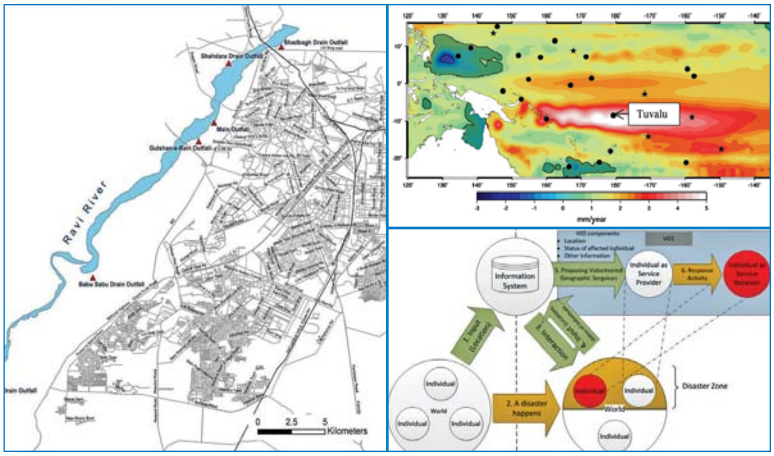
Sea Level Change FACT or FICTION

Best practices in surveying



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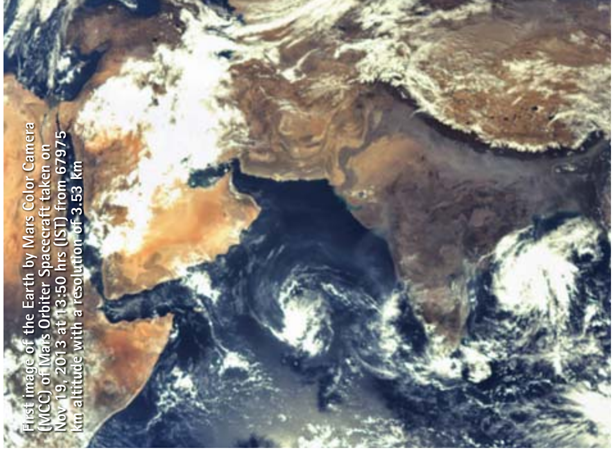

First image of the Earth by Mars Color Camera (MCC) of Mars Orbiter Spacecraft taken on Nov 19, 2013 at 13:50 hrs (IST) from 67975 km altitude with a resolution of 3.53 km

India goes to Mars

It was September 24, 2014.

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which was launched on-board India's launch vehicle PSLV on November 5, 2013

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Successfully entered into an orbit around planet Mars.

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Sea level change - An inconvenient fact or an irritating fiction?

Claims that sea level has not risen significantly over the last 150 years and, indeed, should not be expected to do so over the next 100 years can be safely disregarded

Emeritus Professor John Hannah
University of Otago and Managing Director, Vision NZ Ltd, New Zealand

In 2012, the United Nations Environment Programme issued its report on the most important emerging issues related to the global environment (UNEP, 2012). The top ranked issue in that report related to the alignment of land governance to the challenges of global sustainability. Global sustainability, however, has itself been firmly linked by the UN both to the challenges of mitigating the effects of climate change, and adapting to its impacts (UN, 2013). If anthropogenic climate change is a fiction or, indeed, presents little threat to the world of the future, then the challenge of global sustainability becomes considerably less severe, giving the human race more time to deal with some of its deep environmental issues.

One of the impacts of climate change of particular concern to surveyors is the issue of sea level rise. The height systems used for topographic mapping and for building coastal engineering infrastructure (e.g., storm water systems, bridges, roads, etc.) are typically referenced to Mean Sea Level (MSL). Coastal cadastral boundaries are also defined with respect to sea level datums such as Mean High Water (MWH) or Mean High Water Springs (MHWS). If there is no steady rise in sea level, then apart from storm damage and the normal coastal erosion processes that have prevailed over the last two millennia, there should be no concern with possible long-term inundation.

While sceptics make many assertions regarding climate change, this paper will focus specifically on arguments with respect to sea level change. Having refuted these arguments, it will then suggest a reasonable sea level rise scenario that can be used for future planning purposes.

Global oceans have been rising at a linear rate of approximately 1.8 mm/yr throughout the 20th century with satellite altimetry data, and other sources, indicating an increase in rate to 3.2 ± 0.5 mm/yr from 1993-2009

The academic context

A perusal of a wide sample of the papers written by perhaps the most quoted sea level rise sceptic, Professor Nils Mörner, reveal him to be very capable paleogeophysicist with advanced knowledge of the Earth's lithosphere and plasticity. He has clearly undertaken a great deal of research into historical vertical crustal movements in Scandanavia over geological time scales (i.e., the last 100,000 BP). This peer-reviewed material, mostly published well over a decade ago, is widely available. The knowledge developed from these studies, together with more recent field trips to places such as the Maldive Islands and Bangladesh, forms the basis from which Professor Mörner makes various assertions regarding present and future sea level rise.

It is unfortunate that in some regards Professor Mörner's credibility as an expert in global sea level rise is compromised by overly grandiose descriptions of his academic credentials. For example, Lord Monckton,who is widely quoted by sceptics, states that Professor Mörner is, "the world's foremost sea level expert, who has studied this complex phenomenon for half a century and has published several hundred papers on it," (Monckton, personal communication). What is not mentioned, however, is that many of Professor Mörner's recent papers on the subject have not been published in high quality peer reviewed journals, but appear essentially as personal opinion pieces.This issue is discussed later in this paper. Additionally, peer reviewed publications by Professor Mörner related to the comprehensive analysis of a global set of modern day tide gauge records such as have been done by Douglas, (1997); Peltier, (2001); Woodworth et al, (2008); Church and White, (2011); or Jevrejeva et al, (2013) appear to not exist.

The primary assertions

Before elucidating upon the primary assertions advanced by Professor Mörner, it is perhaps useful to note that the author is in full agreement with him on the need to use reliable observational data as the basis for the assessment of sea level rise as seen in present day. It is from this perspective that the assertions made have been considered.

Assertion 1: There is no Rising Trend in Global Sea Levels

Mörner (2007[a]) is explicit is this assertion. He speaks of a maximum rising trend in global sea levels of 1.1 mm/yr from 1850-1930 followed by a fall. The net result is, in his words, "*absolutely no trend*". He notes that tide gauging is very complicated, giving different answers wherever one might be in the world, thus necessitating the use of geological information for a correct interpretation of the results. There is no dispute with this comment. Not only are different regions of the world subject to different levels of glacio-isostatic adjustment (GIA) following earlier ice ages, but local tide gauges can be subject to local subsidence due to ground water withdrawal or sediment compaction, and also to differing levels of tectonic deformation. These effects are well known and are fully described in Hannah, (2010). Indeed, there are many other errors that can subtley influence a tide gauge record (e.g., unrecorded datum offsets), that are not mentioned and that can be far more important to a correct interpretation of a tide gauge record.

When all these effects are appropriately considered, the observational data from a global set of reliable tide gauges will provide an unambiguous answer to the issue of global sea level trends over the 20[th] century. Douglas (1997), using 24 long tide-gauge records and Tushingham and Peltier's (1991) GIA model, estimated global sea levels to be rising at a rate of 1.8 ± 0.1 mm/yr. Peltier (2001), using essentially the same tide gauge set plus a more recent GIA model estimated the rise to be 1.84 – 1.91 mm/yr. Importantly, these are the very systematic effects that Mörner himself advocates as necessary for correcting tide gauge data.

Church and White (2011), using a 'reconstruction' method on a sea level data set that extended from 1880-2009, determined a global sea level trend of 1.6 mm/yr when the data was weighted by its uncertainty estimates (a statistically correct procedure). Jevrejeva et al (2013), using a global set of 1,227 tide gauge records, taken in 14 ocean basins/regional blocks, calculate a linear sea level trend of 1.9 ± 0.3 mm/yr for the 20[th] century. They note, however, that the choice of GIA correction is crucial to the result, having the ability to alter the global trend by 0.3-0.6 mm/yr. In New Zealand's case, the observational data are unambiguous in revealing a non GIA corrected estimate of sea level rise since 1900 of 1.7 ± 0.1 mm/yr and a GIA corrected estimate of 2.1 mm/yr (Hannah, 2004; Hannah and Bell, 2012). In arriving at these figures, all factors have been considered, including any possibility of tide gauge subsidence.

> Professor Mörner's writings indicate that he is an advocate of the theory that there is a global conspiracy amongst many of the world's scientists aimed towards confusing and deluding the unsuspecting public. Their supposed motivation – a desire to obtain and/or retain their research grants

Irrespective of the analysis method used, the data set and the researcher, the outcome is the same, namely, that contrary to Professor Mörner's assertions, global eustatic sea levels have been rising consistently throughout the 20[th] century at an average linear rate in the order of 1.8 mm/yr. It is of interest to note that the more recent presentations of some sceptics appear to depart from Professor Mörner's position such that they now acknowlege the reality of this rise (Moncton, personal communication). This is encouraging to see.

Assertion 2: The results from Satellite Altimetry Data have been fudged

While satellite altimeters have been in use since the 1980s, high precision altimetry began with the launch of Topex/Poseidon in 1992 and its successors Jason-1 (2001) and Jason-2 (2008). It is the data from these last three missions that is in question here.

While it is difficult to fully understand the nature of the problem being identified in Mörner (2007[a]), it becomes clearer both in Mörner (2003) and in the subsequent discussions found in Nerem et al, (2007), and Mörner (2007[b]). In part, Mörner appears to start from the premise that his view of global sea level rise is correct and that any contradictory evidence is incorrect. He thus dismisses the work of Douglas (1991, 1995, and 1997) as being *widely debated and far from generally accepted* (Mörner, 2007[b]). Unfortunately, he is incorrect on both issues such that Douglas' work has been shown to be both robust, and has also been widely accepted, both by other paleogeophysicists (e.g., Peltier, 2001) and now, seemingly, by some sceptics. When sea level data from a global tide gauge network is used to calibrate the satellite altimeter data (as is the case), Mörner dismisses the subsequent altimeter results as having been fudged.

The second, but associated leg to Mörner's argument is the bias that he claims exists between the three different satellite missions. While the author of this paper advises caution on the bias issue, the weight of evidence suggests that Mörner's criticisms lack substance. These are refuted in Nerem et al (2007). In addition, the process of calibrating a satellite alimeter is described at *www.psmsl.org/train_and_info/training/gloss/gb/gb1/alt_cal.html);* whilst the creation of a single uniform altimeter data set from the various satellite altimeter missions is described in Leuliette et al, (2004) and Beckley et al, (2010). Both processes are open and transparent. Furthermore, Meyssignac and Cazenave (2012), show the full altimetry based mean sea level data set superimposed upon the 20th century mean sea level data set. Crucially, both data sets show an almost linear rise in sea level over the entire altimetry time period (1993-2010) with the altimetry data revealing a 3.2 ± 0.5 mm/yr rise over those years. Importantly, and over the same time period, Church and White (2011) estimate a sea level rise using in situ tide gauge data of 2.8 ± 0.8 mm/yr. Jevrejeva et al (2013) refine this estimate to 3.1 ± 0.6 mm/yr.

As an aside, the satellite altimetry record merely complements the ongoing tide gauge record. New data sets such as those associated with recent gravity satellite missions are becoming available and should, as their time series lengthen, add to the picture. In New Zealand, the linear sea level trend as determined from the tide gauge record at Auckland (perhaps the most stable and reliable in New Zealand), has been analysed as two distinct series. The first from 1899 – 1992 and the second from 1899 – 2013. The second, which includes the complete altimetry period, shows that the rate of rise in mean sea level has increased by 0.19 ± 0.13 mm/yr, a result that while not yet quite statistically significant certainly corroberates with the results being delivered by the altimetry data (Denys et al, 2014).

Assertion 3: Sea Levels in the Maldives fell 20-30 cm in the 30 years prior to 2004

This claim can be found in Mörner et al (2004) and is used as evidence to support his contention that global sea levels are not rising. Fortunately this claim, which is based upon an interpretation of morphological and sedimentological data, is made in a peer reviewed paper and thus, is open to much wider scientific scrutiny than publications such as Mörner (2007[a]) or Mörner (2010). Mörner himself notes that a rate of change of 10 mm/yr in sea level is *most surprising*, attributing this fall to *a regional eustatic change confined* [my emphasis], *to the central Indian ocean*. This fall is attributed to the effect of increased evaporation. The objections to Mörner et al's comments are multiple.

Firstly, if the sea level fall were actually real, Mörner has already conceded that it can only be a localised regional effect. In that case, it cannot be used as the basis for any definitive statement regarding global sea level change.

Secondly, Woodworth (2005), after examining a number of met-ocean data sets and regional climate indicies, at least one of which would have been expected to reflect a large sea level fall, could find no supporting evidence for such a fall. He not only concluded that such a fall was *implausible*, but that the suggestion that it could have been caused by an increase in evaporation was demonstrably incorrect.

Thirdly, Kench et al (2004), challenge the correctness both of Mörner et al's interpretations and the conclusions drawn from their morphological evidence. Mörner and Tooley (2005) seek to reply to these challenges but are unable to do so in any detail, substantially falling back on the argument that all will be revealed in future presentations of their observational material. To the best of the author's knowledge, such peer review assessments as to the content and accuracy of this additional data have yet to appear.

Assertion 4: There is No Rise in Sea Level at the Tuvalu Islands

As with the Maldives, this claim is made as supporting evidence that global sea levels are not rising. In Mörner's words, *There is absolutely no signal that the sea level is rising.*

The first response to this assertion is, to wonder why this should be important. The Tavalu Islands are located close to an active and complex plate tectonic zone where vertical crustal deformation is likely. Until there is a history of tide gauge data coupled with continuous GPS data at the same site, any determination of the rise or fall in eustatic sea level at this location will be uncertain.

However, putting this issue aside, Becker et al (2012) have examined in detail sea level variations in the tropical Pacific islands since 1950. By reconstructing the sea level record from 1950-2009 through the use of good quality tide gauge records and gridded heights an Ocean General Circulaton Model, they find that sea level has risen at Tavalu at a rate of approximately 5.1 ± 0.7 mm/yr over the period 1950-2009. This result takes full cognizance of the known periodic effects such as the 2-4 year ENSO effect and the 20-30 yr Interdecadal Pacific Osillation (IPO). The reconstructed sea level trends for the tropical western Pacific taken from Becker et al (2012), are shown in figure 1.

The broader picture

It is important to note that Professor Mörner typically chooses to make

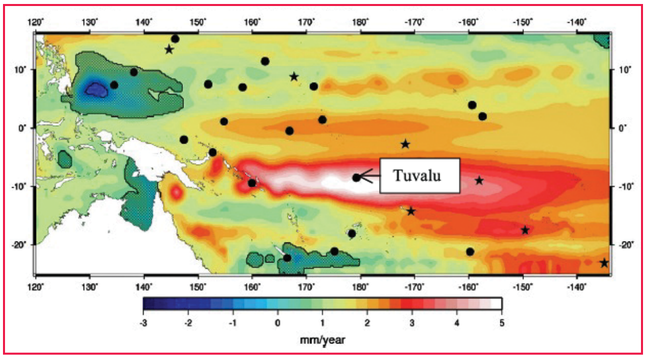

Figure 1: Map of reconstructed sea level trends in the tropical western Pacific (1950-2009)

his assertions in non-peer reviewed publications. This is nowhere more apparent than in Mörner (2010) – a document that is more explicit in its critisms than Mörner (2007[a]). In his more recent document, he not only substantially fails to address the criticisms of his work as raised earlier in this paper, but he introduces new inaccuracies. He states for example, that local sedimentary ground changes cannot be recorded – overlooking the fact that many world tide gauge sites have been precisely monitored for well over 100 years using leveling techniques, and by GPS measurement techniques for at least a decade (e.g.,Wöppelmann et al, 2009,Santamaría-Gómez et al, 2012).

Interestingly, Professor Mörner's writings indicate that he is an advocate of the theory that there is a global conspiracy amongst many of the world's scientists aimed towards confusing and deluding the unsuspecting public. Their supposed motivation – a desire to obtain and/or retain their research grants (Mörner, 2007[a]). In Mörner (2010), he further accuses scientists as being driven by a hidden 23-year-old Intergovernmental Panel on Climate Change (IPCC) agenda that specifies what tide gauges in a global network should be selected for analysis. Having been associated with the first three IPCC assessment reports, the author of this paper can testify personally that this is a delusion of the highest order. Furthermore, the author has no research grants that hinge upon climate change and no vested interests in any particular outcome of this discussion, beyond seeing truth prevail.

Table 1: Projected change in global mean surface air temperature and global mean sea level rise for the mid- and late 21st century relative to the reference period of 1986–2005, taken from IPCC (2013)

		2046-2065		2081-2100	
	Scenario	**Mean**	***Likely* range**	**Mean**	***Likely* range**
Global Mean Surface Temperature Change (°C)	RCP2.6	1.0	0.4 to 1.6	1.0	0.3 to 1.7
	RCP4.5	1.4	0.9 to 2.0	1.8	1.1 to 2.6
	RCP6.0	1.3	0.8 to 1.8	2.2	1.4 to 3.1
	RCP8.5	2.0	1.4 to 2.6	3.7	2.6 to 4.8
	Scenario	**Mean**	***Likely* range**	**Mean**	***Likely* range**
Global Mean Sea Level Rise (m)	RCP2.6	0.24	0.17 to 0.32	0.40	0.26 to 0.55
	RCP4.5	0.26	0.19 to 0.33	0.47	0.32 to 0.63
	RCP6.0	0.25	0.18 to 0.32	0.48	0.33 to 0.63
	RCP8.5	0.30	0.22 to 0.38	0.63	0.45 to 0.82

Future sea level change

If there is a point at which the author and Professor Mörner are likely to agree, it is in the difficulty of assessing a most likely sea level rise scenario for the future. Clearly, some predictions have been alarmist in nature and not based on strong science. However, as science has improved so has the understanding of likely future sea level rise. It is now understood, for example, that while a global sea level rise scenario can be determined, it is likely that there will continue to be significant regional variations for periods of a decade or more, most likely due to changes in trade winds and other forcing factors (IPCC, 2013). Equally, vertical land motion due to local subsidence, GIA, or other tectonic factors will also have a marked influence. Fortunately, GPS techniques now allow such land motion to be measured in a global reference frame with a high degree of confidence.

While these factors must be recognised as being of potential influence in any local or regional future sea level rise scenario, a realistic estimate for a global sea level change scenario is still of importance.

Any future assessment of sea level change rests heavily upon the extent to which climate changes – change that is estimated through the use of climate models. These models produce a wide range of possible outcomes depending upon the various forcing factors used – factors that in turn depend upon assumptions relating to industrial growth, greenhouse gas emissions, deforestation, the impact of clouds, and human response (amongst other things).

IPCC (2013) provides a number of climate change model scenarios derived from the concentration-driven CMIP5 model simulations. The different model simulations produce temperature change scenarios that are then combined with process based models and a literature assessment of glacier and ice sheet contributions to produce associated sea level change scenarios. These results, which vary between the strictest emissions mitigation scenario (RCP2.6) to a high emissions scenarion (RCP8.5) are shown in Table 1. While higher projections for sea level rise than are shown in the table have been mooted, the IPCC considers that there is insufficient evidence to evaluate the probability of specific levels above the ranges shown. There remains a lack of consensus and low confidence in the semi-empirical model projections.

Given a mean reference period date of 1995, and an assumed rise in sea level of about 3 mm/yr since then (i.e., 0.05 m to the present day), a reasonable planning range for sea level rise to 2090 from the present day is between 0.21 m and 0.77 m (i.e., 0.26–0.05 m and 0.82-0.05 m).

Given a mean reference period date of 1995, and an assumed rise in sea level of about 3 mm/yr since then (i.e., 0.05 m to the present day), a reasonable planning range for sea level rise to 2090 from the present day is between 0.21 m and 0.77 m (i.e., 0.26–0.05 m and 0.82-0.05 m)

In deriving a sea level change scenario for a particular region, one needs to take the global figures given above and correct them for any ground motion derived from local precise leveling and GPS tide gauge monitoring data. In New Zealand, for example, where a general tectonic stability seems to have prevailed over the last 100 years (the Wellington excluded over the last 15 years and the Christchurch region since 2010), and where the local rates of sea level rise almost exactly match the global average, these numbers can be used directly.

Conclusions

Global oceans have been rising at a linear rate of approximately 1.8 mm/yr throughout the 20th century with satellite altimetry data, and other sources, indicating an increase in rate to 3.2 ± 0.5 mm/yr from 1993-2009. While there remains some debate as to whether or not this increase is permanent or whether that it reflects some periodic oceanic signal,or whether there has been an acceleration in the rate of sea level rise over the last few decades, best future sea level rise scenarios indicate a likely rise in global sea levels of between 0.26 m and 0.82 m, relative to 1986-2005 by 2081-2100. Claims that sea level has not risen significantly over the last 150 years and, indeed, should not be expected to do so over the next 100 years can be safely disregarded.

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Sea level changes in the 19-20th and 21st centuries

I have read the paper by Hannah (this volume), and I arrive at a totally opposite conclusions, viz. that there is no indication what so ever of a recent sea level acceleration, and that it is the high rates around 3 mm/yr that should be "safely disregarded"

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I have read the paper by Hannah (this volume), and I arrive at a totally the opposite conclusions, viz. that there is no indication what so ever of a recent sea level acceleration, and that it is the high rates around 3 mm/yr that should be "safely disregarded".

In the present paper, I will review some of my own observations and arguments with respect to present sea level changes.

There is only one place in the world where we have a full control of the crustal component, and hence are able to isolate the true eustatic component from the relative sea level changes recorded, and that is the Kattegatt Sea (Mörner, 2014a). Here, the eustatic factor can be closely fixed at 0.9 mm/yr. This implies a value only half of the value favoured by Hannah (this volume) and only about 30% of the value from satellite altimetry – which is far too large differences to be attributed to regional variability.

In Figure 1, I have plotted the sites used and the values of sea level changes arrived at on the NOAA map of rates of sea level changes based on satellite altimetry (NOAA, 2014), and in Table 1 further details are added (all to be discussed below).

> Shore morphology and tide gauge records indicate a present rate of sea level rise in the order of ±0.0 to +2.0 mm/yr. IPCC models and satellite altimetry, on the other hand, suggest rates in the order of 3 mm/yr. These two data sets are in too large a conflict: one of them must be discarded. The author concludes that it is the high-rate values that have to be discarded. This provides an estimate of the most likely changes in sea level up to year 2100 of -10 to +20 cm, which poses little or no problems of coastal inundation

Sea level complexity

The sea level is changing both vertically and horizontally for several different reasons (as recently reviewed in Mörner, 2013a). At the shore itself, crustal, oceanic and dynamic factors interact in a complicated manner (e.g. Figure 1 of Mörner, 2010a).

At the shore, we make our observations of changes in the coastal environment, usually manifested in the details of the shore morphology. Therefore, our studies have to be diverged to different coastal settings; off-shore environments, hard-rock coasts, sandy coasts, lagoons and lakes. This is how we worked in the Maldives (Mörner et al., 2004; Mörner, 2007a, 2011a; 2013a).

The tide gauges are by necessity located to the shore zone, and generally to river mouths where harbours are located. The oldest tide gauge was installed in Amsterdam in 1682. As the name says, it is an instrument to measure the tides in order to know the best time of entering or leaving a harbour. There was, however, also a long-term consideration. In Sweden and Finland, numerous tide gauges were

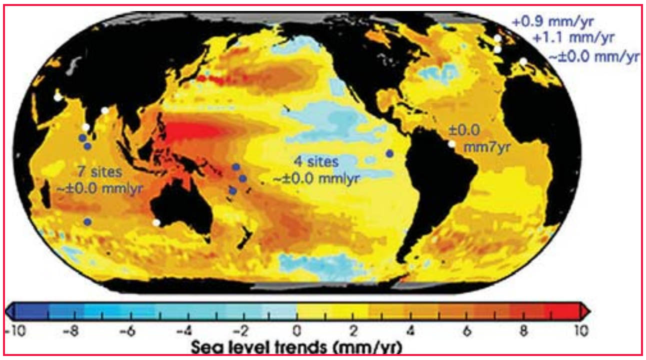

Figure 1: The NOAA (2014) map of sea level changes as derived from satellite altimetry with the sites discussed in the text marked and their sea level component given (cf. Table 1)

installed in order to measure the land uplift. If not compensated by continual dredging and lowering of quay constructions (as recently was the case in Stockholm), the harbour had to be dislocated down-streams. In other parts of the world, a river mouth usually also implies a delta area, which predominantly is subjected to a long-term subsidence. This means that tide gauges in such environments are likely to be affected by a subsidence factor, which has to be quantified in order to asses true sea level rise. The sediments themselves are subjected to compaction, especially if loaded by a heavy harbour construction (where the tide gauge was used to be placed). Coastal water-withdrawal has resulted in high-rate subsidence in places like Bangkok and Nirita in Japan. Therefore, a global set of tide gauges (away from uplifted areas) has a tendency of overestimating the sea level rise (Mörner, 2004, 2010a, 2013a).

Table 1: Summary of sites discussed in the text with respect to coastal stability with known subsidence/uplift rates, regional eustasy in tide gauges and mean satellite values of Figure 1.

Locality	Stability subm(+),em(-)	Regional eustasy (mm/yr)	Reference	Satellite altimetry (Fig. 1)
Indian Ocean:				
The Maldives	±0.0 in 40 yrs	small to <1.0	1, 2	2.5-3.7
Bangladesh	±0.0 in 50 yrs	small to <1.0	3	3.7-5.0
Goa, India	±0.0 in 50 yrs	~0.0 in 50 yrs	4	2.5-3.7
Minicoy	±0.0 in 40 yrs		5	2.5-3.7
Perth		~0.0 in 15 yrs	6	3.7-5.0
St Paul	stable	no rise in 135 yrs	7, 5	2.5-3.7
Qatar	stable	no rise	8	2.5-3.7
Pacific:				
Kiribati		±0.0 in 20 yrs	5	5.0-6.2
Tuvalu		±0.0 in 30 yrs	9,10	5.0-6.2
Vanuatu		±0.0 in 20 yrs	9	5.0-6.2
Galapagos		±0.0 in 30 yrs	5	0.0-1.2
S. Atlantic:				
Guyana	stable	±0.0	10	3.7-5.0
Mediterranean:				
Venice	+2.3 in 300 yrs	±0.0 in 140 yrs	9,11	2.5-3.7
North Sea:				
Brest	~0.0 in 9500 yrs	~1.0	11	1.2-2.5
Amsterdam	+0.4 in >5000 yrs	~1.1 in 100 yrs	11, 12	1.2-2.5
Ijmuiden	+0.4 in >5000 yrs	~1.2	11	1.2-2.5
Cuxhaven	+1.4 in >170 yrs	~1.1 in 160 yrs	11, 4	1.2-2.5
Kattegatt:				
Korsör	±0.00 in 8000 yrs	0.81±0.18 in 125 yrs	13, 12	2.5-3.7
Sliphavn	+0.10 in 8000 yrs	~0.9 in 125 yrs	13, 12	2.5-3.7
Aarhus	-0.28 in >3000 yrs	~0.9 in 125 yrs	13, 12	2.5-3.7
Varberg	-1.75 in >1000 yrs	~0.9	11, 12	2.5-3.7
Klagshamn	-0.30 in 8000 yrs	~0.9	11, 12	2.5-3.7

References: (1) Mörner, 2007a, 2011b, (2) Mörner et a., 2004, (3) Mörner, 2010b, (4) Mörner, 2013a, (5) Mörner, 2011b, (6) Mörner & Parker, 2013, (7) Testut et al., 2010, (8) Mörner, 2014b, (9) Mörner, 2007b, (10) Mörner, 2010a, (11) Mörner, 2014c, (12) Mörner, 1973, (13) Mörner, 2014a.

The Indian Ocean

In the Maldives, we have very strict morphological evidence of a sea level stability over the last 30 years (Mörner, 2007a, 2011a; Mörner et al., 2004). The tide gauges show incomplete cyclic patterns (Mörner, 2010a, 2011a). If there is any trend hidden, it seems to be less than 1.0 mm/yr. The morphology of numerous coastal sites shows an absence of any rising trend (Mörner, 2007b). The sea level curve of the last 500 years is backed up by numerous data from different coastal settings, and repeated at several atolls (Figure 2a).

Bangladesh is another region, which has been doomed to be severely flooded in the near future. My observations in the area (Mörner 2010b) give a totally different picture, however, with a lowering in 1955-1962 followed by 50 years of stable sea level conditions around zero (Figure 2b).

In Goa, India, I was able to obtain a very detained record of the sea level changes over the last 400 years (Mörner, 2013a) as illustrated in Figure 2c. We have morphological, archaeological and an old painting documenting a high level in the 17th century and a low level in the 18th century. Multiple morphological data provide firm records of a recent sea level lowering, followed by 50 years of stability around zero. The tide gauges both in Mumbai and in Visakhapatnam (on each side of India) record a 12 cm drop in sea level between 1955 and 1962 (Mörner, 2010b, Figure 12).

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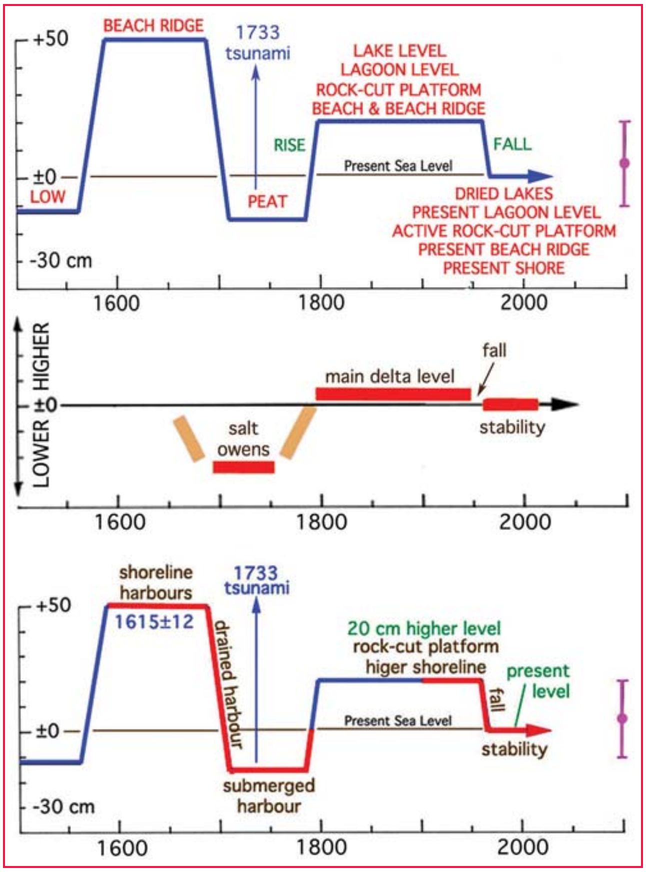

Figure 2. Observed, documented and dated sea level changes during the last 500 years in the Indian Ocean. (a) ***Top:*** **the Maldives. (b)** ***Middle:*** **Bangladesh. (c)** ***Bottom:*** **Goa, India. The agreement is striking. All three curves show (1) a stability during the last 40–50 years, (2) a fall around 1960, (3) a 20 cm higher level 1790–1960, (4) a rise around 1790, (5) a distinct low level in the 18th century, and (6) a +50-60 cm high level in the 17th century.**

At Minicoy of the Laccadives, there are similar data indicating a recent fall in sea level followed by stable conditions (Mörner, 2011a, Figure 6).

The Fremantle tide gauge at Perth gives an interesting record (Mörner and Parker, 2013, Figure 2) changing from 6.0-6.5 mm/yr for short-term cyclic behaviour of the last decades, to a long-term mean trend of 1.5 mm/yr, which transform into little or no rise at all, if calibrated for eustasy. A zero trend is recorded for 15 years but may extend over the last 60 years.

In St Paul Island, there is a long-term record (Testut et al., 2010), which gives no sea level rise at all over the last 135 years.

In Qatar, there are excellent coastal records indicating a long-term stability of the present coastal regime (Mörner, 2014b).

So, over most of the Indian Ocean, it is hard to find any records of a present sea level rise. In contrast to the satellite altimetry map of NOAA (Figure 1), suggesting variable rates sea level rise ranging from 2.5 to 5.0 mm/yr; i.e. far from what is actually observed. I take this as a strong argument that there is something basically wrong with the satellite reconstruction (cf. Mörner, 2010c).

The Pacific

This is an enormously large ocean. Still, I restrict my analysis to a few islands, because they have been used as examples of a rapid on-going flooding. The only actual facts we have in order to assess the coastal stability are the tide gauge records (Mörner, 2011b).

Kiribati has been claimed to be in the process of being flooded. The tide gauge record shows no such trend, however; only a variability around a flat zero level (Mörner, 201lb).

Tuvalu is a classical site – like the Maldives – in the claim of an on-going flooding. The tide gauge, going back to 1978, shows no such trend, however (Mörner, 2007b, 2010a). After an initial compaction subsidence 1978-1984, the record indicates coastal stability for the last 30 years (punctuated by three major ENSO events).

Vanuatu was claimed to be in the process of flooding. Still, the tide gauge shows no such trend; just a stability over the last 20 years of recording (Mörner, 2007b).

The Galapagos lies in an area often shown to be in the process of a sea level lowering. Even here, the tide gauge gives a mean trend of zero (Mörner, 2011b).

The disagreement between satellite altimetry values and tide gauge observations cannot be more different. One data set must be in serious errors. Personally, I favour the tide gauge observations (Mörner, 2007b, 2010a, 2011b) indicating little or no actual sea level rise.

Australia lies between the Pacific and Indian Oceans. Mörner and Parker (2013) have assessed its tide gauge records; the 39 mainland stations give a mean value of 0.9 mm/yr, the 70 non-official stations give a mean value of 0,1 mm/yr, and all the 86 official station give a mean value of 1.5 mm/yr, which made the authors to conclude that the true eustatic factor was to be found in the sector between 0.1 and 1.5 mm/yr, i.e. far below the value proposed by White et al. (2014) and Whitehead & Associates (2014), but well in harmony with the values here proposed (Mörner, 2013a, 2013b).

French Guyana and Surinam

From French Guyana and Surinam, there is an excellent sea level record, which shows the 18.6 tidal cycle for 2.5 full cycles (Gratiot et al., 2008; Mörner, 2010a). The cyclic behaviour shows ups and downs around a stable zero level of ±0.0 mm/yr (Mörner, 2010a, Figure 3). For the same area, satellite altimetry gives a rise of about 3.0 mm/yr. "There is a message in this difference", to say the least.

Venice

The long-term subsidence rate of this part of the Po delta is very well recorded over the last 300 years (Mörner, 2007b) at a mean rate of 2.3 mm/yr. The tide gauge

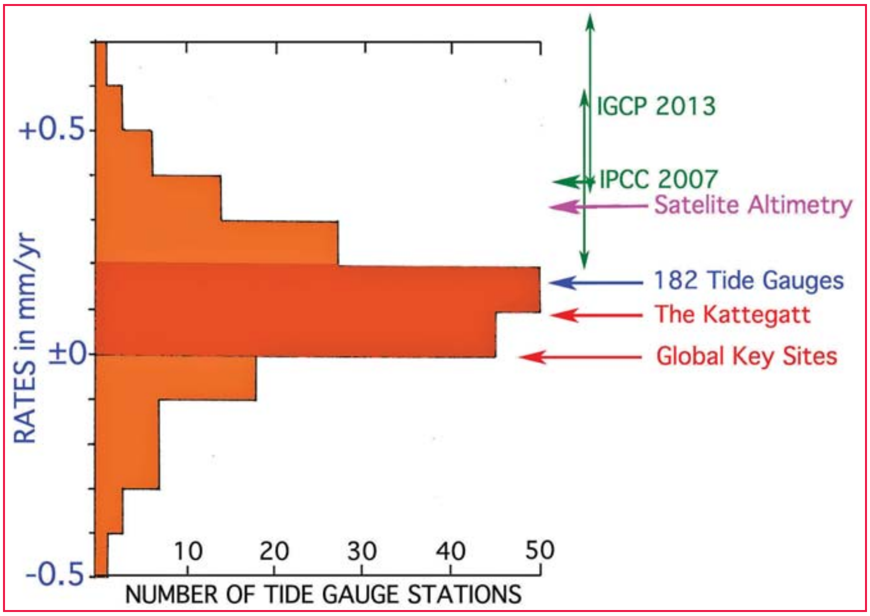

Figure 3: Spectrum of sea level rate estimates (from Mörner, 2013a, 2013b): observations at global key sites (±0.0), the Kattegatt (0.9), mean of 182 tide gauges (+1.6), satellite altimetry (+3.2) and IPCC model estimates. The big differences indicate errors and mistakes.

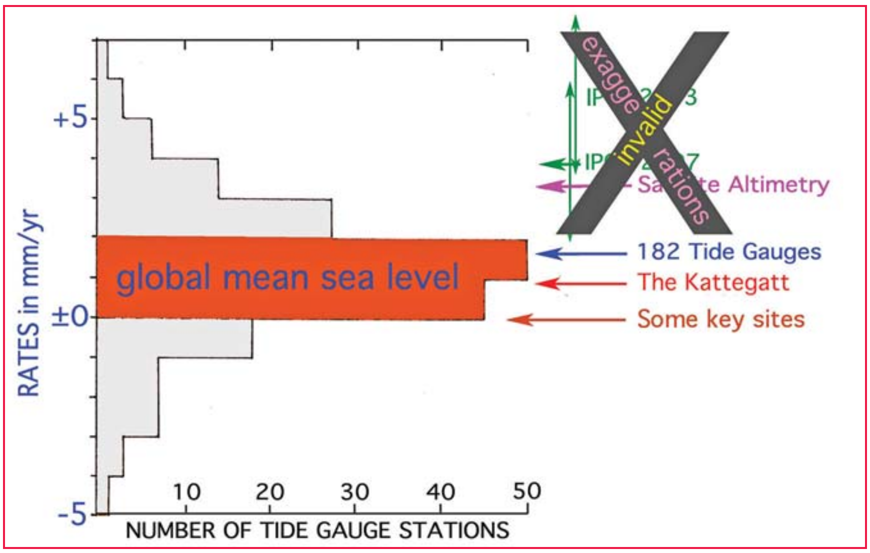

Figure 4: The high rates values are here discarded because they refer to models (IPCC) and subjective "corrections" (satellite altimetry. The true global mean sea level has to be searched for within the zone ranging from ±0.0 to +2.0 mm/yr, and most likely in its lower half of ±0.0 to +1.0 mm/yr.

record gives a relative sea level rise of 2.3 mm/yr for the past 140 years (PSMSL, 2014), implying a eustatic component of ±0.0 mm/yr over the past 140 years, with a negative trend after 1970 (Mörner, 2007b).

The North Sea

Many sites along the southeast coast of the North Sea are dominated by a long-term postglacial crustal subsidence. In Amsterdam, the subsidence is known to be of a rate of 0.4 mm/yr (Mörner, 1973; Kooijmans, 1974), a value that should also apply for the Ijmuiden tide gauge. At Cuxhaven, the subsidence is estimated at 1.4 mm/yr (Mörner, 2010c, 2013a). Brest, on the other hand, seems to represent a more or less stable area over the last 10,000 years (Mörner, 1969, 1973).

With the crustal component reasonably well established, we can assess the eustatic components from the tide gauge values presented by PSMSL (2014); viz. 1.0 mm/yr for Brest, 1.1 mm/yr for Amsterdam, 1.2 mm/yr for Ijmuiden and 1.1 for Cuxhaven.

Therefore, it seems fair to conclude that the eustatic component of the North Sea region has been in the order of 1.1 mm/yr for the last 100-150 years.

The satellite altimetry data (Figure 1) give a general rise in the area of 1.8 ±0.6 mm/yr (Table 1). If that value would be valid, all the classical sites of subsidence would instead be uplifting areas, which is out of the question for solid geological facts (Mörner, 1996, 2004, 2013a).

The Kattegatt Sea

I have recently discussed the eustatic component in the Kattegatt Sea (Mörner, 2014a). Because the crustal component is known in such great details (Mörner, 1969, 1971) and the zero isobase of uplift has remained stable for the last 8000 years (Mörner, 1973, 2014a), the regional eustatic component can be isolated and determined with a high precision for the last 125 years; viz. at 0.8 mm/yr in Korsör, 0.9 mm/yr in Sliphaven, and 0.9 mm/yr in Aarhus (Mörner, 2014a), and 0.9 mm/yr in Varberg and 0.9 mm/yr in Klagshamn (Mörner 2014c).

Consequently, we can firmly set the mean eustatic component at 0.9 mm/yr for the last 125 years. Because I previously recorded a eustatic rise of 1.1 mm/yr for the period 1830-1930 (Mörner, 1973), we can also conclude that there cannot be any recent acceleration recorded.

Comparing rates

Figure 3 gives a histogram of the tide gage records used by University of Colorado (UC, 2013) in their global sea level assessment. The mean of 182 sites (excluding a few out-layers) scattered all over the globe is 1.6 mm/yr (Mörner, 2013a, 2013b). Because of long-term

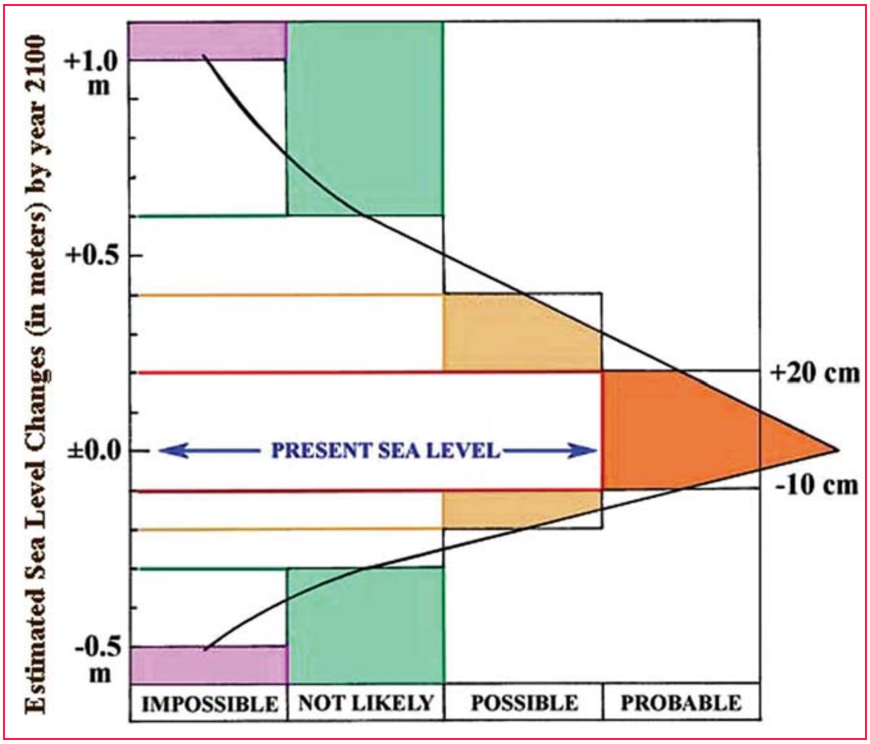

Figure 5: Frames and likelihoods of sea level changes up to hear 2100 with the most probable values ranging between -10 cm and +20 cm.

subsidence of many river mouth sites and site-specific compaction problems (as discussed under Section 2, above), this value may, in fact, represent a slightly too high value. The key sites here discussed provide values of about 0.0 mm/yr, and the Kattegatt and North Sea records give firm values around 1.0 ±0.1 mm/yr (Figure 1).

This data set is in deep conflict with the high rates proposed by the IPCC (2007, 2013) and satellite altimetry (NOAA, 2014). In Figure 4, I therefore propose that those data sets should be "safely disregarded" (to use the terminology of Hannah, 2014), and claim that the mean global eustatic component is to be found in the zone ranging from +2.0 mm/yr to ±0.0 mm/yr, and most probably in the lower half of this zone; i.e. within 1.0–0.0 mm/yr.

Setting frames and likelihoods

The INQUA Commission on "Sea Level Changes and Coastal Evolution" (consisting of some 400 sea level specialists) had the issue of possible future sea level up at five international meetings, and arrived at a best estimate of +10 ±10 cm by years 2100 (INQUA, 2000). Personally, I later updated this value at +5 ±15 cm by year 2100 (Mörner, 2004).

There are certain physical and observational facts we have to consider because they set the frames of what can be considered possible and what must be discarded as not possible (Mörner, 2011c). Below follows four of the most important ones:

(1) No present sea level rise can exceed 10 mm/yr, because this value was the mean rate of rise during the most intensive phase of postglacial deglaciation (Mörner, 2011c, 2013a). Any present rise must be considerably lower.

(2) Thermal expansion is zero at the coasts (Mörner, 2010c, 2013a).

(3) We are moving into a new Solar Grand Minimum, which in analogy with previous ones is likely to generate cold climate and glacial expansion (Mörner, 2010d, 2011d; Mörner et al., 2013) that might lead to a minor lowering in sea level (Mörner, 2013b, Figure 2).

(4) Firm geological records indicate that the North Sea basin and the southeastern parts of the Unites States are subsiding as a function of long-term glacial isostasy (Mörner, 1969, 1973; Newman et al., 1971). These trends can, of course, not be reversed (as the discarded high values in Figure 3 and 4 would imply). The same applies for uplifting coasts. In Stockholm, for example, the absolute rate of uplift has been 4.9 mm/yr, at least for the last 3000 years. PSMSL (2014) gives a tide gauge value of -3.8 mm/yr, which sets the eustatic factor at +1.1 mm/yr. This is the same value as established by Mörner (1973) for the period 1850-1930, implying the absence of acceleration in the last decades.

With this in mind, I have in Figure 5 assessed the frames and likelihoods of future sea level changes.

As "impossible" maximum rise and minimum fall of sea level by year 2100, we can quite safely set +1.0 m and -0.5 m.

As "not likely", I put values exceeding +0.6 m and -0.3 m.

As "possible", I put values up to +0.4 m and down to -0.2 m.

As "probable", I put values below +20 cm and above -10 cm.

This gives a graphical peak at around present zero with an uncertainty range of +20 to -10 cm.

Conclusions

The present global eustatic changes have to be confined to rates between +2.0 and 0.0 mm/yr, with a preference to the lower half of this zone; i.e. +1.0 to 0.0 mm/yr (Figure 3 and 5).

In view of this, it is the high-values of the IPCC models and satellite altimetry that have to be "safely disregarded" (Figure 4).

Therefore, my best estimate of the amount of sea level change by year 2100 is +5 ±15 cm, which is nothing to worry about.

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Best practices in surveying

Best practices in surveying are not limited to field procedures and accuracy requirements but must include professionalism and ethics. This paper will look at essential best practice approaches for achieving desired quality surveying products and establishing integrity among peers and clients

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Textbooks and scholarly publications describe best practices for using various surveying equipment, capturing and processing field data, and gathering and analyzing evidence. Since there are varieties of surveying activities, ranging from national survey control networks, boundary surveys, construction, hydrographic, topographic, mining, and cadastral, etc., it is fair to say that there are no standardized approaches, which can be classified as "best practices" for practitioners to follow. Evidence and procedures go hand-in-hand with data processing and visualization. For land surveying professionals, the key to producing quality product is to understand the objectives of the client, determining the scope of the project, researching evidence and descriptions, selecting appropriate equipment adopting methods that can produce desired results, based on the required accuracies. In all aspects of the surveying tasks, professionalism, ethics and due diligence are paramount. Professional surveyors should always be aware of their responsibilities to the public and adhere to ethical conduct in the execution of their professional obligations to clients.

Not so long ago, when the essential tool for land surveying was the total station, surveyors accomplished tasks by measuring angles and distances. Coordinates of surveys monuments were tied to coordinated passive control monuments, which had been established at strategic locations in the jurisdiction. The positional accuracies of these passive control networks were classified as first, second and third order accuracies based on angular and linear misclosures of the network. In many jurisdictions, there are state laws, rules and regulations for conducting certain surveying activities such as boundary determination and cadastral surveys. Therefore, in discussing best practices, the focus will be on generic rather than specific tasks. Below are steps that can be taken to accomplish tasks successfully.

> Surveying is a profession of public trust. The educational preparation and experience that combine to make him a professional requires that he operates in a manner that will earn him the public trust that he deserves. In doing so, he has to adopt the most stringent of professionalism

Understanding the Purpose and Scope

The first thing for the surveyor is to understand the purpose for which surveying services are being acquired. For large scale survey projects, the requirements from inception to the deliverables will be specified in the Terms of Reference. Therefore, it is the responsibility of the surveyor to understand the requirements and be able to ask questions where necessary. On smaller projects without written Terms of Reference, the best approach is for the surveyor to spend time and confer with the client to discuss the needs of the client in detail so that there are no ambiguities in the expectations. Often times, clients are unable to fully articulate their needs completely. A detailed discussion would clarify the scope of the project, amount of information to be provided, field survey and mapping methodologies, acceptable accuracies and the types of deliverables. An experienced surveyor should be able to ask questions, explain technical issues, discuss options, and to clearly define the services that need to be performed. Based on these discussions, surveyor should be able to define the scope of the project, identify the types of equipment that can get the job done, accuracy requirements, duration of the project, and deliverables.

In determining the scope of the project, it is incumbent upon the surveyor, to record the tasks so that both parties understand, and agree on the types and extents of the service. The identified tasks must be defined in a written agreement, which must include any exceptions by either the client, or the surveyor. To preserve his professional integrity, exceptions which have been recommended by either party, should be included in the written agreement with supporting evidence.

Assessing Capabilities and Resources

Having defined the scope and expectations of the project, professional ethics requires that the surveyor should be able to determine whether he has the knowledge, expertise or personnel to undertake the tasks. It will be unethical for a surveyor with expertise in cadastral surveying to undertake a project to monitor deformations in a dam. Assessment of capabilities should include equipment and other resources that are needed to accomplish the tasks. Assuming that all these requirements are satisfied, the surveyor should then plan the method for successfully accomplishing the tasks. This plan includes selecting the equipment that will produce the required accuracies.

Defining Equipment, Methodology and Accuracies

As technology advances, so does the procedure for conducting surveys and associated accuracy assessment methods. It is important to stress at this point that not all tools are adequate for performing all types of surveys. Best practices include selecting the right equipment for the right project.

In recent times, Global Positioning Systems (GPS) and Global Navigation Satellite Systems (GNSS), Light Detection and Ranging (LiDAR), Unmanned Aerial Vehicles (UAVs) technologies are becoming popular tools on surveying projects. GPS and LiDAR provide three-dimensional coordinates instantly. Therefore, the best practices for using them require an understanding of positional accuracies which are no longer related to measured distances but determined in terms of the reliability (or confidence level) of the data.

With Total Stations, coordinates of positions are determined from measured angles and distances. Most errors occur in the angular and linear measurements.

Table 1: Accuracy Standards for Order C Survey work.

Order C	
Class	**a (1:a)**
1	1:100,000
2-I	1:50,000
2-II	1:20000
3	1:10,000

> The surveyor's work is meant to be kept for posterity. Therefore, details of any sketches, field observations, calculations and data capture should be a part of the permanent records of the surveyor

Therefore, accuracies are listed as linear or relative precisions. In the United States for example, the Federal Geodetic Control Committee has defined minimum accuracy standards for terrestrial based control surveys for mapping, land information, property, and engineering in Table 1.

Based on the information from Table 1, if the relative positional error is ±1 cm (2 sigma), the minimum distance between stations in a project will be 1 km.

Field Procedures and Standards

Depending on the type of project and tasks involved, the best practice it to use the most appropriate equipment to get the task completed successfully. It is important for a professional surveyor to know the limitations of the equipment and sources of errors that can affect the desired accuracy. For example, many surveyors are applying GPS/GNSS technologies on projects. In many cases field procedures may be static, fast-static, kinematic, Single-base Real-Time Kinematics (RTK) or Real-Time Network (RTN) GNSS methods. It is important as part of the best practice policy, to understand the suitability of the methodology, with special regard to site conditions, and the possible positional accuracies. Based on the required accuracies, a suitable procedure may be to include post-processing of the data in order to improve the reliability of the results. Generally, the accuracy of RTN surveying depends on many factors including the reference station distances, equipment and its settings, survey procedures, and the survey environment. Accuracy typically is in the range of a few centimeters, and in some cases can exceed, that of traditional RTK surveying.

Boundary Surveys

Projects dealing with property boundary issues involving deed records require special attention. Best practice procedures include deed research to find evidence to the fact that the client actually owns the property, and that there are no restrictions affecting the use of the property in the manner that the client intends to. Such due diligence includes identification of the client's record boundaries, conflicting record of ownership, actual locations of the boundaries etc. In addition, any exceptions including rights of way, easements, encumbrances, and reversions of any kind which limit the rights of the client. Where necessary, historical information may be used as evidence to support the surveyor's decisions in the execution if his duties.

Deliverables and Record keeping

The types of deliverable are normally decided prior to commencement of the project. They come in variety of formats. On projects where the surveyors is required to render an opinion, professionalism requires that the surveyor provides the opinion in a written report, graphical representation, electronic files, or in the manner that has been agreed upon. This will avoid misinterpretation and ambiguities. Ethical and professional, the surveyor must render the opinion in a fair and honest manner and within the scope of the written agreement with the client, the scope of his professional knowledge, and supported by facts and evidence which were used to arrive at the opinion. Irrespective of the required format, the deliverable must convey relevant information and organized in a comprehensible manner.

Good record keeping is essential. The surveyor's work is meant to be kept for posterity. Therefore, details of any sketches, field observations, calculations and data capture should be a part of the permanent records of the surveyor. The surveyor must make a habit of keeping copies of field data capture as well as computations and deliverables in the project file. The best practice is to maintain the records in a manner as to support the basis of decisions and determinations that were made regarding the project.

Conclusion

Surveying is a profession of public trust. The educational preparation and experience that combine to make him a professional requires that he operates in a manner that will earn him the public trust that he deserves. In doing so, he has to adopt the most stringent of professionalism. There are no universal rules that define the best practices for land surveying because whereas surveying principles are the same, regulations vary and therefore equipment and methodologies vary in various jurisdictions. Besides, evolving technology is providing opportunities for surveyors to perform the same tasks with different equipment. The best practice is for the surveyor to adopt the methods that will enable him to provide the service effectively within stipulate accuracies by applying professionalism and ethics throughout the process.

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VGS based framework for disaster response

This paper introduces a new framework to utilise Volunteered Geographic Service (VGS) for identifying and distributing potential help requests as volunteered services in an automatic and proactive way among potential volunteers in situ right after a disaster

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In the wake of growing number of disasters happening across the world, it is essential to make our society more flexible and resilient to disasters by managing crisis-related information more opportunely. To achieve this goal, Volunteered Geographic Information (VGI) which is created and disseminated by the crowd could be employed as a significant source of information for decision making (Horita, Sp, & Zipf, 2013). In fact, VGI is spatial data produced by ordinary citizens using everyday tools like web browsers and mobile applications, and transferred via Internet (Goodchild, 2007). Not only VGI can be used as a precious piece of information, but also Volunteered Geographic Services (VGS), a framework proposed by Savelyev et al. (2011), which turns information to actions could be leveraged to respond to a disaster timely and more appropriately.

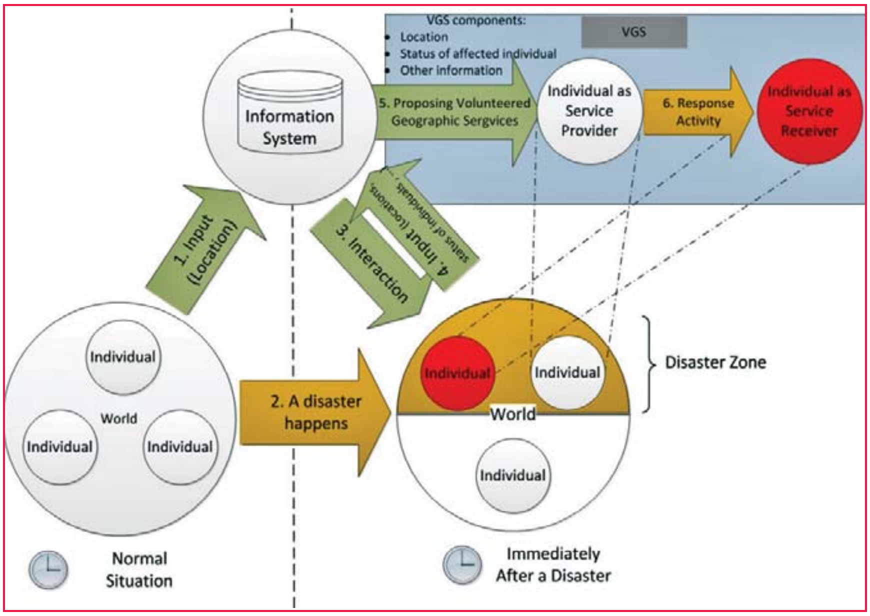

Figure 1: VGS Conceptual framework

Savelyev et al. (2011) has highlighted that despite the role of volunteers in data collection processes, actions are taken by authoritative agencies such as firefighters, emergency teams and so on. Unfortunately, volunteers have no role in disaster response services to speed up the whole ongoing rescue and aid processes. Thatcher (2013) has argued that current VGI-based disaster response platforms such as Ushahidi have a 'top-down' approach because information is gathered by volunteers for disaster response organizations while they are not allowed to participate directly in decision making processes.

Addressing the abovementioned issue, Savelyev et al. (2011) have suggested Volunteered Geographic Services (VGS) which is one step beyond the VGI and intends to motivate general public to participate in response operations along with responsible disaster response agencies. VGS intends to enable ordinary citizens with a smartphone not only to collect information but also to work as respondents to a disaster.

Timely distribution of help requests among volunteers could lead to better disaster responses. Since VGS-based platform does not follow top-down structure of many VGI-based disaster response platforms and it does not inherit their related limitations, it could be more timely and efficient. Thus, this paper introduces a new framework to utilise VGS for identifying and distributing potential help requests as volunteered services in an automatic and proactive way among potential volunteers in situ right after a disaster. In addition, based on the proposed framework, a mobile application is developed which is presented in this paper.

Proposed framework

Volunteered Geographic Information is used to automatically locate people based on the information they have provided. Figure 1 illustrates proposed framework which employs both VGI and VGS. When a disaster happens, location information will be used to gather status of the people in the impacted areas. Then, this collected information will be employed to create VGS packages which are disseminated to the people in the impacted areas to motivate potential volunteers. Potential volunteers as service providers could use these VGS packages to decide about their participation in disaster response activities in a bottom-up manner without interference of the authoritative organizations in a very short period of time immediately after a disaster strikes. In doing so, the response and rescue processes will speed up. In addition, these volunteers could also be employed in data collection processes through VGI. This collected information including geo-tagged photos, geo-tagged information about the incident, etc. could be used by government agencies to increase situational awareness of the first respondents.

Research methods

In order to develop a mobile application based on the proposed framework, the interaction design model proposed by Sharp et al. (2007) was used. This interaction design model suggests multi iterations of requirement analysis, design, interactive interface building and evaluation in order to achieve a final product. The requirement analysis of application was done through investigating the literature. Since Rudd et al. (1996) argue that a high-fidelity prototype demonstrates complete functionality of a user interface, it was employed to get more useful feedback from experts. Several iterations of re-design process were performed to achieve all usability goals (functionality) of the product. Finally, Cognitive Walkthrough method (Wharton et al.,1994) was used for evaluation in this stage.

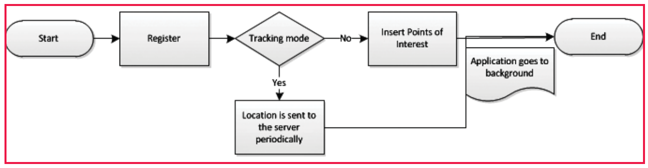

Figure 2: Flowchart of tracking mode

Application design

Based on the proposed framework, a mobile application named DisasterSaver is designed and developed. The App can work in two modes as shown on Figure 2. One mode tracks the users in the background and consequently collects geo-location of the user using device's GPS. The other mode is designed to satisfy users' concerns about privacy issue by not collecting geo-location. Instead, user determines some points of interest.

When a disaster like an earthquake happens, server backbone of the app is notified about the incident, its location, impacted areas and other features. Then, server finds all the users in the proximity of the incident and notifies them about it. This notification also asks users in the impacted areas if they need help. Then, depending on responses, a user could have three statuses which are 'Help needed', 'No help' and 'Unanswered (Unknown)'.

System automatically starts to collect location information of users with 'Help needed' and 'Unanswered' statuses. This information is used later by emergency response agencies or by VGS. If a user has a 'No help' status, system motivates that user to collect VGI or help others through VGS. These users could help to collect geo-tagged information about the incident or start helping others, who have 'help needed' or 'unanswered' status, in situ. Users who are in the impacted areas but do not need help, could help others via two different options:

I. Informing about incident by answering some questions about the incident or sending geo-tagged photos.

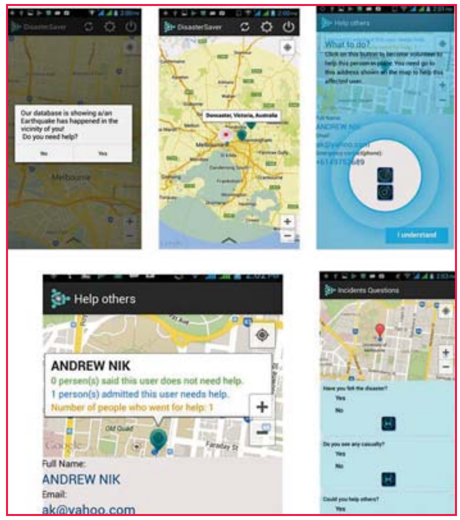

Figure 3: DisasterSaver interface

II. Attempting to help close-by affected people in situ whose statuses are "help needed" by checking their locations using the App.

In addition to these two main options, volunteers could also participate in response processes via collecting information about users whose statuses are "unknown" by calling their emergency numbers and then updating this information about them. Figure 3 shows some snapshots of DisasterSaver interface.

Application components

This system has a server side backbone and client side mobile app. Also, Google cloud solution has been used for messaging between mobile application and the server along with ordinary HTTP connections on the Internet. Google Cloud provides this application with a reliable medium for messaging and connection. This system is fed by External databases as authoritative and reliable resources which disseminate timely information about occurrence of major disasters such as National Earthquake Information Centre (NEIC) for earthquake in USA.

Items of concern

Undoubtedly, the location of affected people in the impacted areas is one of the most important pieces of information which is required in disaster management. This location data enables VGS to be employed. Gathering location information of the users via GPS before any occurrence of a disaster could be a hindrance for using the mobile applications since users may find it against their privacy. However, during a disaster, gathering location information of individuals is more acceptable for people since they are in a crisis situation. Instead of gathering precise locations of users before a disaster, they could determine some points of interests like their homes and work offices.

Furthermore, since the prototype is developed with Google Android, it inherits Google policy which does not allow Android mobile applications to enable mobile device's GPS programmatically. In other words, mobile applications cannot turn on GPS without user's intervention. User intervention for enabling GPS could be a weakness in disaster-related mobile applications because it may be impossible for some users to have access to their mobile devices in a disaster due to getting stuck or unconsciousness.

Technical architecture of DisasterSaver

In the architecture of DisasterSaver (Figure 4), server is responsible to send and receive information to/from mobile app, perform geometric calculations and communicate with external resources and Google Cloud Messaging (GCM). All these services are available to the mobile app as front-end via REST API. REST API uses HTTP (Hypertext Transfer Protocol) protocol to transfer information over the network and it complies with some architectural principles. Server has been implemented using PHP as server side programming language. As soon as a record of disaster incident is added to the database, server finds all points of interests or users which fall inside the boundaries of the incident by doing geometric calculation. Then notifications are sent through Google Cloud Messaging (GCM) to the users. GCM for Android is a service that allows server-to-client communication as an alternative to traditional client-to-server connection using IP (Internet Protocol) addresses. In other words, GCM enables a server to contact a mobile device when it is needed.

In this architecture, there are GI-related functions which are responsible for performing geometric calculations, identifying affected users and handling geographic information. Disaster-related functions are responsible for checking database(s) for any new disaster record and informing GI-related functions based on specific time intervals. This component also filters incoming information and checks validity of registered disasters in terms of time. Finally, user-related functions are responsible for general activities like user registration and authentication along with registering users in the GCM and saving their unique GCM IDs in the database.

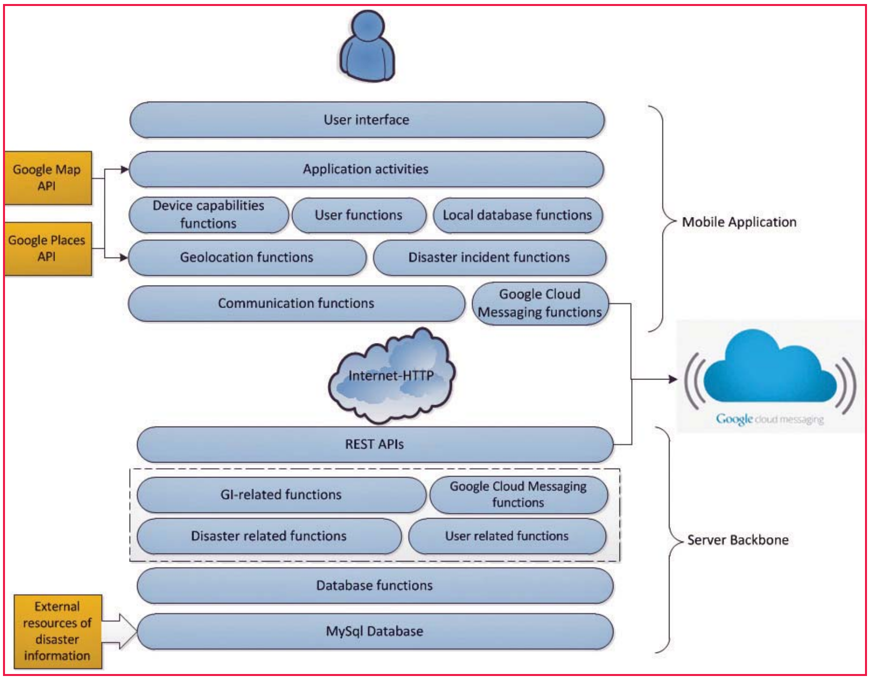

Figure 4: Technical architecture of DisasterSaver

In client side, Google Maps Android API v2 is used to represent spatial information. This service enables Android applications to visualise maps and show objects on it. Google Places API has also been employed to enable auto-completion capability for adding points of Interest.

Limitations and future work

Although it is believed that the proposed framework and its implementation in the developed mobile application will extensively help disaster management in response phase, there are a number of limitations that need to be considered. One limitation of DisasterSaver is due to accuracy of mobile GPS data. With all enhancements happened in positioning systems such as GPS, their location accuracy differs in different devices and different situations. This lack of precision becomes more critical in indoor environments and multi-storey buildings.

One other limitation is concerned with off-line condition of GPS. As Google policy does not allow enabling GPS programmatically and without user's approval due to privacy concerns, in a case that an affected individual has a mobile phone with disabled GPS and is unable to have access to his/her mobile phone because of some reasons like being stuck or unconscious right after a disaster, collecting location information becomes impossible.

As other limitations, difficulty and lack of tendency in using mobile devices in the middle of a disaster, resilience of communication infrastructure against natural disasters, validity and integrity of crowd-sourced information in Volunteered Geographic Services and safety of volunteers while helping others through a non-authoritative system could be also mentioned.

Conclusion

In this research, a new framework and a prototype system are introduced to leverage VGI for enabling VGS in order to help disaster management in response phase. Based on the proposed framework, a mobile application is designed and implemented which attempts to enable society to be involved in response phase of disaster management process alongside public and private disaster management agencies. This mobile app identifies affected people in the impacted areas, at first. In the second step, it harnesses the immediate availability of the people in situ to speed up response processes by providing potential interested volunteers in relevant proximity of disaster with required information about potential affected individuals. Hence, it provides a systematic intelligent mechanism for connecting help services and help needs.

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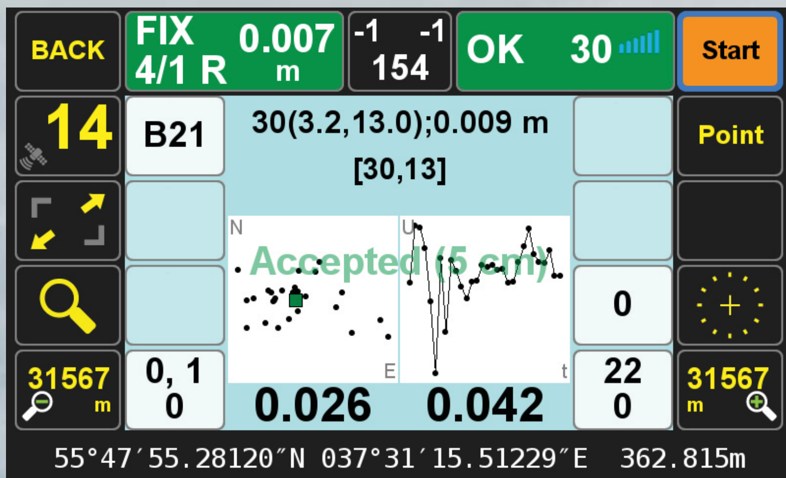

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TRIUMPH-1M + Victor-LS

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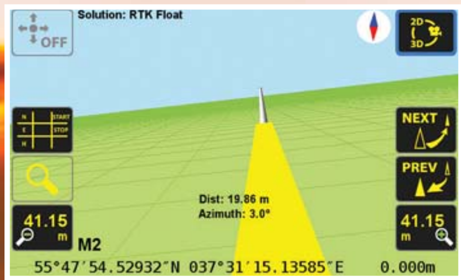
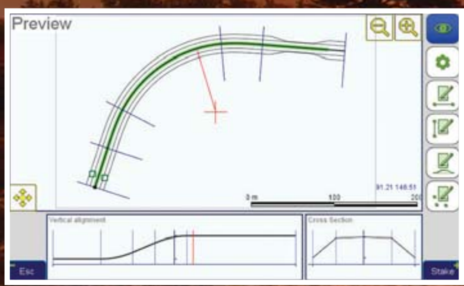
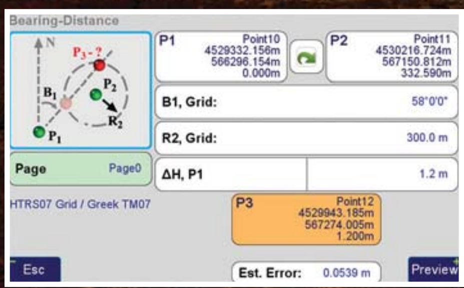
Receiver+Antenna+Radio Modem+Controller+Pole







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Similar to TRIUMPH-LS but without integrated GNSS antenna.

TRIUMPH-NT and GrAnt antenna makes a complete RTK system.

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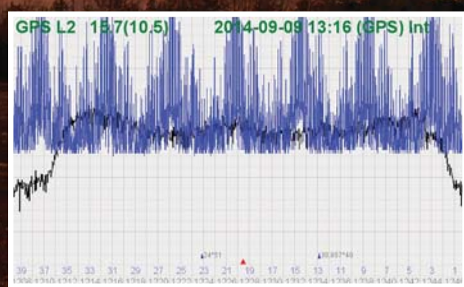
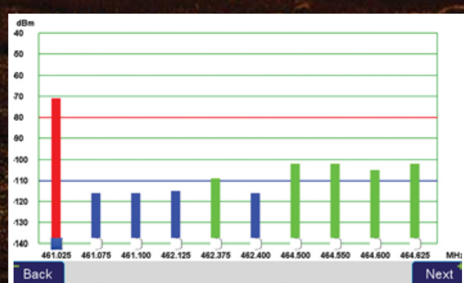
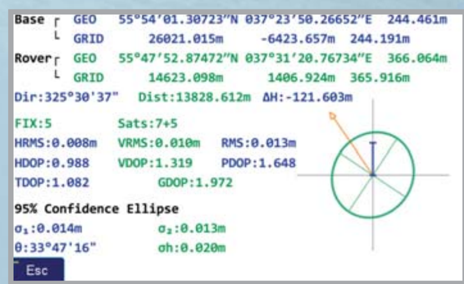




Victor-LS

The Rugged Field Controller

Victor-LS is a rugged field controller. It runs J-Field and can be used with TRIUMPH-1 and TRIUMPH-2.



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TRIUMPH-2 + Victor-LS

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Rugged GNSS Unit


OMEGA + Victor-LS + GrAnt

OMEGA is the most advanced GNSS receiver. It does not include integrated antenna and controller. It is suited for applications like **machine control** and in **marine** and **avionics** applications.

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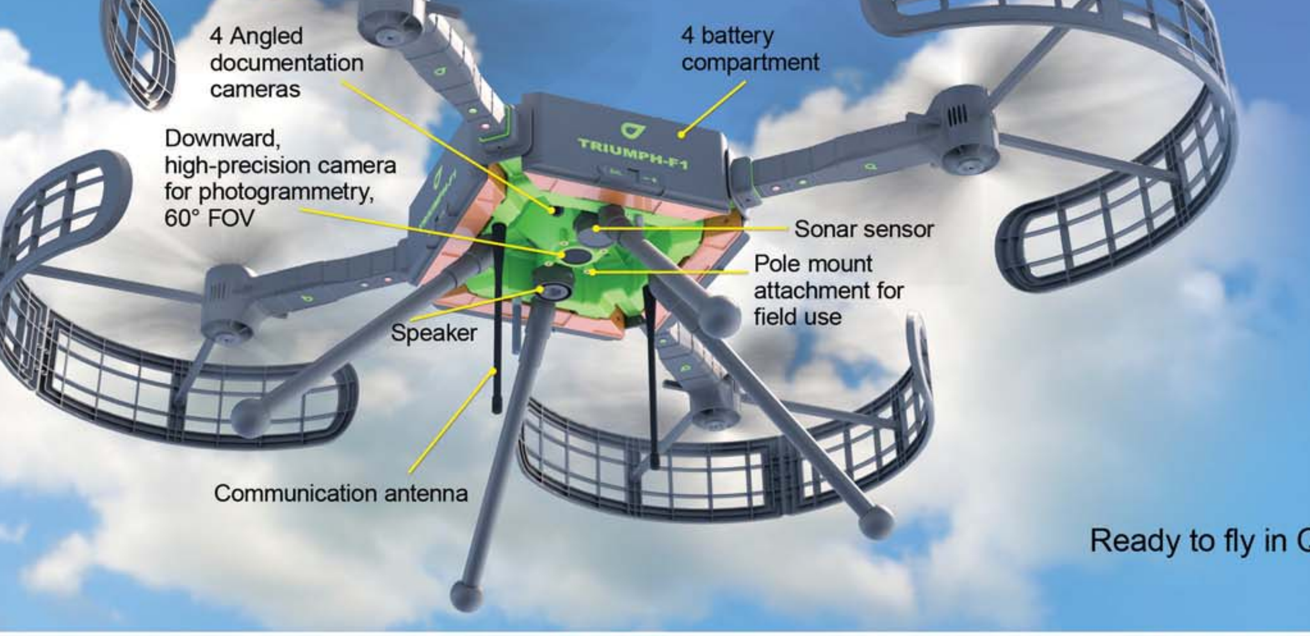

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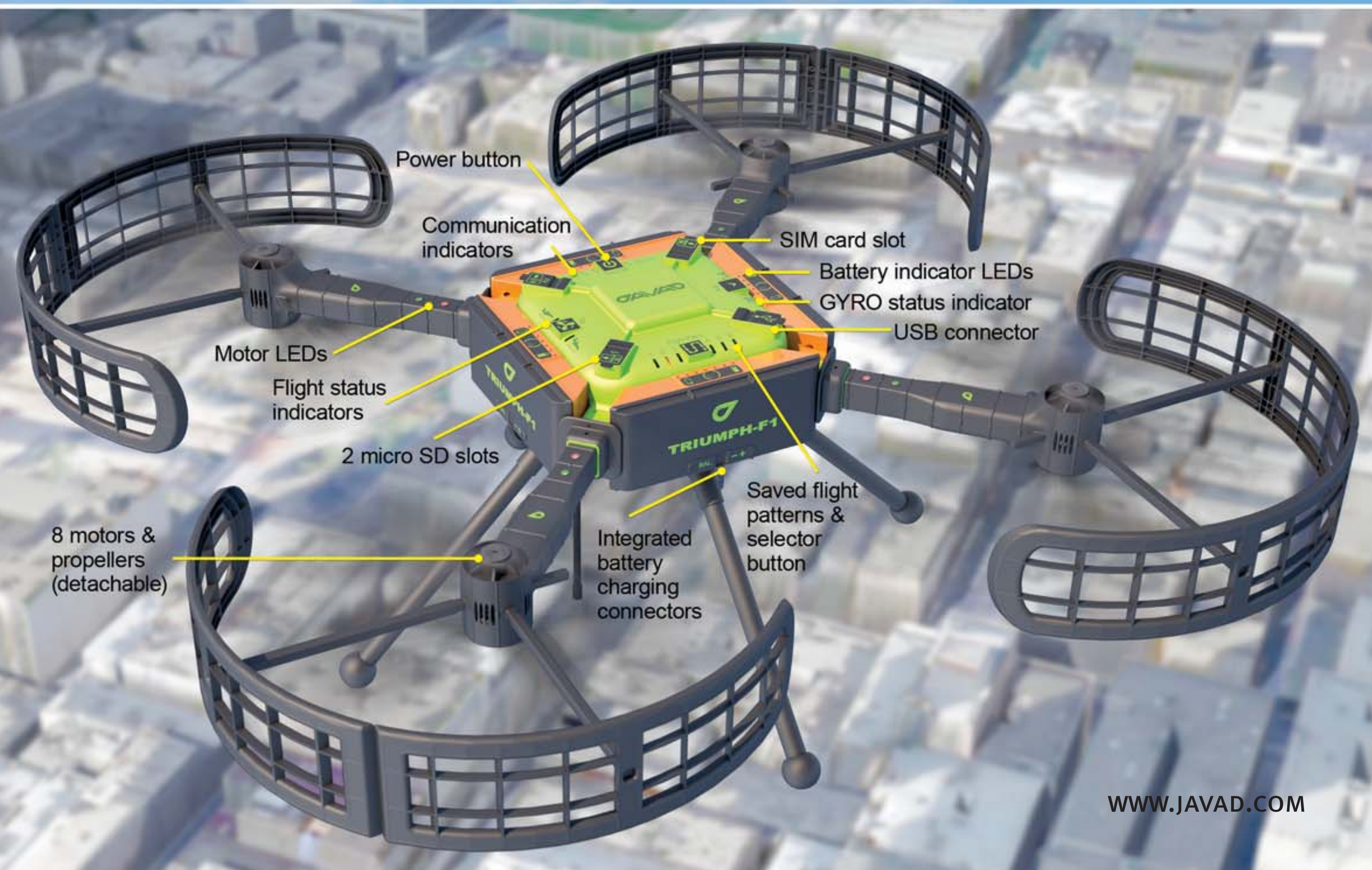

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COWI India Pvt. Ltd
Gurgaon, India

India was one amongst the few countries – including the advanced ones – to have completed topographic mapping on 1:50,000 and 1:25,000 scales, employing photogrammetric techniques, about four decades back. Since then there has been a tremendous progress in the field of Imaging and Geomatics by way of Global Positioning System (GPS), Inertial Measuring Units (IMUs), Large-Format High-Resolution Aerial Digital cameras, etc. Due to these developments, quite a few countries have standardized the scales as large as 1:2,500 and 1:1,250 for country-wide topographic mapping, and even larger scales ranging from 1:240 to 1:1,200 for engineering applications mainly due to operationalization of GPS, IMU and Digital cameras resulting in nearly complete automation in various photogrammetric processes, viz., aerial triangulation, Digital Terrain Model (DTM) / orthophoto generation, etc. The main advantage accrued due to these advancements is that there is a very little requirement of plan as well as height ground control points (GCPs) for photogrammetric aerial triangulation (AT).

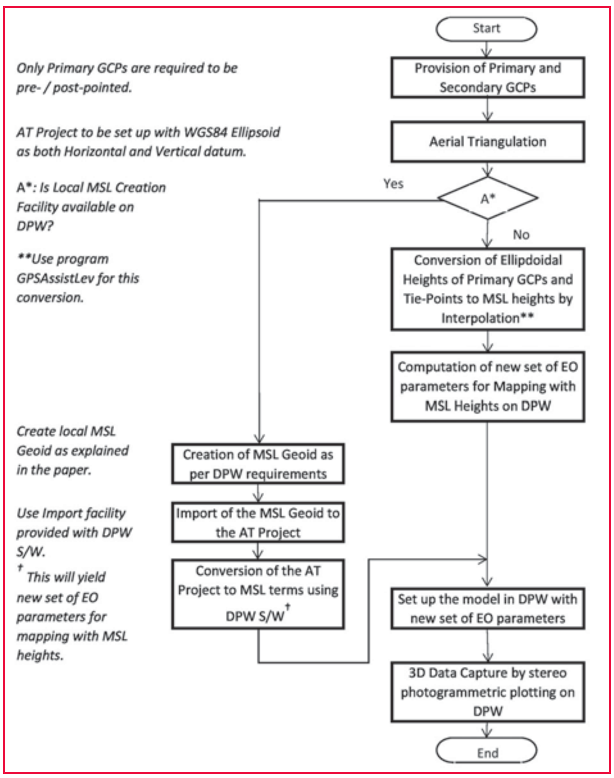


Figure 1: Flow Chart for Photogrammetric Mapping as per the Proposed Methodology

It is well established that with aerial imagery flown with GPS / IMU for photogrammetric applications, GCPs are required only at the corners of the photogrammetric block. Whereas, if aerial imagery is flown without GPS/IMU, full (plan + height) control points are required at close intervals along the periphery of the block and height control points at much closer intervals in every flight line.

The provision of control points along with ellipsoidal heights is an easy task because these can expeditiously be established with the help of GPS. But height control points, also known as Bench Marks (BMs), are invariably required with heights above Mean Sea Level (MSL) and, therefore, cannot be determined by GPS.

Especially in countries like India, that have not yet established their own geoid, the only method available to determine the heights above MSL, known as Orthometric heights, is by means of precision leveling that is cumbersome, slow, costly and prone to errors. Some countries like US and Canada have established their own precise geoid along with a correction surface and have made the facility available to public for conversion of GPS (ellipsoidal) heights to Orthometric heights. The correction surface is generated from a sufficiently dense network of GPS control points and height BMs established by precise leveling.

Geomatics Center Canada provides an on-line facility for direct transformation of NAD83 or ITRF ellipsoidal heights of any point in Canadian territory to CGVD28 Orthometric heights, (CSRS-A). The National Geodetic Survey (NOAA) of US have released the GEOID96 (recently upgraded to GEOID12A) hybrid Height Model for Conversion of GPS Heights to NAVD88 Orthometric elevations, (Milbert and Smith, 1996). Facilities are available online for interactive computation of Orthometric heights from GPS ellipsoidal heights, (NGS Geodetic Tool Kit). Because of these facilities, these countries are able to take full advantage of the recent developments and carry out large-scale photogrammetric mapping most economically in a much smaller time-frame as compared to others who don't have such a facility.

India is one amongst such countries who have not yet established a precise geoid along with the required correction surface. As a result, though India has the capability of acquiring aerial imagery employing most-modern digital cameras equipped with GPS / IMU, the requirement of plan and height control points for photogrammetric surveys is the same as was obtaining during the analogue era. The net result is that photogrammetric mapping, even on scale as small as 1:10,000, is not viable due to its huge time and cost implications.

An interim solution, especially for such countries, is proposed in this paper to make the large scale photogrammetric mapping viable that takes maximum possible advantage of the current advances in the field of geomatics.

The Proposed Solution

The flow chart for photogrammetric mapping as per the proposed methodology is given in Figure 1. We will now describe each step in detail in this section.

As can be seen from the flow chart, the proposed methodology with some modifications can also be employed without using the program GPSAssistLev, described in a separate section, in case the Digital Photogrammetric Workstation (DPW) software has the facility of creation of local MSL geoid with the help of a network of GCPs with known ellipsoidal and orthometric heights. Most of the modern DPWs do have this facility. The modified methodology is detailed in one of the following sections.

Provision of Ground Control Points (GCPs)

Provision of Primary GCPs

In the proposed solution, planimetric coordinates X, Y in UTM and height H (WGS84 Ellipsoidal height) of GCP's are provided only at the corners of the photogrammetric block with the help of GPS. Such GCPs will be referred to as the Primary GCPs in this paper. The Primary GCPs will also include a few more GCPs to be provided in the photogrammetric block to serve as Check Points. No precision leveling of the Primary GCPs is required. However, all the Primary GCPs will need to be accurately transferred to the digital images. This does not pose much of a problem as the requirement of Primary GCPs is drastically reduced since this method makes full use of GPS/ IMU data.

Provision of Secondary GCPs

Uniformly distributed GCPs will be provided, 12 to 15 km apart, in the Area of Interest (AoI) by GPS with X, Y and H coordinates. These are referred to as Secondary GCPs in this paper. The Secondary GCPs will be connected to MSL height BMs by precision leveling to obtain their precise Orthometric Heights (h). Thus for each Secondary GCP, we will have both the Ellipsoidal Height (H) as a result of GPS survey and Orthometric Height (h) as a result of precision leveling.

Precise positioning of Primary Control Points on aerial imagery

In the methodology proposed, only the Primary GCPs, that would be very few in number due to reason explained earlier, need to be precisely positioned on the aerial photography. This can be best achieved by signalizing the GCPs on the ground prior to aerial photography (also known as pre-pointing) or by transferring the exact position of GCPs to the concerned aerial images, with the help of photos taken/ sketches made during GPS survey, after aerial photography (post-pointing). Pre-pointing is more accurate but requires a lot of logistic support. There is no need of pre-pointing or post-pointing the Secondary GCPs in this method.

Aerial Triangulation (AT)

Based on the coordinates of Primary GCP's so obtained (viz., X, Y in UTM and H as height above WGS ellipsoid), aerial triangulation is carried out to determine the precise tie-point coordinates in the same coordinate system as that of GCP's. This is achieved by setting up the AT project in UTM coordinate system with WGS84 Ellipsoid as the Horizontal as well as the Vertical Datum. It may be noted that no Orthometric Heights are required for AT in the method proposed here. The AT will yield a large number of Tie-Points with X, Y and H coordinates whose Orthometric Height will not be known.

The AT will also yield six Exterior Orientation (EO) parameters for each image. These EO parameters can readily be used for generation of DTM in Ellipsoidal height system and precise orthophotos.

Conversion of Ellipsoidal Heights of the Primary GCPs and Tie-Points to Orthometric Heights

For each Secondary GCP, height of the MSL surface over the WGS84 ellipsoid is determined by subtracting the precision Leveling Height (h) from the corresponding Ellipsoidal Height (H) of the GCP. The Orthometric Height of all the Primary GCPs/ Tie-Points in the AoI is now computed as explained hereunder as per the mathematical model described in the next section.

(a) For each Primary GCP/ Tie-Point, the six parameters of 2^{nd} order polynomial are computed by Least Squares solution of the equations, represented by equation (1) given in the next section, using the height differences (z) along with the X, Y values of at-least nine Secondary GCPs, that are nearest to the Primary GCP/ Tie-Point and the corresponding weight matrix. These nine Secondary GCPs are required, evenly spaced, in a 3x3 grid pattern for best results.

(b) The height of the MSL surface over the ellipsoid (z) at the Tie-Point/ Primary GCP location is then determined by equation (1) using the six parameters of the 2^{nd} order polynomial and X, Y values of the point.

(c) Finally, the Orthometric Height is calculated by subtracting the z value from the ellipsoidal height of the point.

Computation of new set of EO Parameters for Mapping with Orthometric Heights

If the photogrammetric projects require the vector data/ DTM also as deliverables, such outputs are invariably required with heights above MSL. As such, the EO parameters, obtained by AT as described above, cannot be used for photogrammetric model set-up for generation of vector data/ DTM in MSL height system.

In the proposed method, therefore, a fresh set of EO parameters are determined by setting up the stereo models in a DPW by importing the AT measurements. All DPWs have this Import module that requires the adjusted image coordinates (x, y) and the terrain coordinates (X, Y, h), where h is the height above MSL, of all the points measured during AT (Primary GCPs and Tie-Points in this case) as input. This setup yields a new set of EO parameters which are then used for data capture for 3D vector mapping and DTM generation with heights in MSL system.

Mathematical model

A local MSL surface, represented by the six parameters of the following 2^{nd} order polynomial, is modeled for each point whose height is to be determined by interpolation:

$$z = a_0 + a_1X + a_2Y + a_3XY + a_4X^2 + a_5Y^2 \qquad (1)$$

where,

$z = H - h$;

H = Ellipsoidal height of the GCP (measured by GPS)

h = Orthometric Height of the GCP (measured by precision field leveling)

X, Y are the UTM coordinates of GCP; and

a_0 to a_5 are the six parameters of the 2^{nd} order polynomial.

All the Secondary GCPs, falling within a specified Search Radius from the point with unknown Orthometric Height, are used as control points for generating the local MSL surface. Each such Secondary GCP yields one observation equation like (1). As already stated earlier, the Search Radius should be such that a minimum of nine control points (in a 3x3 pattern) are available for interpolation. For this, it is essential that Secondary GCPs with GPS coordinates (X, Y and H) and Orthometric Height (h) are provided in an approximate grid pattern (equally spaced at a certain interval), throughout the AoI. The optimal value of the interval depends on the required accuracy of Orthometric Height derived by interpolation and will be discussed at a later stage in this paper.

If there are n number of control points within the Search Radius from the point with unknown Orthometric Height, there will be n observation equations. These equations are solved by the method of Least Squares to yield the six parameters of the 2^{nd} order polynomial. A weight equal to the inverse of the square of the distance of the control point from the point with unknown Orthometric Height is assigned to each observation equation. Together, these weights form the weight matrix that is used in the Least Squares solution of the observation equations. The weight matrix is a diagonal nxn matrix with the weights of the observation equations as diagonal elements.

A detailed treatment of the mathematical model, weight matrix and the Least Squares solution can be found in (Naithani, 1991).

Development of Computer Program GPSAssistLev

A computer program named GPSAssistLev has been developed in Microsoft Visual Studio C#.NET for GPS assisted densification of a leveling network, as per the algorithm based on the mathematical model outlined above. One of the inputs required by the program is the file containing the X, Y, H and h (both Ellipsoidal and MSL Heights) of the height control points (Secondary GCPs) and X, Y, H (only Ellipsoidal Height) of the points with unknown Orthometric Height, in this case the Primary GCPs and the Tie-Points. First, all the Secondary GCPs are entered in the file ending with '-99' followed by all the Primary GCPs and the Tie-Points. The other input is the Search Radius which enables the program to short-list all the Secondary GCPs, which fall within this radius, for use in interpolation. The output of the program is a list of X, Y and h (orthometric height) coordinates with Point ID for all the Primary GCPs and Tie-Points contained in the input file.

Validity of Concept

The proposed methodology is based on the fundamental concept that the MSL surface is a smooth surface, of course with hills and valleys, but of very large wave lengths especially for the areas that are not highly mountainous. Even in highly mountainous terrain, the wave length of undulation remains significantly large making it amenable to derive precise Orthometric Heights by interpolation from a sparse precision leveling network without employing any gravimetric observations.

The smoothness of the WGS84 Geoid can be easily understood from the well-known fact that despite the presence of mountains as high as 8,000 m (viz., Mt. Everest) and oceans as deep as 10,000 m (viz., Pacific Ocean), the separation between the WGS84 Geoidal surface and the WGS84 Ellipsoidal surface varies within a very small range, i.e., between +100 m to -100 m throughout the globe. Since an MSL surface is very nearly an equipotential surface, the smoothness of the MSL surface will be similar to that of a geoid. This is further confirmed by the results of Test Area A and Test Area B later elaborated in this paper.

Validation of Concept

Test data

To prove the concept and to determine the optimal spacing at which the Secondary GCPs with precise Orthometric Heights are required for the sparse leveling network, it was required to have some reliable test data. As we are well aware, it is a cumbersome process to obtain the Orthometric Heights in India and many other countries due to security concerns. Many countries, including US and Canada, provide facilities for conversion between Ellipsoidal Heights and Orthometric Heights for their respective territories.

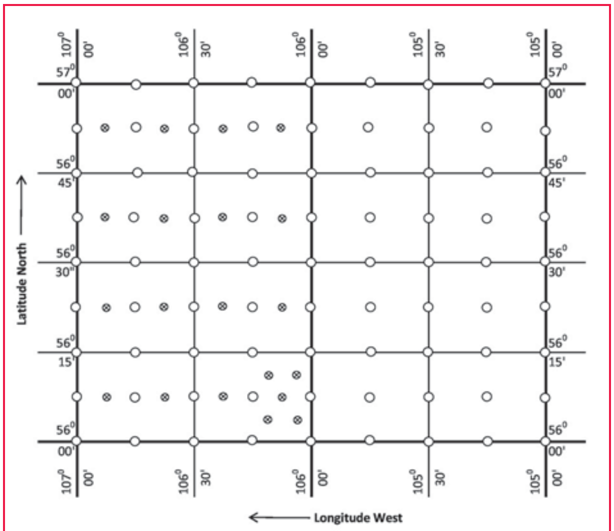
In view of above, two test areas, Area A and Area B described hereunder, falling in Canadian territory, were selected to validate the concept. Each of these test areas measures 1^0 Latitude by 2^0 Longitude that translate to near rectangular areas each measuring approximately 100 km in North-South and 115 km in East-West direction.

The test areas have been chosen pertaining to Canadian (and not Indian) territory only because of the availability of authentic data dealing with Ellipsoidal and Orthometric Heights. Natural Resources Canada (NRCan) provides the facility, online, for conversion from Ellipsoidal Heights to CGVD28 heights, (CSRS-A). The CGVD28 heights can very well be compared with the MSL Heights, (Hlasny, 2013). Using this online facility, the height of the MSL surface over the ellipsoid (H – h) was determined at every 7.5' Lat x 15.0' Longitude (thus, a total of 81 points for each test area). The heights of another set of 24 points for Test Area A and 30 points for Test Area B were also obtained in between the first set of points. The layouts of Secondary GCPs/ Check Points for Test Area A and B are given in Figure 2 and 3, respectively. The X, Y coordinates of all these points were also obtained in UTM coordinate system using another online facility, (CSRS-B).

(a) **Test Area A:** The area is bound by 56^0 N and 57^0 N Latitude and 105^0 W and 107^0 W Longitude. This terrain is undulating with terrain heights varying by 610 m (from 900 m to 290 m). The height of MSL surface above the Ellipsoid varies by 2.1 m (from -30.7 m to -28.6 m). The maximum separation of -30.7 m is at point with the height of 429 m and the minimum at the point with height of 888 m.

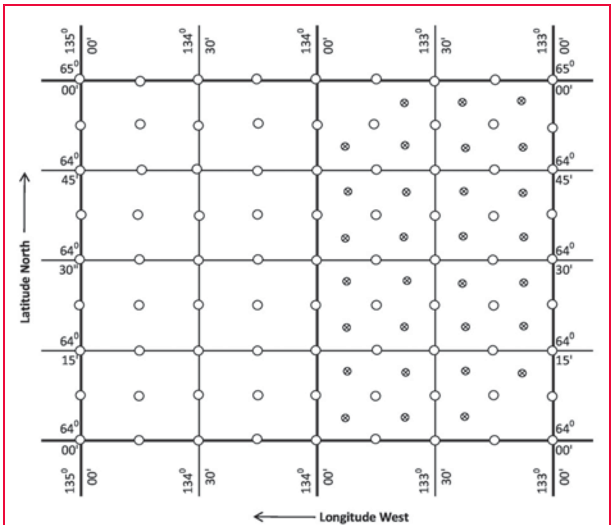
(b) **Test Area B:** The area lies between 64^0 N and 65^0 N Latitude and 133^0 W and 135^0 W Longitude. This area is quite hilly with terrain heights varying by 1,556 m (from 1,943 m to 387 m). The MSL separation from the ellipsoid varies by 3.3 m (from 8.6 to 5.3 m): the maximum at the point with height of 1,620 m and the minimum at the point with height of 657 m.

It may be seen that for both test areas, the maximum and minimum heights of MSL surface from the ellipsoid are not at the highest and the lowest terrain points.



1. These points were used as Secondary GCP or Check Point depending on the value of control point spacing used for testing .
2. Points marked as ⊗ were obtained especially for use as Check Points for Testing with control point spacing of 12 km (7°30' x 15°30').
3. The terrain of Test Area A is more or less flat.

Figure 2: Layout of Secondary GCPs / Check Points (Test Area A)



1. These points were used as Secondary GCP or Check Point depending on the value of control point spacing used for testing.
2. Points marked as ⊗ were obtained especially for use as Check Points for testing with control point spacing of 12 km (7°30' x 15°30').
3. Test Area B pertains to hilly terrain.

Figure 3: Layout of Secondary GCPs / Check Points (Test Area B)

Test Result and Analysis

The accuracy of height achieved by this method is outlined in Table 1. It can be seen that the accuracy is dependent on the density and distribution of Secondary GCPs in the AoI.

For test area A pertaining to flat terrain, the height accuracy achieved is 1.2 cm, 4.9 cm and 13.1 cm for heights interpolated from Secondary GCPs provided at every 7.5'x15' (12 km), 15'x30' (25 km) and 30'x10 (50 km), respectively.

For test area B pertaining to hilly terrain, the accuracy achieved is 8.4 cm, 17.6 cm and 35.3 cm for heights interpolated from Secondary GCPs provided at every 7.5'x15' (12 km), 15'x30' (25 km) and 30'x 10 (50 km), respectively.

From the above results, it can be categorically stated that if Secondary GCPs are available at every 12 km or so, the heights of points derived by the proposed method is suitable for

Table 1: Accuracy of MSL heights achieved by the proposed method

Distance Between MSL Height Control Points (BMs)	Search Radius for Control Points	Area A (Lat: 56⁰ - 57⁰; Long: 105⁰-107⁰)				Area B (Lat: 64⁰ - 65⁰; Long: 133⁰-135⁰)			
		Max MSL Height Undulation = 40 m. Max Geoidal Height Undulation** = 2.1 m				Max MSL Height Undulation = 1556 m. Max Geoidal Height Undulation** = 3.3 m			
		Delta Z Max (m)	Delta Z Min (m)	RMSE (m)	Height Accuracy at 95% Confidence Level (cm)*	Delta Z Max (m)	Delta Z Min (m)	RMSE (m)	Height Accuracy at 95% Confidence Level (cm)*
7.5' x 15' (12 km)	35 km	0.009	-0.012	0.006	1.2	0.095	-0.075	0.043	8.4
15' x30' (25 km)	70 km	0.043	-0.060	0.025	4.9	0.148	-0.226	0.090	17.6
30' x 1⁰ (50 km)	140 km	0.057	-0.143	0.067	13.1	0.320	-0.466	0.180	35.3

Notes:
1. *Height Accuracy at 95% Confidence Level = 1.96 * (RMSE)
2. **Geoidal Height Undulation means height of MSL surface over the Ellipsoid at a point.

contouring at a height interval of 25 cm. This will meet the requirements of most of the projects. For contouring requirement at 50 cm and 1 m interval, the spacing between Secondary GCPs could be as large as 25 km and 50 km, respectively. For less undulating terrain, the height accuracy would be suitable for even lower contour intervals.

However, particular care must be taken to get accurate GPS (ellipsoidal) heights on which the proposed method is based.

Application of the Proposed Method employing existing DPW software

From the above, it is well established that densification of leveling network employing the proposed method can be adopted for most of the photogrammetric mapping projects. The method may also be adopted employing any DPW system available in the market that allows creation of local geoid. The method of accomplishing this employing Socet Set DPW software is outlined in this section. The choice of Socet Set has been made only as an example. Any other DPW software with this facility can also be used.

Steps Involved

(a) **Create AT project:**

Create AT Project with the following datum:

- Horizontal datum: UTM/ WGS84 Ellipsoid
- Vertical datum: WGS84 Ellipsoid

The coordinates of the control points included for AT calculations will be in the above horizontal and vertical datum. The Primary GCPs established as per the earlier section will be used for this purpose. The Primary GCPs are required only at the corners of the photogrammetric block and will be very few in number. All these GCPs are required to be signalized prior to aerial photography or accurately positioned on images post aerial photography. Orthometric height of these GCPs is not required as input for AT.

(b) **Aerial Triangulation:**

Perform AT that includes automatic tie-point generation, GCP measurements, editing of tie-points, etc., and carry out AT adjustment employing suitable photogrammetric adjustment program as per the usual procedure.

(c) **Create MSL geoid for the AT Project:**

i. Derive the height of MSL surface over WGS 84 Ellipsoid (z) at all the Secondary GCP locations using the formula: z = Ellipsoidal Height - Orthometric Height.

ii. Prepare input ASCII file (in the format: X,Y, z) with values of X and Y coordinates in UTM and z value for all the Secondary GCPs provided throughout the AoI at a spacing of 12-15 km. It may be noted that signalization on ground or transfer of these GCPs on images is not required.

iii. The ASCII file so obtained will be imported into the AT project using DTM ASCII import of Socet Set. This will result in creation of MSL surface (or MSL geoid) for the AT Project.

(d) **Convert the above AT project to MSL Project:**

This is done employing the Create/ Edit utility of Socet Set (using MSL geoid created above) and saving it as an MSL Project. This will also yield the new Tie-Point and EO files with heights above MSL datum.

(e) **Use of MSL project for Production**:

Use the Converted AT Project for DTM/Ortho/3D Vector Data Generation or any other requirement. The height datum of DTM/Vector data so generated would be in MSL terms as is required by most clients.

Saving in overall cost and effort due to the proposed methodology

On the face of it, the time, effort and cost advantage resulting due to the proposed method may not appear significant due to the fact that leveling is still required. But if one works out the leveling effort required using the proposed method vis-à-vis the leveling effort required otherwise, the advantage becomes very significant. There are other advantages too. A few GCPs need to be transferred to images that save a considerable effort. It also results in more automated aerial triangulation.

Table 2: Summary of Input Specifications

1	Area to be mapped	100 km x 50 km
2	Camera used	DMC-1
3	GSD in images	9 cm
4	Image size (in Pixels)	7,680 x 13,824
5	Image size	691 m x 1,244 m
6	Model size with 60% / 25% overlaps	276 m x 933 m
7	No. of flight lines	55
8	No. of models per flight line	370
9	Total No. of models	20,350

Table 3: Comparison between the conventional and the proposed methods

Sl. No.	Item	As per the tender document	With the proposed method
1	No. of control points to be provided by GPS	172	75
2	No. of BMs to be provided by leveling	5150	66
3	No. of points to be pre- (post-) pointed on aerial imagery	5322	9
4	Total length of precision leveling line (lin km)	5,550	720

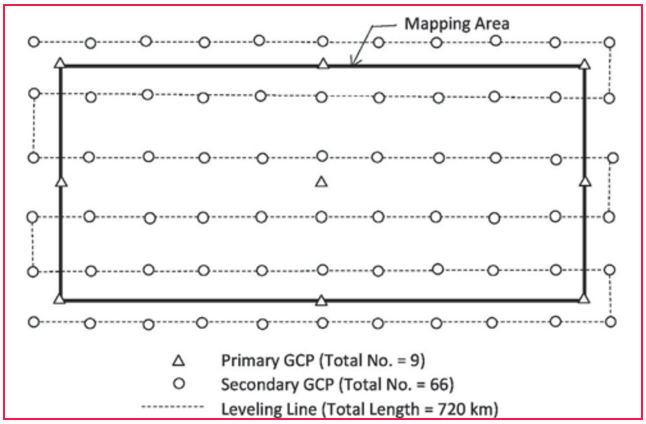


Figure 4: Layout of Primary and Secondary GCPs and Leveling Line for 100 km x 50 km Area

In fact, this paper was triggered by the technical specifications of a tender by the Government of India for one of their major large scale mapping project, namely, the Integrated Coastal Zone Management Project, (SICOM, 2011). The tender pertained to aerial triangulation (AT) followed by production of DTM/Orthophoto/3D Vector data along coastal area of India employing DMC-1 aerial images acquired with air-borne GPS/IMU at 1:7,500 scale with fore and side overlaps of 60% and 25%, respectively. Full control points were required to be provided by relative static GPS observations and field leveling every fifth model along the periphery, whereas bands of height control points (BMs) were required to be provided by field leveling four models apart.

These specifications resulted in a very large number of plan control points and BMs increasing the cost of the project considerably, despite the fact that the imagery was acquired with onboard GPS/IMU. To illustrate this point, we will now discuss the control requirement for a photogrammetric block of 100 km x 50 km as per the tender specifications and also as per the proposed methodology. For this discussion, we will assume the same input specifications as given in the tender document which are summarized in Table 2.

The total requirement and layout of Primary and Secondary GCPs and field leveling for photogrammetric mapping of the 100 km x 50 km block as per the methodology proposed in this paper is given in Figure 4. It may be noted from the figure that some Secondary GCPs are also provided a little outside the AoI to ensure the availability of a minimum of nine control points in a 3x3 pattern for the Primary GCPs and Tie-Points located at the periphery.

Comparison between the conventional and the proposed methods

The effort involved in provision of ground control points by GPS observations/ field leveling and pre-/post-pointing on aerial imagery for the two methods is summarized in Table 3. It can be seen that by adopting the proposed method, the number of GCPs to be provided by GPS reduces by 56%, the number of BMs to be provided by leveling reduces by 98%, the total length of leveling line reduces by 87%, and the number of points to be precisely pre- or post-pointed on aerial imagery by more than 99%. All this saving would have made the project much more economical and viable.

Conclusions

Photogrammetry is a very efficient and economical method of 3D mapping in advanced countries like US and Canada. GPS has become the de facto standard for provision of GCPs. The heights are still required in MSL terms, whereas GPS provides heights in Ellipsoidal terms. But it does not pose any problem since these countries have a precise geoid and a correction surface to automatically convert the GPS ellipsoidal heights to MSL terms.

However, this is not the case with countries like India that have not yet established their own geoid and correction surface. So these countries cannot make full use of airborne GPS/IMU though they have already acquired these technologies. As a result, these countries still insist on the conventional requirement of plan and height control for photogrammetry making the mapping projects quite un-economical and unviable. So there is an urgent need for establishing a precise geoid and a correction surface for conversion of Ellipsoidal Heights to Orthometric Heights.

The establishment of precise geoid does require a lot of resources, planning and time. So till the time these countries are able to establish their own geoid, the method proposed in this paper provides an interim solution that makes full use of airborne GPS/IMU making mapping projects economical and viable.

Acknowledgements

I am grateful to Survey of India, where I have been closely associated with the R&D and digital mapping departments, and where I dealt with horizontal and vertical datum and also developed a module for generation of DEM from contours which has been taken further in this paper. I am equally grateful to COWI India Pvt. Ltd., to which I have been providing technical consultancy services in mapping and GIS during the last 8 years that also enabled me to understand the current mapping practices in US, Canada, Europe and other countries that have already established their own precise geoid and have facilities for conversion from GPS Ellipsoidal Heights to Orthometric Heights.

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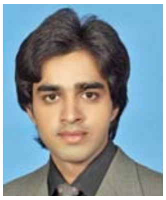
GIS mapping to determine river pollution

The study focuses on the incorporation of GIS mapping to indicate the status of pollution in the sketch of River Ravi downstream to the wastewater outfalls in Pakistan



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Water is essential for all forms of life and ecosystems. Rivers are essential as they serve humans with ample fresh water supply. Although rivers contain only 0.0001% of the total global water, they are key carriers of nutrients and water worldwide (Wetzel, 2001). The evolution of human civilization is associated with rivers and its adjoining fertile flood plains. However, a dynamic shift in human civilizations resulted in variation of water use patterns along with unavoidable discharge of sewage and solid wastes into water bodies (Song & Kim, 2006). The condition of river pollution in third world countries worsens day-by -day, where the rivers are considered easy disposal points for effluents. Similar is the case of River Ravi, which is significantly polluted due to excessive discharge of untreated sewage and waste water released from Lahore and its associated industrial estates (Ahmed & Ali, 1998) through five wastewater drain outfalls and a surface drain (WWF, 2007). This discharge is estimated to be 40 m3/s, which would be increased approximately to 56 m3/s by 2025 (Haider, 2010). Besides this, another major cause of pollution of River Ravi is the Indus Water Treaty of 1960, signed between India and Pakistan that governs the trans-boundary water rights of the two countries leading to extreme flow variation in the river which ranges between 10 and 10,000 m3/s (IPD 1967-2004).

The discharge of untreated effluent into the environment may have severe adverse impact on the quality of the receiving water body (Eluozo, 2012). Therefore, river water quality management is essential to meet the water quality expectations for streams and rivers to ensure protection of the drinking water resources, provision of healthy environment for aquatic ecosystem and encourage recreational activities (Amadi et al., 2010). The proper monitoring of water quality is an essential component of river water quality management. However, the selection of parameters for water quality assessment and monitoring of the pollution of rivers depends on the objectives of the monitoring (Bartram & Balance, 1996). The parameters of special concern for waste water pollution estimation are temperature, pH, TSS, TDS, COD, BOD_5, Chloride, Sulfate, Sulfide, and heavy metals.

In recent years, the Geographic Information System (GIS) is considered as an effective tool in wastewater management as it enables the large volume of data handling much easier (Gemitzi et al., 2007; Huffmeyer et al., 2009). Its application leads to more effective decision-making (Hughes, 2006). The objectives of the study involves determination of the concentration of 19 pollutants at six wastewater outfalls of Lahore, integrate GIS mapping to identify the potential pollution loading sites, and geographically indicating pollution in various portions of the river, downstream to the wastewater outfall points.

Materials and Methods

Study Area

River Ravi is a trans-boundary river, part of the Indus Basin System that originates in India and enters Pakistan where it passes through Lahore, Pakistan's second largest city. It receives untreated municipal and industrial wastewater through five

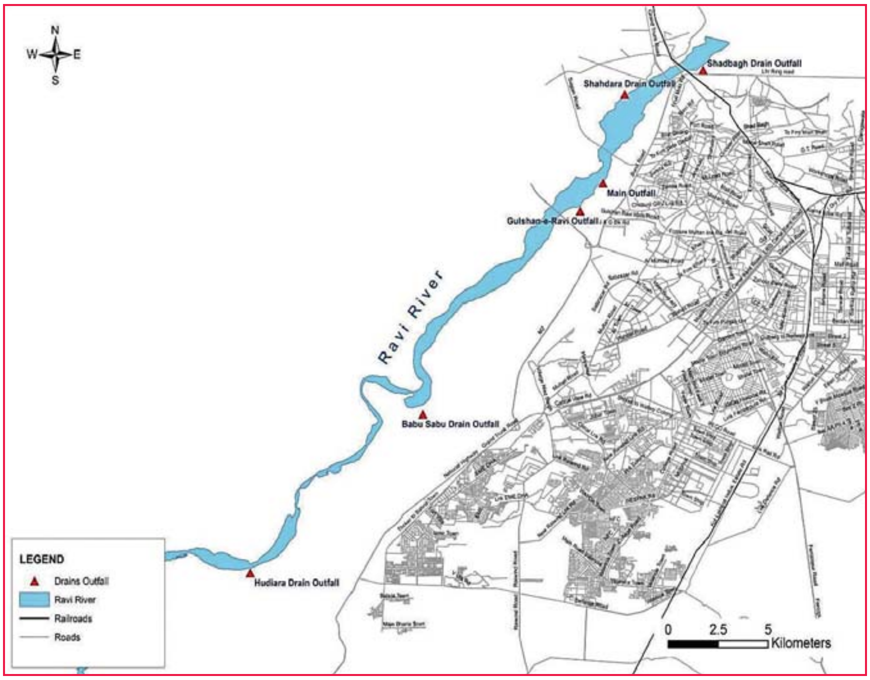


Figure 1: Schematic diagram showing the sampling stations in study area

Table 1: Description of the Sampling Locations

Sr. No.	Sampling Locations	Flow Rate (m^3/s)	Left/ Right Bank	GPS Coordinates	
				Latitude	Longitude
1.	Shadbagh Drain Outfall	4.672	Left	31° 36' 54.92" N	74° 18' 50.09" E
2.	Shahdara Drain Outfall	5.946	Right	31° 35' 45.29" N	74° 16' 50.9" E
3.	Main Outfall	5.238	Left	31° 33' 53.93" N	74° 16' 2.93" E
4.	Gulshan-e-Ravi Drain	6.371	Left	31° 33' 12.28" N	74° 15' 25.95" E
5.	BabuSabu Drain Outfall	7.645	Left	31° 28' 21.93" N	74° 11' 10.50" E
6.	Hudiara Drain Outfall	10.76	Left	31° 24' 22.59" N	74° 6' 5.59" E

municipal drains outfalls of the city and one surface water drain (Figure 1).

Sampling Sites

The sampling for the purpose of this research was carried out at six sampling stations located at each wastewater outfall point in Lahore (Table 1).

Sample Collection, Preservation and Chemical Analyses

Time proportional composite sampling of the wastewater was carried out four times during the study period with the interval of two months between October 2012 and April 2013 at all the six sampling locations. The sample collection was done at the point of turbulent flow near the outfall points of the drains and all the sampling was performed during day time, between 10 am to 4 pm, using simple manual sampling apparatus such as a bucket and rope. The collected wastewater samples were then transferred to prepared sampling bottles, i.e., pre-rinsed with 10% nitric acid or only washed with detergents, depending on the parameters of interest. Furthermore at the time of sampling, the detail sample descriptive information and GPS coordinates using GARMIN eTrex 20 were recorded along with each sample. The collected samples were then transferred and preserved in a certified environmental laboratory for analysis, and the analyses of the samples were performed in accordance to ‘Standard Methods for the Examination of Water and Wastewater’, 21st Edition by American Public Health Association, 2005 (APHA, 2005).

GIS Mapping

GIS mapping of the different pollutants at the wastewater outfalls, assessment of the pollutant loads discharged into River Ravi from six wastewater outfalls of Lahore and relative contamination of different portions of River Ravi downstream to each outfall point was done using ArcGIS 9.0.

Flow Rate Data

The flow rate data in the drains (Table 1) required to calculate the unit pollutant load were obtained from JICA, 2010 - “The preparatory study on Lahore water supply, sewerage and drainage improvement project in Pakistan”, JICA report WASA Lahore report no. 24, pp. 5-48.

Results and Discussion

Physicochemical Characteristics of the Wastewater

Results of the wastewater analyses for the samples collected from the six wastewater outfalls of Lahore (Table 2) revealed that the total dissolved solids (TDS), sulfate (SO4), chloride (Cl-), fluoride (F-), manganese (Mn), chromium (Cr), zinc (Zn), and nickel (Ni) were found within the permissible limits of the Pakistan’s National Environmental Quality Standards (NEQS) at all the six wastewater outfalls. However, the biochemical oxygen demand (BOD_5), chemical oxygen demand (COD), and sulfide (S2-) throughout the study period, at all six wastewater outfalls of Lahore, were exceeding the NEQS permissible limits. Moreover, the total suspended solids (TSS) in Shadbagh Drain Outfall, Main Outfall and Gulshan-e-Ravi Outfall, and copper (Cu), cyanide (CN), and cadmium (Cd) in Hudiara Drain Outfall exceeded the set limits. Furthermore, the GIS mapping (Map 1 (a) – 16 (a)) of the mean pollutant

Table 2: Mean concentrations (± SD) of different wastewater parameter (mg/l) at the wastewater outfalls (Lahore) during the study period

Sr. No.	Parameter	Hudiara Drain Outfall	BabuSabu Drain Outfall	Gulshan-e-Ravi Outfall	Shahdara Drain Outfall	Main Outfall	Shadbagh Drain Outfall
1.	pH*	7.35 ± 0.46	7.42 ± 0.09	7.12 ± 0.35	7.47 ± 0.25	7.20 ± 0.28	7.25 ± 0.29
	NEQS*	6-9	6-9	6-9	6-9	6-9	6-9
2.	BOD	177.7 ± 56.16	314.5 ± 52.34	455.5 ± 44.65	166.7 ± 30.01	235.7 ± 21.91	192.2 ± 14.08
	NEQS	80	80	80	80	80	80
3.	COD	392.5 ± 102.96	939.5 ± 38.85	902.2 ± 57.52	370.7 ± 33.82	539.7 ± 31.98	542.7 ± 62.77
	NEQS	150	150	150	150	150	150
4.	TDS	1040.2 ± 188.6	643.5 ± 38.1	582.5 ± 41.4	450.5 ± 82.5	403.7 ± 25.9	505 ± 21.3
	NEQS	3500	3500	3500	3500	3500	3500
5.	TSS	165.7 ± 55.30	34.5 ± 7.32	257 ± 38.59	84.7 ± 7.80	273.2 ± 37.33	698.7 ± 27.36
	NEQS	200	200	200	200	200	200
6.	Cl^-	203.5 ± 60.40	90 ± 8.64	110.7 ± 26.99	44.2 ± 6.75	101.2 ± 22.15	102.2 ± 15.17
	NEQS	1000	1000	1000	1000	1000	1000
7.	SO_4	269.2 ± 50.13	166.2 ± 36.77	141.5 ± 20.98	84.7 ± 7.80	108.5 ± 21.85	109 ± 13.63
	NEQS	600	600	600	600	600	600
8.	S^{2-}	7.82 ± 1.23	6.75 ± 1.26	19.5 ± 2.64	7.75 ± 1.26	16.5 ± 3.11	11.5 ± 2.08
	NEQS	1.0	1.0	1.0	1.0	1.0	1.0
9.	F^-	0.205 ± 0.08	0.008 ± 0.01	0.943 ± 0.42	0.868 ± 0.17	1.642 ± 0.68	0.961 ± 0.29
	NEQS	10.0	10.0	10.0	10.0	10.0	10.0
10.	CN^-	10.981 ± 1.18	0.110 ± 0.14	0.834 ± 0.13	0.382 ± 0.25	0.041 ± 0.04	0.807 ± 0.33
	NEQS	1.0	1.0	1.0	1.0	1.0	1.0
11.	Mn	0.732 ± 0.43	0.718 ± 0.28	0.232 ± 0.09	0.412 ± 0.33	0.188 ± 0.06	0.357 ± 0.09
	NEQS	1.5	1.5	1.5	1.5	1.5	1.5
12.	Cu	1.712 ± 0.43	0.469 ± 0.28	0.340 ± 0.10	0.088 ± 0.03	0.065 ± 0.02	0.404 + 0.24
	NEQS	1.0	1.0	1.0	1.0	1.0	1.0
13.	Cd	0.832 ± 0.59	0.019 ± 0.03	0.047 ± 0.01	0.055 ± 0.03	0.055 ± 0.03	0.076 ± 0.05
	NEQS	0.1	0.1	0.1	0.1	0.1	0.1
14.	Cr	0.497 ± 0.21	0.047 ± 0.04	0.089 ± 0.03	0.072 ± 0.03	0.053 ± 0.03	0.450 ± 0.36
	NEQS	1.0	1.0	1.0	1.0	1.0	1.0
15.	Zn	2.009 ± 0.81	2.039 ± 0.99	1.722 ± 0.70	0.051 ± 0.01	1.431 ± 0.42	1.459 ± 0.37
	NEQS	5.0	5.0	5.0	5.0	5.0	5.0
16.	Fe	8.221 ± 2.20	6.521 ± 0.81	2.263 ± 0.49	4.952 ± 2.13	3.954 ± 0.58	10.451 ± 0.86
	NEQS	8.0	8.0	8.0	8.0	8.0	8.0
17.	Ni	0.491 ± 0.25	0.050 ± 0.02	0.422 ± 0.27	0.021 ± 0.01	0.080 ± 0.02	0.091 ± 0.03
	NEQS	1.0	1.0	1.0	1.0	1.0	1.0

1. NEQS – National Environmental Quality Standards for Municipal and Liquid Industrial Effluents (mg/l, unless otherwise defined)
* no unit for pH level

concentrations indicating the portions of River Ravi most affected by the untreated wastewater discharges of these pollutants from the six wastewater outfalls of Lahore could be expedient in effective decision-making to control the wastewater pollution of the river on exact area of requirement.

Organic Loading

The high organic loading (BOD_5 and COD) of River Ravi from the wastewater outfalls of Lahore is mainly due to lack of a single primary or secondary municipal wastewater treatment plant located at any of the wastewater drains in Lahore. The conventional primary wastewater treatment facility and secondary wastewater treatment facility can reduce the BOD level up to 35% and 85%, respectively (Stoddard et al., 2002). Moreover, as the water flow in river upstream to Balloki Headwork is very low in most parts of the year (Shakir&Qazi, 2013), with addition of such high oxygen demanding wastewater, the dissolved oxygen availability may lessen to the level which would be fatal to most aquatic species. The GIS maps (Map 1(a) and Map 2(a)) have indicated that the portions of the river downstream to the point of confluence of Main Outfall, Gulshan-e-Ravi Outfall, BabuSabu Outfall and Shadbagh Drain Outfall, are most affected by the organic loading from Lahore.

Total Solids

Total solids include total suspended solids (TSS) and total dissolved solids

(TDS) present in the wastewater (APHA, 2005). Map 4(a) indicates that high suspended solid content in wastewater effluents of Shadbagh Drain Outfall, Main Outfall, and Gulshan-e-Ravi Outfall are affecting the stretch of the river, downstream to their confluence points. The high TSS contents may bind toxins with them that are toxic to the fish and other aquatic ecosystem. The research literature reveals that high level of TSS introduced to the riverine water increases the turbidity of the water, and thus affects the spawning, growth and reproduction of the fish species (Bonisławska et al., 2011).

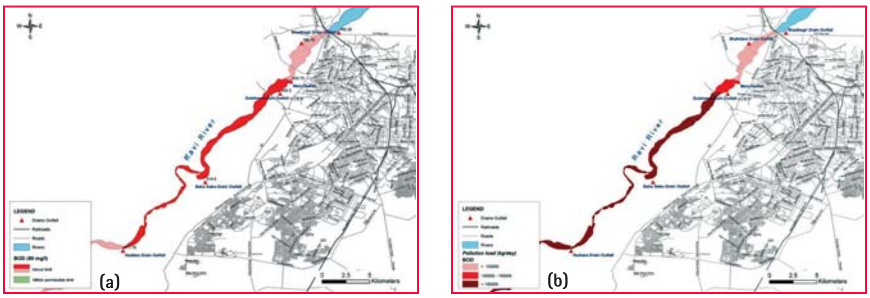
Moreover, Map 3(a) has highlighted that the TDS contents in the wastewater of Lahore discharging into the river is between 276 mg/l and 1300 mg/l, i.e., within the NEQS limit.

Sulfates/ Sulfides

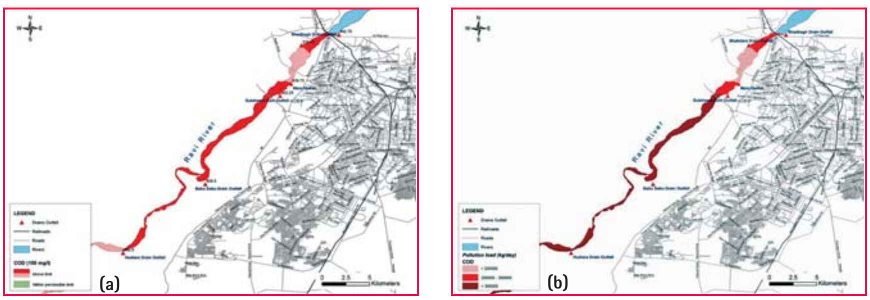
The sulfate concentrations in all the wastewater outfalls of Lahore were well within the NEQS limit (Map 6(a)). However, the sulfide concentrations (Map 7(a)) in all the wastewater samples of the outfalls were found exceeding the 1.0mg/l permissible limit of the NEQS, thereby polluting River Ravi significantly. These high sulfide concentrations in Lahore's wastewater were possibly due to the industrial discharges into the municipal wastewater collection system. The sulfide present in the wastewater may react with hydrogen to produce hydrogen sulfide, a highly toxic, odorous and corrosive gas (Muyzer&Stams, 2008). Even at low concentrations, hydrogen sulfide gas has a foul odor and possesses significant threat to human health in the exposed communities (Sutherland-Stacey et al., 2008). Therefore it would make the river water unfit for recreational activities. Moreover, the communities developed on the banks of the river, i.e., Kachi Abadis would be exposed to health hazards arising from the hydrogen sulfide presence in the environment.

Table 3: Unit Pollutant Load (kg/day) of study parameters at wastewater outfalls of Lahore

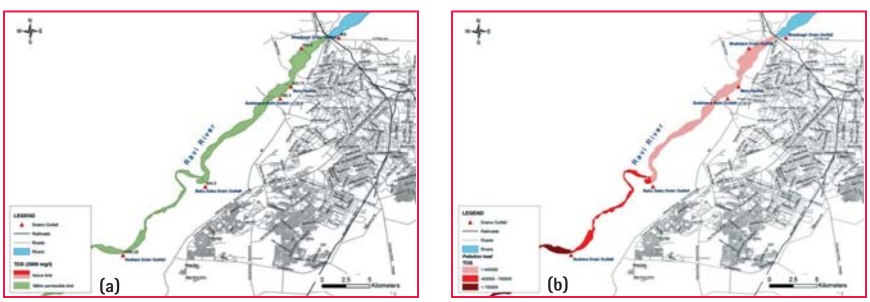
Sr. No.	Parameter	Hudiara Drain Outfall	BabuSabu Drain Outfall	Gulshan-e-Ravi Outfall	Shahdara Drain Outfall	Main Outfall	Shadbagh Drain Outfall
1.	BOD	165247.81	207736.11	250732	85665.21	106691.78	77603.79
2.	COD	364893.12	620566.09	496647.51	190467	244271	219086.91
3.	TDS	967083	425049.82	320639.73	231437.29	182722.42	203848.79
4.	TSS	154091.79	22788.22	141466.81	43538.99	123662.91	282058
5.	Cl	189186.61	59447.52	60962.82	22732.75	45822.02	41274.32
6.	SO_4	250312	109812.79	77889.33	43538.99	49103.11	43999.03
7.	S^{2-}	7274.62	4458.56	10733.86	3981.44	7467.29	4642.09
8.	F^-	191.28	5.28	519.49	446.18	743.45	388.22
9.	CN^-	10212.36	66.05	459.63	195.22	20.25	323.23
10.	Mn	680.97	474.42	127.84	211.78	85.42	144.21
11.	Cu	1591.58	309.78	187.15	45.33	29.42	163.38
12.	Cd	743.73	12.88	26.15	28.51	25.23	30.88
13.	Cr	462.51	31.05	48.99	37.37	24.09	181.95
14.	Zn	1875.59	1350.78	948.43	29.54	651.46	591.06
15.	Fe	7646.49	4308.29	1247.74	2545.55	1778.46	4199.78
16.	Ni	455.53	30.38	229.81	10.66	38.81	36.63



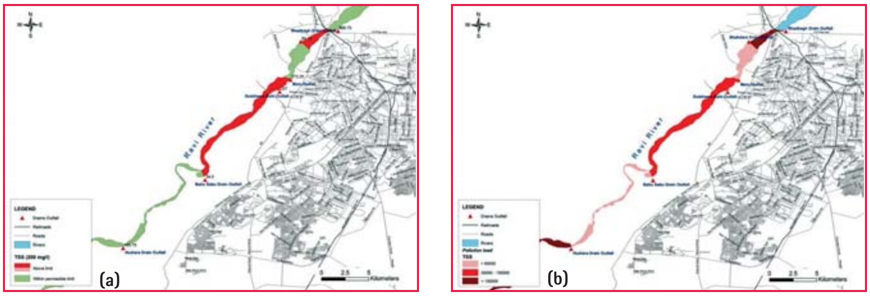
Map 1: (a) Mean BOD Concentrations (b) BOD Pollution Load at/ of Wastewater Outfall of Lahore discharging into River Ravi



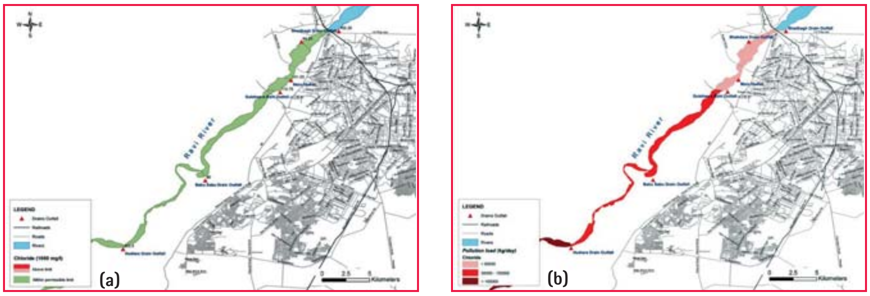
Map 2: (a) Mean COD Concentrations (b) COD Pollution Load at/ of Wastewater Outfall of Lahore discharging into River Ravi



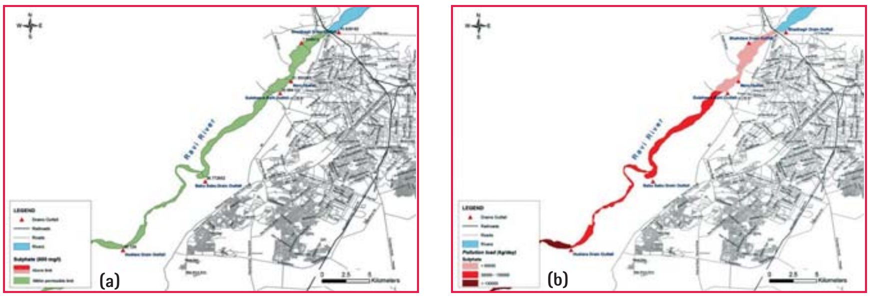
Map 3: (a) Mean TDS Concentrations (b) TDS Pollution Load at/ of Wastewater Outfall of Lahore discharging into River Ravi



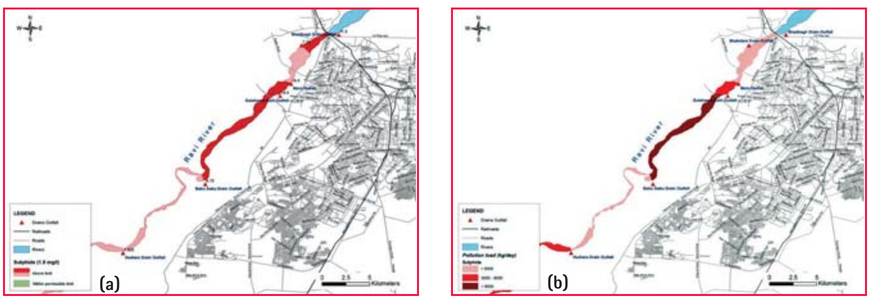
Map 4: (a) Mean TSS Concentrations (b) TSS Pollution Load at/ of Wastewater Outfall of Lahore discharging into River Ravi



Map 5: (a) Mean Chloride Concentrations (b) Chloride Pollution Load at/ of Wastewater Outfall of Lahore discharging into River Ravi



Map 6: (a) Mean Sulphate Concentrations (b) Sulphate Pollution Load at/ of Wastewater Outfall of Lahore discharging into River Ravi



Map 7: (a) Mean Sulphide Concentrations (b) Sulphide Pollution Load at/ of Wastewater Outfall of Lahore discharging into River Ravi

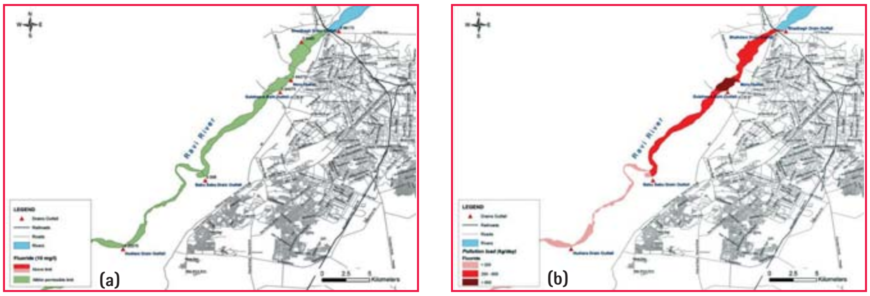
Halides (Chloride and Fluoride)

Halides, including the chlorides and fluorides presence in the wastewater outfalls were within the permissible limit (Map 5(a) and Map 8 (a) respectively). However, the fluorides in the riverine ecosystem even at low concentrations would tend to accumulate in bone tissues of the fishes and exoskeleton of invertebrates (Camargo, 2003). Moreover, the major impacts associated with the presence of chloride in the wastewater discharging into River Ravi are degradation of aquatic biota and terrestrial flora irrigated with chloride contaminated surface water. The high chloride concentration accumulated in soil, chronically irrigated with chloride contaminated water would decrease the rate of microbial degradation (Gryndler et al., 2007).

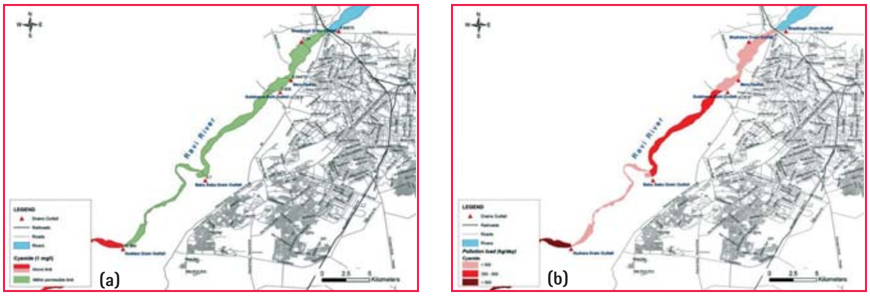
Metals

Among the metals in the wastewater drains discharging into River Ravi, the Hudiara Drain Outfall samples have shown the highest relative mean concentration for all metals, except for zinc whose maximum mean concentration was determined in Babu Sabu Drain Outfall, and iron whose maximum mean concentration was at Shadbagh Drain Outfall during the study period (Map 9(a) – 16(a)). The mean concentrations of Cd, Fe, CN, and Cu in the Hudiara Drain Outfall exceeds the permissible limits, which is hypothetically due to collection of untreated industrial wastewater by the Hudiara Drain and its tributary drains that passes through the areas where majority of the industrial zones exist. There are 212 industries located in India and Pakistan that discharge their untreated industrial effluents into Hudiara Drain (Shakir&Qazi, 2013). Moreover, the Fe concentration at the Shadbagh Drain Outfall exceeded the permissible limit throughout the study period because the drain receives untreated industrial wastewater from steel foundries, scrap yards, and steel re-rolling mills located in the collection area of the drain.

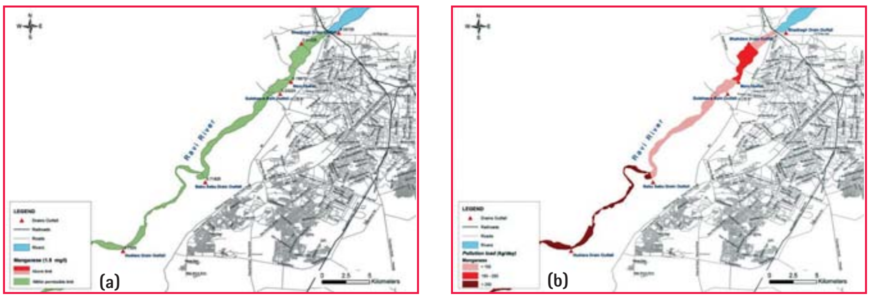
The high concentration of metals in Hudiara Drain Outfall and Shadbagh Drain Outfall might exert high eco toxicological impacts on the aquatic ecosystem of the river, downstream to the points of confluence, i.e., outfall points. The metallic elements can disrupt the metabolic function in aquatic organisms by binding the enzymes essential elements, and also produce adverse effects on their growth and reproduction. Fish are recognized as good accumulator of metals, especially heavy metals; they accumulate the heavy metals in their fatty tissues and thus enter the food chain. Thereafter, these heavy metals undergo biomagnification as they travel through the food chain and are transferred in



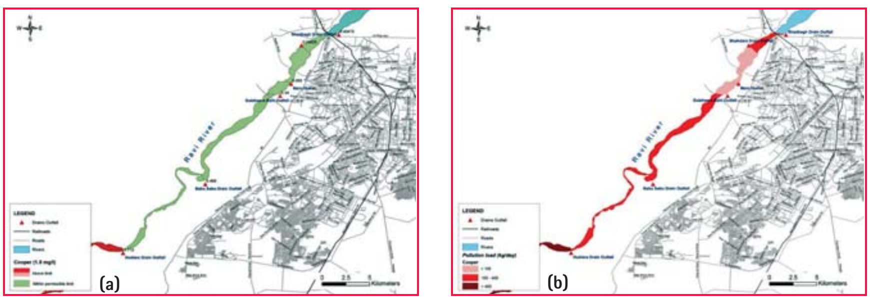
Map 8: (a) Mean Fluoride Concentrations (b) Fluoride Pollution Load at/ of Wastewater Outfall of Lahore discharging into River Ravi



Map 9: (a) Mean Cyanide Concentrations (b) Cyanide Pollution Load at/ of Wastewater Outfall of Lahore discharging into River Ravi



Map 10: (a) Mean Manganese Concentrations (b) Manganese Pollution Load at/of Wastewater Outfall of Lahore discharging into River Ravi



Map 11: (a) Mean Copper Concentrations (b) Copper Pollution Load at/ of Wastewater Outfall of Lahore discharging into River Ravi

magnified concentrations to humans and other animals, and thus consuming the contaminated aquatic food poses a threat to public health (Miller et al., 2002). Over the years, eco-toxicity associated with heavy metal pollution has become a major health concern because the heavy metals in the form of colloidal, particulate and dissolved forms are persistent in surface water bodies (Miller et al., 2003).

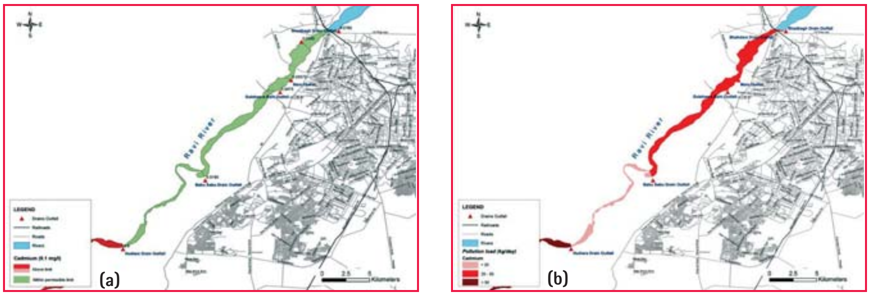
Pollutant Load Assessment

The pollutant load assessment of the study (Map 1(b) to Map 16(b)) revealed that although few pollutants that were discharged into River Ravi were relatively low in concentrations at one wastewater outfall point as compared to others and in some cases, even within the permissible limits of NEQS, but they have a high pollutant load. For instance, the mean BOD concentration in Main Outfall was greater than that in the Hudiara Drain Outfall, but the BOD pollutant load of these two outfalls were inverse (Map 1). Similarly, the mean concentration of COD in Hudiara Drain Outfall was less than that in Main Outfall and Shadbagh Drain Outfall, but the COD pollutant load was greater in Hudiara Drain Outfall relative to these two outfalls (Map 2).

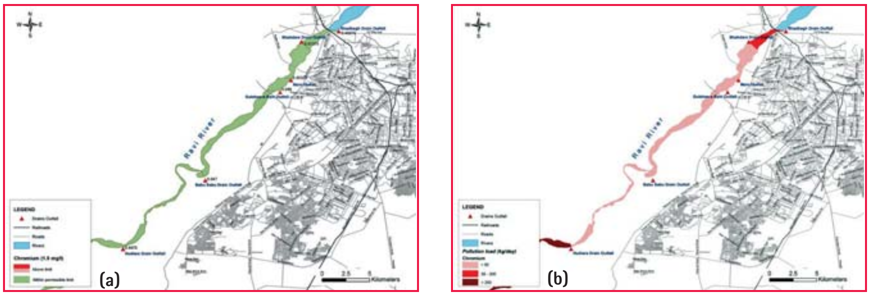
Similarly, the sulphide mean concentration in Hudiara Drain Outfall is lesser than the Main Outfall and Shadbagh Drain Outfall, but still it has a relatively higher sulphide pollution load (Map 7). Moreover, the chloride mean concentration in Main Outfall was greater than Babu Sabu Drain Outfall but in terms of chloride pollution load, the relationship was contrary (Map 5). Similar was in the case of iron's pollutant load, for which mean the iron concentration in Shadbagh Drain Outfall was greater than that in Hudiara Drain Outfall. But in terms of iron pollution load, the Hudiara Drain Outfall with a mean concentration within the NEQS limit has the greatest pollutant load among all six wastewater outfalls of Lahore (Map 15).

Furthermore, the GIS mapping of the study revealed that even though the mean TSS concentration in Hudiara Drain Outfall (i.e., 165.7 mg/l) was within the NEQS limit of 200mg/l, while concentration in the Main Outfall (273.2 mg/l) and Gulshan-e-Ravi Outfall (257 mg/l) exceeded the NEQS limit. However, the TSS pollutant load of the Hudiara Drain Outfall is still greater than the wastewater mentioned in these two outfalls.

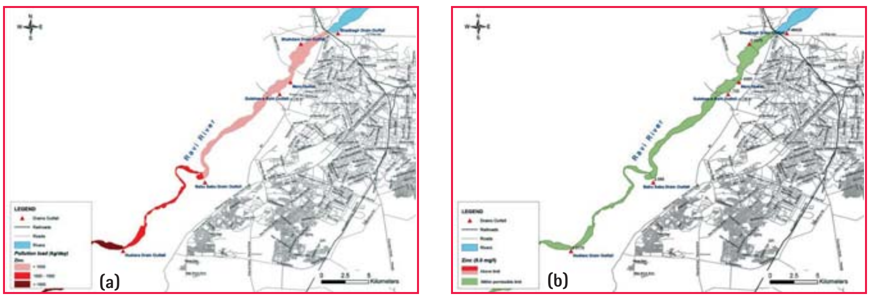
Therefore although in Pakistan, legislative requirements only demand the concentration of pollutants in the wastewater to be within the prescribed standards, no pollutant loads standards or procedures exist. But as revealed by comparison through GIS mapping, the



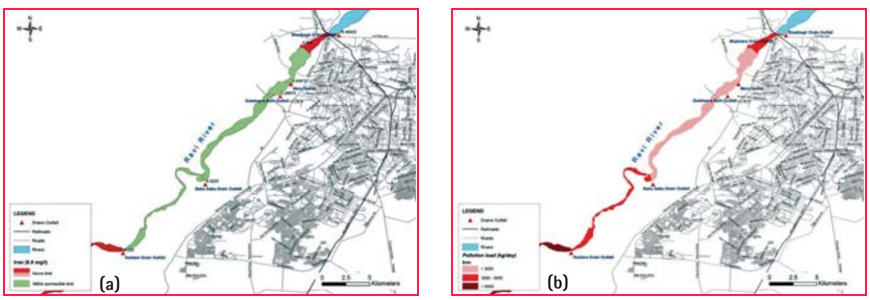
Map 12: (a) Mean Cadmium Concentrations (b) Cadmium Pollution Load at/ of Wastewater Outfall of Lahore discharging into River Ravi



Map 13: (a) Mean Chromium Concentrations (b) Chloride Pollution Load at/ of Wastewater Outfall of Lahore discharging into River Ravi



Map 14: (a) Mean Zinc Concentrations (b) Zinc Pollution Load at/ of Wastewater Outfall of Lahore discharging into River Ravi



Map 15: (a) Mean Iron Concentrations (b) Iron Pollution Load at/ of Wastewater Outfall of Lahore discharging into River Ravi

mean concentration determination should not be the only parameter to determine the characteristics and quality of wastewater, because significant pollution might be ignored due to monitoring of only pollutant concentration. Thus, a specific legislation is needed to be set in Pakistan, especially for River Ravi because of its low dilution factor to avoid pollution shock in the river.

Conclusion

The present study has recognized the potential polluted spots of River Ravi and revealed that although the few pollutants discharged into the river were relatively low in concentration at one wastewater outfall point as compared to another, it may have a high pollutant load that may lead to significantly higher ecological impact. Thus, GIS application in environmental monitoring could be an effective tool in environmental decision-making to introduce optimum treatment engineering controls at points of interests to prevent the ecological damages and protect human health. Therefore, there is a critical need to incorporate GIS applications in environmental decision-making to assess the environmental impacts effectively.

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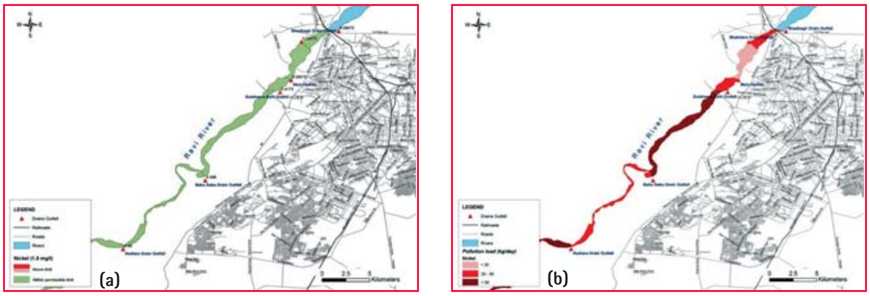

Map 16: (a) Mean Nickel Concentrations (b) Nickel Pollution Load at/ of Wastewater Outfall of Lahore discharging into River Ravi

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The paper was presented at 9th National GIS Symposiun in Saudi Arabia at Damman during April 28-30, 2014.

Galileo update

Rockwell tracks Galileo signal with secure software receiver

Rockwell Collins has successfully received and tracked a Galileo satellite signal using a prototype GNSS receiver designed for secure military use.

In 2013, Rockwell Collins received a $2 million contract from the Air Force Research Laboratory (AFRL) and the GPS Directorate to develop and demonstrate a Secure Software Defined Radio (S-SDR) GNSS receiver capability. By using multiple available satellite signals, improved and more robust signal availability can be obtained.

Hosted in a software-defined radio, the S-SDR program will develop the security architecture required for receiver equipment approvals and certifications. The arrival of modernized GPS signals and other global constellations is changing the way the U.S. military and its allies accomplish secure GNSS-based positioning, navigation and timing. The European Galileo constellation coming on line during 2015, including its open signals and secure Public Regulated Service, is expected to provide an opportunity for improved robustness in satellite based navigation, in both commercial and government applications.

ESA releases diagrams showing Galileo 5 and 6 Orbit

The fifth and sixth Galileo satellites have been in a safe state since August 28, under control from ESA's center in Darmstadt, Germany, despite having been released on August 22 into lower and elliptical orbits instead of the expected circular orbits. ESA said that the potential of exploiting the satellites to maximum advantage, despite their unplanned injection orbits and within the limited propulsion capabilities, is being investigated. Various ESA specialists, supported by industry and France's CNES space agency, are analyzing different scenarios that would yield maximum value for the program, and safeguard — as much as possible — the original mission objectives. More detailed analysis, alongside consultations with industry, is under way.

EU Agencies start work on cohesive GNSS plan for Europe

The European Global Navigation Satellite System Agency (GSA)– which operates and maintains Egnos, Europe's Waas equivalent–and Eurocontrol signed a new cooperation agreement under which they will jointly implement European satellite navigation policies in the aviation sector. The move will set the stage for the EU to evolve its air traffic management infrastructure from one based primarily on ground-based systems to a more satellite-based system, improving accessibility, efficiency and safety for European operators, pilots and airports.

To accomplish this objective, the agreement focuses on defining aviation user requirements for Egnos and the European Galileo GPS satellite network; introducing European GNSS services for aviation within the European Civil Aviation Conference area; coordinating aviation research and development; monitoring aviation-specificGNSS performance; and promoting European GNSS aviation activities at the international level. *www.ainonline.com*

SNIPPETS

At a Glance

- Handheld launches the NAUTIZ X8
- Septentrio consolidates sales for Americas in Altus Subsidiary
- NovAtel Inc.'s Calgary facility has been awarded the prestigious 2014 Manufacturing Excellence Award from the Association for Manufacturing Excellence (AME), Canada
- Pratap Misra honored with ION Kepler Award
- MDA wins contract to ground station solution for DigitalGlobe satellites
- Rio Tinto introduces new 3D technology for mining operations
- Taiwan's new map of disputed South China sea nears completion
- Fugro wins offshore survey contract by Pemex
- Ethiopia to develop its Urban Land Information System
- LizardTech releases GeoGofer as powerful imagery solution
- PCI Geomatics wins Canadian Space Agency contract
- Trimble acquires Gehry Technologies
- IndoorAtlas gets US $10 mn investment from Baidu
- 2020 Company wins $97.2M Contract from NOAA
- SSTL collaborates with Kypros Satellites
- German Forest Service Uses Juniper Systems' Mesa Rugged Notepad to Manage Sustainable Forests

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80th PENTAX SURVEYING SINCE 1933 TI Asahi Co., Ltd. anniversary

PND shipments fell to 22 million units while users of navigation apps up to 180 million

According to Berg Insight report, global shipments of PNDs declined from 28 million units in 2012 to 22 million units in 2013. There are signs that the decline is slowing and some emerging markets still experience growth.

According to a another report, shipments of OEM embedded telematics systems worldwide are forecasted to grow from 8.4 million units in 2013 at a CAGR of 30.6 percent to reach 54.5 million units in 2020. *www.berginsight.com*

Samsung Offers Gear S Smart Watch with GPS + GLONASS

Samsung Electronics has unveiled its next-generation smart wearable device, the Samsung Gear S watch. The Gear S has assisted GPS+GLONASS, as well as 3G connectivity, allowing them to be active whilst always being able to access their smartphone information. It is also equipped with an accelerometer, a gyroscope, a compass, a heart rate monitor, and a barometer. The two-inch curved Super AMOLED display has an easy-to-use interface that allows users to read messages and notifications in a single glance with features such as conversation view and condensed font.

Rx Networks enables fast GNSS Positioning

Rx Networks, Inc., has licensed its GPStream PGPS GNSS assistance technology to Recon Instruments, a Canadian technology company. GPStream PGPS will tightly integrate with the GPS chip inside of Recon's upcoming Jet smart glasses, an advanced wearable computer planned for the first quarter of 2015. GPStream PGPS solution, licensed and deployed in more than 100 million smartphones and PNDs, predicts the future orbits of satellites for up to two weeks in advance. It then stands by, ready to deliver this assistance data into a GNSS chipset when it powers up. This not only speeds up initial time to first fix (TTFF) from 45 seconds down to less than 3 seconds, it also improves the receiver sensitivity and reduces power consumption.

Hertz And Navigation Solutions launch next generation Hertz NeverLost® GPS System

Hertz and Navigation Solutions has launched the next generation Hertz NeverLost® GPS navigation system across the U.S. The system now offers even more customization capabilities for travelers along with new navigation tools for ease, convenience and personalization when planning trips. It syncs directly with the recently launched Hertz NeverLost® Companion app, giving travelers access to more than 10 million U.S. destinations on their mobile devices.

Broadcom unveils low-power GNSS chip for mobiles

Broadcom has announced a low-power GNSS and sensor hub combo chip to deliver new always-on location applications for a full range of mobile devices. The Broadcom BCM4773 minimises battery drain and adds a new layer of intelligence to location technology on mobile devices by integrating the GNSS chip and sensor hub into a single combo chip. Its architecture enables information from Wi-Fi, Bluetooth Smart, GPS and micro electro-mechanical systems (MEMS) to be calculated on a single system-on-chip (SoC) instead of the application processor (AP). *www.telecompaper.com*

Beeline, Fort Telecom test M2M terminals for Glonass

Russian mobile operator Vimpelcom, working under the Beeline brand, and Fort Telecom, has carried out testing of the M2M terminals for the federal Era-Glonass navigation project. The terminals, with Sim-chips, have been tested for resistence to extreme temperatures and mechanical damage. *www.telecompaper.com*

IRNSS Interface Control Document released by ISRO

The Indian Space Research Organization (ISRO) has released the Signal-in-Space Interface Control Document (ICD) for Standard Positioning Service (SPS) for the Indian Regional Navigation Satellite System (IRNSS). Currently under development, the IRNSS constellation will serve as India's domestic Global Navigation Satellite System (GNSS). The first two of seven satellites, IRNSS 1A and IRNSS 1B were launched in 2013 and 2014 respectively.

The Signal-in-Space ICD for SPS provides information for research and development purposes to facilitate commercial applications for the satellites.

IRNSS is designed to provide a Standard Positioning Service (SPS) and a Restricted Service (RS). Once completed, it is expected to provide position data with accuracy of better than 20 meters in India — the primary service area. The constellation will also cover 1,500 km outside the country for extended regional coverage.

UN recognition for disaster resilience apps

Software developers from around the world were recognized at the UN Climate Summit for their ingenuity in devising life-saving apps for use in reducing the impact of extreme weather events on cities and coastal communities. Entries to the Esri Global Disaster Resilience App Challenge included apps which allow communities to measure the impact of permafrost melt and storm water on vital infrastructure, to access sea-level rise and landslide forecasts, and an app which allows disaster-affected citizens to check out evacuation routes, shelter locations, and much more.

Rio Tinto accelerates productivity drive with 3d mapping technology

Rio Tinto is set to capture a crucial advantage in the recovery of mineral deposits, with the launch of its three-dimensional mapping technology to reduce costs and improve the efficiency of mining operations. The RTVis™ 3D software provides pinpoint accurate mapping which improves efficiency of mining activity by ensuring it is tightly focused on removing high value ore, significantly reducing both waste and operational costs. *www.riotinto.com*

Program for printing 3D maps for the blind

Japan's cartographic authorities said software will be developed that will allow users to download data from the Internet and, using a 3D printer, produce low-cost tactile maps for the visually impaired of different parts of the country.

The software will ensure that highways, walkways and railway lines can be differentiated in the final product. The program's data will allow users to print streets that are raised one millimeter off the surface and can be easily detected with the fingers. Plans are in the works to introduce topographical features, such as uneven surfaces and hills, so these maps can be used in courses for the blind focused on earthquake- or tsunami-related evacuations and other emergencies. *www.globalpost.com*

The Great Wall of China in 3D

The project of modeling the Great Wall of China in 3D was officially launched on September 16, 2014. It will be supervised by China's Ministry of Culture and State Administration of Cultural Heritage and funded by China Great Wall Society and UNESCO. Three years will be dedicated to create the whole 6,000km length of the Great Wall of China and its surroundings in 3D, in high resolution. *www.acute3d.com*

SuperPad assists Public Works Planning in Liberia

Supergeo Technologies has announced that SuperPad assists Ministry of Public Works in Monrovia, Liberia in geospatial data collecting and updating to improve rural regional living conditions. SuperPad 3.1a is the professional mobile GIS and data collection application, specially designed for Windows Mobile devices. It can help field surveyors to easily capture, display, edit, and manage field data. With SuperPad 3.1a, damaged and old data can be accurately updated for officers to make proper policy in time. *www.supergeotek.com*

Odisha, India for common pool of Geo-spatial Info

The Odisha Government has decided to chalk out a Data Sharing Policy to bring all geo-spatial information generated by Odisha Space Application Centre (ORSAC), administrative departments and State-run agencies to a common pool. ORSAC along with a group comprising representatives of Revenue and Disaster Management, IT Departments and National Spatial Data Infrastructure (NSDI) will develop the policy which will include protocols on sourcing, sharing, pricing, uploading and alteration of the spatial data. The State SDI will also be linked to NSDI for flow of information. *www.newindianexpress.com*

Nigeria okays N485 Trillion Infrastructure Master Plan

A thirty-year National Integrated Infrastructure Master Plan (NIIMP) that would cost N485 trillion was ratified by the Federal Government of Nigeria.The approved document which is to serve as a blueprint for accelerated integrated infrastructure development in the country from 2014 to 2043 was endorsed at the Federal Executive Council (FEC). The plan which would cover a period of 30 years is expected to take $3.05 trillion (N485 trillion) to execute. *http://allafrica.com/*

Thailand land survey to be ten times faster

Officials from Thailand's Treasury Department can soon update information on the use of state land more accurately and efficiently on the field with a new GIS. The department is currently testing the system using 1000 mobile devices. Field officers surveying state land can access the department's database and update information in real-time. Besides enabling officers to take photos of the land, the devices accurately track locations using GPS. The department expects the system to speed up land survey projects by 10 times.

Indonesia launches open data portal

The Indonesian government has officially launched its open data portal starting off with 700 datasets from 24 agencies.

The portal data.id aims to promote a more credible government, better public services and encourage innovation in the society. The portal also features visualisations which citizens and government agencies have made using the open datasets, so that users without data skills can benefit from the portal as well. Another section on the website has applications which the government and citizens have developed using open data. The portal is currently in beta and will later become data.go.id.

Russian Transport Ministry authorized to create ERA-GLONASS system

The Russian Transport Ministry has been made the authorized federal body of executive authority for the creation, organization and ensuring functioning of the ERA-GLONASS automated information system. The large-scale ERA-GLONASS project was launched in Russia in 2011. This road accident urgent response system that uses Russia's GLONASS envisages the introduction of the single 112 emergency phone number in the country. The project is implemented in conjunction with the Social GLONASS program that will help aged people and persons with impaired vision to find the needed route, and parents to be always in the now where their children are. *http://en.itar-tass.com/*

GPS pressure leads Ordnance Survey to ponder map co-ordinates change

Britain's national mapping agency is considering abandoning a system of co-ordinates on its maps first devised more than 180 years ago.

Ordnance Survey is seeking views on changing its latitude and longitude markers to a system used by most GPS devices.

The organisation stressed it is not changing its national grid references, which are used by most outdoor enthusiasts, but may change the lat and long datum to the WGS84 model, in recognition that most users now refer to that, rather than its present Airy 1830, which was devised by Britain's Astronomer Royal in the 19th century. *www.grough.co.uk/*

History created by ISRO! Mars Orbiter Spacecraft Successfully Inserted into Mars Orbit

Mars Orbiter Spacecraft captures its first image of Mars. Taken from a height of 7300 km; with 376 m spatial resolution.

India's Mars Orbiter Spacecraft successfully entered into an orbit around planet Mars on September 24, 2014 by firing its 440 Newton Liquid Apogee Motor (LAM) along with eight smaller liquid engines.

The events related to Mars Orbit Insertion progressed satisfactorily and the spacecraft performance was normal. The Spacecraft is now circling Mars in an orbit whose nearest point to Mars (periapsis) is at 421.7 km and farthest point (apoapsis) at 76,993.6 km. The inclination of orbit with respect to the equatorial plane of Mars is 150 degree, as intended. In this orbit, the spacecraft takes 72 hours 51 minutes 51 seconds to go round the Mars once.

Mars Orbiter Spacecraft was launched on-board India's workhorse launch vehicle PSLV on November 05, 2013 into a parking orbit around the Earth. On December 01, 2013, following Trans Mars Injection (TMI) manoeuvre, the spacecraft escaped from orbiting the earth and followed a path that would allow it to encounter Mars on September 24, 2014.

With the successful Mars Orbit Insertion operation, ISRO has become the fourth space agency to successfully send a spacecraft to Mars orbit. In the coming weeks, the spacecraft will be thoroughly tested in the Mars orbit and the systematic observation of that planet using its five scientific instruments would begin.

India to develop remote sensing satellites with China

India will, for the first time, join hands with China to develop remote sensing satellites. Right from the initial days of its space programme in the 1960s, India had collaborated with the US, USSR (now Russia) and some European countries, but ISRO never had a tie-up with China. Chairman ISRO, Dr. Radhakrishnan said space scientists of the two countries would work together to prepare a roadmap for a series of missions to be implemented together. "A joint team will begin work in the coming weeks and the road map will be ready by April 2015."

The agreement aims at encouraging cooperation for "peaceful purposes", and a lot of emphasis will be on research and development, including in communication satellites. "We look forward to it as both the countries are crucial in creating a strong space presence in Asia. There were some steps in 1991, but nothing much happened. This is a concrete step forward," Radhakrishnan said *http://timesofindia.indiatimes.com*

Sirius Pro for use with RTK base stations or NTRIP

MAVinci GmbH and Topcon Positioning Group have announced the latest version of the Sirius Pro surveying UAS (Unmanned Aerial System) is designed to be compatible with existing RTK (Real Time Kinematic) base stations or NTRIP (network transport of RTCM data over IP). *www.mavinci.de*

Roscosmos active in lifting embargo on sub-metre imagery

Russian's space agency Roscosmos is actively pursuing a new drive to lift embargo on sub-metre resolution imagery. The defence ministry has strongly advocated resolution restrictions should be monitored by lighter rules. It is also mulling the use of satellite imagery from commercial and satellites and those in overseas. Similarly the Ministry of Economic development is also implementing some measures to encourage lifting of ban on sub-metre imagery. *Roscosmos*

Satellite imagery to curb illegal mining in UP, India

The Uttar Pradesh, India geology and mining department has mooted the idea of using satellite mapping and remote sensing techniques to tackle the menace of illegal mining in the state. The department has sought approval to use the GIS technique in Mirzapur district as a pilot project to judge the efficacy of the remote sensing technology to curb illegal mining. *www.business-standard.com*

Boeing to Assist Sky-Watch on Danish UAV Development Project

Boeing and Danish company Sky-Watch have signed an agreement that will enable Boeing to explore assisting the company in its development of a new type of unmanned aerial vehicle (UAV) under a project supported by the Danish National Advanced Technology Foundation. The goal of the "Smart UAV" project is to develop a new generation of vertical take-off and landing (VTOL) UAVs that will combine the advantages of existing rotorcraft UAVs with those of fixed-wing aircraft for longer range and endurance. *www.boeing.com*

Drone wireless Internet in New New Mexico by Google

Google is planning to test Internet delivery by drone high above New Mexico in the US. The company asked the FCC for permission to use two blocks of frequencies for the tests, which are scheduled to last about six months and begin in October. They will be conducted above an area of more than 1,400 square kilometers. Google said its application for temporary permission to make the transmissions was needed "for demonstration and testing of [REDACTED] in a carefully controlled environment." The FCC allows companies to redact certain portions of their applications when they might provide too much information to competitors. *www.orbitalcorp.com.au*

Exelis successfully tests GPS threat detection product

Signal Sentry™ 1000, an Exelis product that detects and locates GPS interference sources, was deployed and tested during GPS jamming trials that occurred at UK in Aug'14. It was able to detect and geolocate stationary and moving jammers in both open and obstructed environments. The trials were managed and administered in the U.K. by the Defence Science and Technology Laboratory. Off-the-shelf jamming devices, available to purchase via the Internet, were used during the tests. Signal Sentry 1000 successfully detected and located all GPS jamming during the trials. Exelis developed Signal Sentry 1000 with Chronos Technology Ltd., U.K.-based company.

Trimble New InSphere Data Marketplace

Trimbles new Data Marketplace service is for the Trimble® InSphere™ geospatial information management platform. It allows geospatial professionals to quickly search, locate and obtain spatial data on demand. InSphere users can now find and use additional free and premium spatial data layers, including aerial and satellite imagery, terrain, elevation and topographic maps, building footprints and other third-party data. In addition, new capabilities have been added to a variety of InSphere applications to streamline geospatial data access. *www.trimble.com*

Down Under and on Top with the New Spectra SP80

The benefits of the Spectra Precision SP80 GNSS receiver with its multi-constellation capabilities has improved the work efficiency of Philip Clark Land Survey Services and is helping the firm grow. According to the firm's owner, Philip Clark, "The SP80 is enabling us to acquire fixed solutions faster that previous dual constellation receivers and to maintain the fixes for far longer even in and around buildings and heavily vegetated areas. We are now expanding the business, thanks in part to purchasing this most up-to-date equipment."

For more than three months, Clark has been using a Nikon Nivo 2.C total station with Survey Pro software combined with the new Spectra Precision SP80 receiver with integrated UHF radio and T41 data collector running Survey Pro on a network configuration. *www.spectraprecision.com*

Dual-Frequency Pinwheel Antenna for Optimal Positioning

NovAtel, Inc. has introduced the GPS-702-GG-HV to its line of high-performance Pinwheel antennas. Tracking L1/L2 GPS and L1/L2 GLONASS frequencies, customers can use the same antenna for GPS-only or dual constellation applications, reducing equipment costs and need for future redesign. With the same form-factor and choke ring performance as the company's other pinwheel antennas, the GPS-702-GG-HV has been enhanced even further to provide the robustness needed for use under high-vibration conditions. The phase center of the antenna remains constant as the azimuth and elevation angle of the satellites change. Signal reception is unaffected by the rotation of the antenna or satellite elevation, so placement and installation of the antenna can be completed with ease. *www.novatel.com*

Loctronix advances GNSS Integrity Monitoring

Loctronix® Corporation has unveiled the HGX Interference Detection System for identifying and monitoring intentional and unintentional interference sources. The IDS can detect sources of interference ranging between 5 dB and 60 dB GNSS Jamming to Signal (J/S) ratio. It not only detects, but can identify the type of interference given a database of known/previously recorded profiles. The IDS was developed using the Loctronix HGX hybrid sensor toolkit along with the company's ASR-2300 ASR Workbench software defined radio platform.

London's Station uses Leica GeoMoS

Crossrail, London's 15 billion pound railway line, taking shape beneath the city, is Europe's largest infrastructure project. A new station, under construction at Paddington, will be a key hub. As work progresses within a densely built area of the capital, a 24-hour monitoring system, using up to 52 Leica Geosystems robotic total stations and precise levelling, measures changes in ground movement caused by deep excavation works alongside an historic London site. Construction on the underground station continues alongside the existing Grade 1 listed terminus, whilst 18m below the site two tunnel boring machines (TBMs) are also in operation. Base readings taken prior to construction allow the surveying team from Costain Skanska to define the level of ground deformation caused by natural daily and seasonal changes and to define the tolerance level for ground movement caused by the excavation process. new scanning geometry that offers industry-leading pulse rates of up to 1.0 MHz. *www.leica-geosystems.com*

Innovative method for measuring ocean winds and waves from space

Surrey Satellite Technology Ltd (SSTL) has successfully demonstrated an innovative method of measuring winds and waves from space, using GNSS Reflectometry. The measurements were taken from the SGR-ReSI, (Space GNSS Receiver Remote Sensing Instrument) which is flying on-board TechDemoSat-1, a technology demonstration satellite which was launched in July 2014. It collects the signals from GPS and other navigation satellites after they have been reflected off the ocean surface and processes them into images called Delay Doppler Maps, from which ocean roughness and wind speed measurements at the sea surface can be interpreted. *www.sstl.co.uk*

IFEN launches SX3 software receiver

IFEN has recently introduced its new SX3 GNSS software receiver, a major upgrade of the company's SX-NSR. Redesigned hardware frontends feature four wideband RF frequency bands that can be split into a maximum of eight sub-bands per unit. At the same time the bandwidth has been expanded to a full 55 megahertz, offering additional signal power especially in the Galileo E5 band. A new USB 3.0 port of the frontend empowers a data transfer rate that makes possible a maximal bit-quantization of up to eight bits for every single stream. The additional power is compressed into a significantly smaller and lighter hardware chassis than before. Among other options, a dual antenna-input feature can be ordered as well as an OCXO-clock. (Standard equipment of the SX3 GNSS software receiver is a precise temperature-controlled oscillator.)

UnicoreComm GPS/BeiDou units

Unicore Communications, Inc. offers the UM220-INS, a BeiDou/GPS+inertial MEMS dual system inertial navigation module for in-dash automotive navigation and high-end navigation, and the UB280, a BeiDou/GPS dual-System dual-antenna high precision heading board for precise RTK position and heading.It also features a built in six-axis (gyroscope and accelerometer, each with three axes operation) microelectromechanical system (MEMS) inertial sensor and can output GNSS+MEMS inertial positions.

SBG Systems Ellipse – more accurate, more robust, more features

SBG Systems released the Ellipse Series, a brand new product range of miniature inertial systems replacing the IG-500 Series. For the same budget, customers benefits from higher accuracy, advanced filtering and features inspired from high end inertial navigation systems. It integrates a GPS + GLONASS / BEIDOU receiver. It receives DGPS corrections and can be connected to an odometer for an even more robust trajectory.

EnsoMOSAIC Cropdrone UAS for agriculture mapping

MosaicMill Ltd. has released integrated UAS for precision agriculture. The system includes a quadcopter by Videodrone, calibrated NDVI camera and EnsoMOSAIC UAV orthomosaicking software. Videodrone is fully autonomous with Google Earth based flight planning. Wind resistance is over 8 m/s and one flight covers up to 100 hectares. Thanks to advanced post processing, CIR modified Sony A6000 outputs pure NIR, RED and GREEN bands instead of filtered NIR, Green and Blue.


NEW
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Long Range, High Speed
3D Laser Scanner with
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Hall 3.1, Booth A3.014
STATIC
laser scanning
MOBILE laser mapping

SilvAssist Mobile by F4

F4 Tech has released its newest software offering, SilvAssist Mobile! This software presents a simple work flow solution for field data collection. It offers features that include but are not limited to: Automated data backup system, capturing cruiser productivity data, and it works seamlessly with SilvAssist toolbar for ArcGIS version 3.5.

Esri Brings Analytics to Urban Modeling for Smarter City Planning

Esri brings together the power of GIS analytics and the beauty of 3D urban modeling in its latest release of CityEngine. Now urban designers and architects can create 3D models with City Engine and export parts of the model into Esri ArcGIS software for spatial analysis. This provides urban planners, designers, and citizens easy to understand intelligence for improving their cities.

Bentley Advantage Seminar

The Bentley Advantage seminar, which was recently held in New Delhi, provided compelling insights on the future of Bentley Systems' innovative software and services for *sustaining infrastructure*. It featured presentations by Bentley executives on the latest technologies enabling information mobility across multiple disciplines and the infrastructure design, build, and operations lifecycle.

Jean Baptiste Monnier, Bentley's Senior VP, APAC, delivered the keynote presentation to around 250 delegates who were in attendance at this event. It highlighted topics like Bentley's BIM Advancement, Bentley CONNECT, MANAGEservices, etc. Industry-focused parallel sessions were also organized to showcase Bentley's solutions for *Transportation Infrastructure, Architecture and Engineering Consultants*, and *Geospatial, Water, and Utilities* industries, and to share global best practices from international projects which have innovatively used Bentley solutions. *www.bentley.com*

MARK YOUR CALENDAR

October 2014

35th Asian Conference on Remote Sensing
27-31 October
Nay Pyi Taw, Myanmar
www.acrs2014.com

NZIS Conference 2014
29 Oct - 1 Nov
New Plymouth, New Zealand
www.nzisconference.org.nz/

November 2014

NaviForum Shanghai 2014
3, November
Shanghai, China
www.naviforum.org.cn/en2007/index.html

Trimble Dimensions 2014
3 - 5, November
Las Vegas, USA
www.trimbledimensions.com

5th ISDE Digital Earth Summit
9 - 11 November
Nagoya, Japan,
www.isde-j.com/summit2014/

4th International FIG 3D Cadastre Workshop
9-11 November
Dubai, United Arab Emirates
www.gdmc.nl/3DCadastres/workshop2014/

ICG-9: Ninth Meeting of the International Committee on GNSS
9 – 14 November
Prague, Czech Republic
www.oosa.unvienna.org/oosa/en/SAP/gnss/icg/meetings.html

G-spatial EXPO
13-15 November
Tokyo, Japan
http://www.g-expo.jp/

11th International Symposium on Location-based Services
26 -28 November
Vienna, Austria
www.lbs2014.org/

December 2014

PTTI 2014: Precise Time and Time Interval Systems and Applications Meeting
1 – 4 December
Boston, Massachusetts, U.S.A.
www.ion.org/ptti/future-meetings.cfm

European LiDAR Mapping Forum
8-10 December
Amsterdam, The Netherlands
www.lidarmap.org/europe

Esri India User Conference
9-11, December
Delhi, India
http://www.esriindia.com/events/2014/indiauc

February 2015

The Unmanned Systems Expo
4 - 6 February
The Hague, The Netherlands
http://www.tusexpo.com

The International Navigation Conference
24-26 February
Manchester, UK
www.internationalnavigationconference.org.uk/

March 2015

Locate15
Brisbane, Australia
10 – 12 March
www.locateconference.com

Munich Satellite Navigation Summit 2015
24 – 26 March
Munich, Germany
www.munich-satellite-navigation-summit.org

May 2015

AUVSI's Unmanned Systems 2015
4-7 May
Atlanta, USA
http://www.auvsi.org/

RIEGL LIDAR 2015 User Conference
5 - 8, May
Hong Kong & Guangzhou, China

MundoGeo Connect
May 5 to 7, 2015
Sao Paulo - Brazil
http://mundogeoconnect.com/2015/en/

36th International Symposium on Remote Sensing of Environment
11-15 May
Berlin, Germany
http://www.isrse36.org

FIG Working Week and General Assembly
Sofia, Bulgaria
17 – 21 May
www.fig.net

GEO Business 2015
27 - 28 May
London, UK
http://geobusinessshow.com/

June 2015

TransNav 2015
17 - 19 June
Gdynia, Poland
http://transnav2015.am.gdynia.pl

July 2015

13th South East Asian Survey Congress
28 – 31 July, Singapore
www.seasc2015.org.sg

October 2015

2015 IAIN World Congress
20 – 23 October
Prague, Czech Republic
www.iain2015.org