

Strategic Spatial Data Management in the Kingdom of Bahrain

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Keywords

Bahrain, spatial data management, capacity building

Abstract

The Survey and Land Registration Bureau is the government organisation charged with management of key strategic spatial data sets covering cadastral, topographic and hydrographic data. These data sets are primary data for the development of the Kingdom.

The Bureau is continuing with the implementation of many initiatives to deliver improved service to customers in government, private companies and individual citizens. Several factors influence the implementation strategies including the ongoing rapid development of the Kingdom and its consequent increase in the demand for appropriate infrastructure. Fundamental to the development of infrastructure are survey control, topographic mapping and secure land ownership. As the National Mapping Organisation of Bahrain, the Survey and Land Registration Bureau is responsible for these activities.

This paper describes a cross section of the projects being undertaken to highlight the important response made by the Bureau to assist the development of the Kingdom.

1. Introduction

The Kingdom of Bahrain is an archipelago in the Arabian Gulf between the east coast of Saudi Arabia and the Qatar peninsula. The main island is a pear-shaped land mass approximately 48 km. long and 16 km. wide [1]. The total land area of the country is approximately 740km².

With a GDP growth of 5.9% Bahrain has the fastest growing economy in the Arab world [1], manifest in the extensive development projects underway and planned in the country. Some of the significant projects commenced or planned are the new Northern Town, Bahrain Bay and the causeway to Qatar. Land is one of the critical factors in such major developments and the Survey and Land Registration Bureau (SLRB) has a significant role to provide spatial information including hydrographic and topographic data to aid planning, survey control for construction, cadastral survey to finalise new title deeds and mapping to incorporate the newly completed work into current topographic maps.

This development requires appropriate spatial data infrastructure and services. Many projects are planned or underway that will develop the Bureau into a truly world-class organisation providing the spatial information necessary for the development of Bahrain.

2. Projects

These projects are essentially a capacity building program for the Bureau. Each project is a combination of societal, organisational and educational aspects [2] as seen in the following brief outline of several key projects.

2.1 Spatial Information Infrastructure Overhaul

The Bureau recognises that accessible high quality spatial information must be available to users. Several projects are underway to progress this concept including cleaning of CAD data and conversion to a GIS. To facilitate the management and distribution of data an enterprise geo-spatial database is to be developed and implemented. Ideally this will include all of the cadastral, topographic and hydrographic spatial data with comprehensive metadata.

The concept of multiple usage of data, interoperability and land information interchange has been discussed in concept [3], with some limited evidence of very successful comprehensive implementation such as the New Zealand LandOnline system [4] and the Nordic countries (for example Sweden [5]). The challenge for the Bureau and its partners will be to implement similar ideas.

2.2 Organisation Overhaul

The Survey Division was previously part of the Ministry of Works and Housing. The formation of SLRB by moving the survey function from MoWH and the registration function from the Ministry of Justice has greatly improved the effectiveness of the business activities. Direct accountability to senior management has seen a significant increase in responsiveness to improvement projects.

A new organisation chart is nearing completion enabling optimum alignment of staff resources to required business outcomes. The close alignment of the organisation structure

to required business processes and outcomes is much better than the previous arrangement which was heavily based on activities and discipline specialisation.

2.3 Spatial Information Profession Development

Tasks that could reasonably be undertaken by the private sector will eventually be discontinued by the Bureau. In order to achieve this aim the professionalism of the private sector requires improvement. This is not a criticism of the private sector as the companies have resources available for the current demands and expectations. The improvement is required because the aim is to greatly expand the contribution and responsibility of the private sector.

The key aspects in this process are;

- Private sector involvement. Cadastral surveying in the Kingdom is largely carried out by the Bureau or by private survey firms under contract to the Bureau. The aim is for the cadastral surveying profession to develop and enable the market to control transactions between end users and service providers within the framework provided by the Bureau.
- Surveyor secondment. In order to build the surveying profession in Bahrain experienced surveyors are required that understand the cadastral survey processes and requirements. The Bureau is seconding a large number of expatriate surveyors to supplement existing staff resources. The initial task is to reduce a large ongoing backlog of work; however these surveyors would then be available for transfer to private sector firms as the transition process continues.
- Development of the spatial profession. An institute of spatial practitioners is to be established to oversee the professional and ethical standards of the industry in conjunction with a board of surveyors which would determine and control competency standards for practice of surveying [6].
- Survey law to regulate activity. This is to define what the government, as the custodian of title deeds and fundamental spatial data, requires in order to continue to guarantee security of title and maintain quality datasets.

Clearly this development of the spatial information profession concentrates on survey activity. In partnership with other organisations and individuals it will be possible to then develop the wider spatial industry.

2.4 Service Delivery Enhancement

In addition to the regulatory role of maintenance of the cadastre, the Bureau is also responsible for actual cadastral field survey. This places a large burden on the Bureau which is ultimately planned for the private sector to adopt.

The timeframe for completion of survey tasks is currently limited by two main obstacles; insufficient field staff and slow access to cadastral records for searching and finalisation. To improve the service delivery times the Bureau is;

- Converting all historical cadastral paper records to digital image files to enable rapid searching and checking of information. The current manual recovery of paper files from archive storage is slow and tedious.

- Expanding the field surveyor resources, as described above, to provide nearly double the current capacity.

The Bureau is conscious of its obligation to all customers. However, particular large companies have a strong financial interest in purchasing an annual licence to access the cadastral and topographic mapping and imagery. As part of these licence agreements the Bureau has committed to maintaining the currency of data and to enhance any areas shown to be unsuitable.

The e-government initiatives of the Bahrain government will have a significant impact on the way in which business is conducted. For the Bureau initial projects under consideration are online access to mapping data and on-demand hydrographic chart printing.

2.5 Data

All topographic base data is currently held in CAD files. This is the legacy of a very specific output oriented approach; the delivery of hardcopy 1:1,000 map data. The extent of digital technology implementation was limited to easing of data editing and update to create hardcopy plots.

Current expectations of data users are much more sophisticated. In short, customers require clean, up-to-date, intelligent data. The CAD format of data storage and management does not provide all of the capability required. However, with over 1500 mapsheets of 1:1,000 scale the conversion to a geo-spatial database is not such a small task. A pilot project has shown that extensive cleaning is required. Inconsistencies in the data structure are not apparent when plotting but when used to form closed shapes and undertake even basic analysis require correction. A sample of the proposed new data structure is shown in Figure 1b while the current format is shown in Figure 1a.



Figure 1a: Topographic data prior to cleaning and re-structure



Figure 1b: Topographic data after cleaning and re-structure

At present no metadata is retained; the plan is to include extensive metadata especially regarding date, method of capture and accuracy so that users can determine the best use of the data for their purposes.

The completion of the pilot project provides the foundation to continue with the cleaning of the remaining data of the whole country. It is planned that this data remain in CAD format until the completion of the spatial information infrastructure project described above. At that stage the data could easily and quickly be converted to a spatial database, accessible by all authorised users and able to be integrated with data from other sources to provide detailed spatial analysis functionality.

All data is currently only retained in 2D, although each data collection technique enables accurate 3D data to be collected. The present process however, discards the third dimension prior to finalisation.

The inherent three dimensional nature of the data collection will enable the development of a very detailed urban model including rendering with photography if desired. The photogrammetric capability can easily provide the detail of the top of the building to produce a more detailed, realistic model [7,8] than other simplistic or improvised approaches that show a fearful avoidance of photogrammetric techniques [9]. In addition, the resolution of the imagery (100mm GSD pixel) is far higher resolution than satellite imagery.

Data currency is arguably the most pressing issue. The ongoing boom in real estate development and construction consequently creates a requirement for map update. The current target for all topographic data is two years but this is not being achieved by field survey; a different approach is required. The new approach is threefold; more efficient field survey through use of the GPS network described below, greater utilisation of aerial photography and removal of duplication of survey work by increased use of the private sector to supply 'as-built' data especially for major private developments and government projects.

Hydrographic surveying activities have previously concentrated on the primary role of providing charts for safety of navigation. With the ongoing dredging and reclamation projects and environmental investigations, further demands are placed on the existence and access to hydrographic data.

A tide gauge network is to be established which will enable more detailed study of the tidal regime around the coast of Bahrain. It is known that the shoals and shallow water areas interact to form a complex movement of ocean waters and this project will enable this dynamic activity to be quantified. The permanent tide gauges will support more accurate and efficient survey activities due to the proximity of a tide gauge to any site.

2.6 Education

The growing demand for survey services requires education and training of Bahraini staff to at least partially meet the work demands. The need to develop new staff is also necessary to provide for replacement of retiring staff whilst retaining and developing corporate knowledge. Some expatriate staff and consultants will be required to provide technical advice and additional staff resources.

The Bureau is currently sponsoring a large group of students in overseas academic education. Courses at Diploma and Bachelor level are being undertaken in Jordan and the UK. It is planned that further staff will undertake overseas study at various institutions, thus ensuring exposure of staff to a variety of courses and teaching expertise.

As the industry develops the expectation is that Continuing Professional Development (CPD) activities will be possible.

2.7 Partnerships

The Bureau is aiming to provide a world class service. To achieve this aim strategic partnerships are being developed with various parties including several government bodies, other National Mapping Organisations and internationally experienced companies. For example, the Bureau is working very closely with the Central Planning Unit of the Ministry of Works on the development and implementation of the infrastructure overhaul. The integration of the spatial data from both organisations will be optimum only if the highest possible co-operation is achieved.

Despite worldwide evidence that reported co-operation between government agencies is rare [10], the Bureau is involved in several sharing arrangements. An initial joint purchase of high resolution satellite imagery has been completed by four government bodies which have a close, cooperative relationship. The vision for this arrangement is that further organisations would contribute enabling such imagery to be scheduled on an annual basis. The Bureau is investigating the feasibility of substituting high resolution aerial photography in place of satellite imagery.

Several cartographic mapping products have been developed with the assistance of experts from the private sector. Additional partnerships are envisaged as the private sector is further engaged and tasked with the execution of work until date completed by the Bureau.

2.8 Permanent GPS Network

The Bureau has established permanent GPS base stations which are used to determine network RTK corrections [11]. The Bureau topographic survey activities rely heavily on GPS data collection. Previous work with mobile base stations required significant time to establish and remove the base stations.

A detailed description of the network configuration [12] and the advantages [11] of the facility has largely been addressed elsewhere. Details of the theory and operation are available elsewhere in the literature [13,14,15,16,17].

The Bahrain network comprises of four main stations and a control centre as shown in Figure 2. The maximum distance between permanent stations is approximately 70km with typical base-rover baseline lengths ranging up to about 20km. A fifth station located at the control centre is an operating spare.

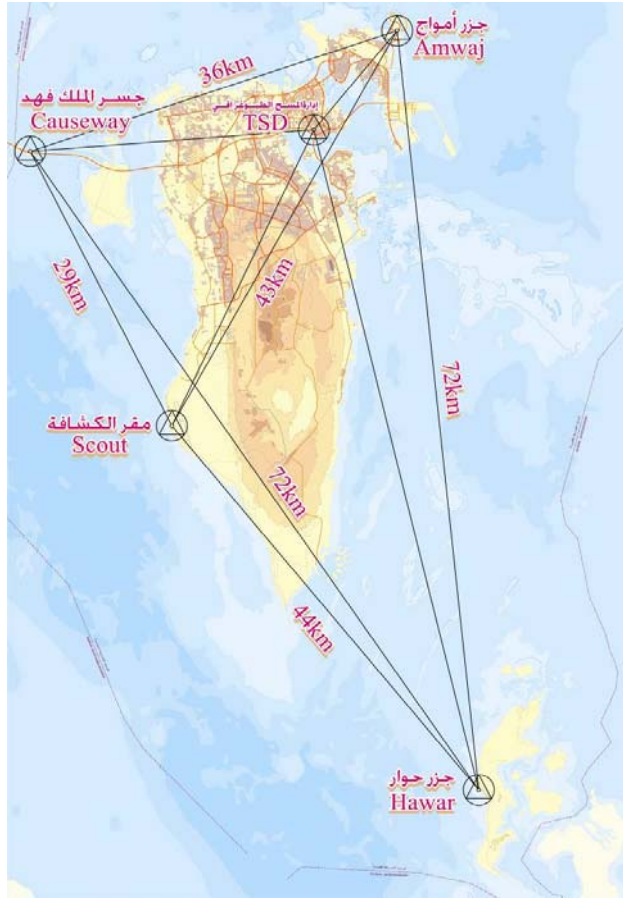


Figure 2: Bahrain PRN Station Locations

Several issues can be discussed regarding the network;

Nationwide coverage. The network provides continuous, secure and accurate RTK corrections over the whole land area of the country. The network processing methodology provides consistent corrections without the distance dependent errors increasing the further the rover is operating from the base. Using the advantage of the area based nature of the calculation means that at least 98% of locations are within 5km of the limits defined by the station baselines. The network is easily scalable to cover future land expansions.

Communications. The RTK corrections are distributed to authorised users using GPRS technology. Rover units from various manufacturers operate with the facility, including new and older equipment converted from radio based units.

Mobile phone communication is used because two-way communication provides access control, extended range, server base processing (including sophisticated transformation and distortion modelling) and avoids radio license issues.

User Acceptance

The system has been operating for nearly 12 months. Based on encouraging support shown by the private sector, the Bureau is working closely with one private firm to evaluate the practicality of a mutual exchange arrangement; the Bureau is provided as-built data in exchange for access to the RTK corrections.

Key reasons for the high degree of acceptance are the improved logistics of field survey activities and resources, and the consistent accuracy of measurement throughout the country.

Existing Control

The higher accuracy and greater consistency across the country achievable from the network is an issue for cadastral surveys due to incompatibility with local distortions in the control network.

Twenty-five points have initially been occupied to determine a seven parameter transformation to relate ITRF coordinates (of the permanent stations) to the local control

system. This transformation is acceptable for topographic survey but not for cadastral work. A larger set of approximately 800 points on a nominal 500m interval has been measured by static survey from which an interpolation model will be created. This model is expected to also account for geoid-spheroid separations. At the time of writing, results have not been finalised.

2.9 Photogrammetry and Aerial Photography

The Bureau commissions large scale aerial photography which until recently had been acquired as much as for pictorial reference than as part of any concerted programme of mapping update using photogrammetric techniques. Previously the photogrammetry equipment consisted of a single converted analogue instrument which was cumbersome to use and largely ineffective for high volume map updating. This equipment has been replaced with three latest technology digital photogrammetry workstations enabling much higher productivity through direct data capture and update to mapping files. With the tripling of equipment and the greater efficiency of the digital approach the estimated productivity is in the order of 10 times or more!!

The target is to have all mapping data current to within two years; this is not presently the case. As described, photogrammetry offers very high productivity and is not impacted by the field survey issues of logistics and unfavourable weather. As seen in Figure 3 the Bureau has an archive of photography dating back to 1947. In the first part of the archive, photography projects were undertaken at very frequent intervals. The second part of the archive has more photography but at much greater intervals.

Aerial Photography Projects

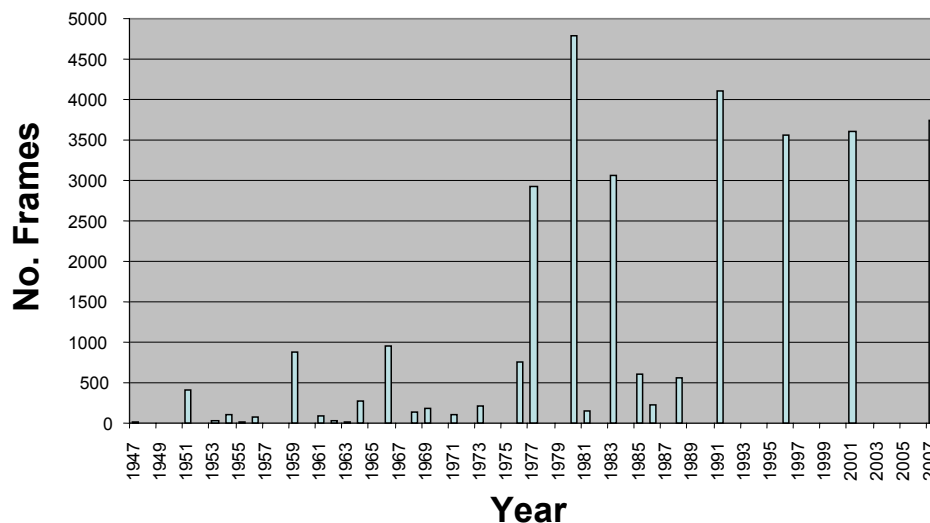


Figure 3: Aerial photography archive

Clearly the effectiveness of this approach is inadequate as there is very little contribution that photogrammetry can make with outdated imagery. The existing five-yearly programme for aerial photography is therefore no longer feasible. The plan is to acquire imagery much more frequently; as frequently as each year. With suitable service providers available within the region the financial cost difference of annual incremental photography compared to complete five-yearly coverage is very little.

There is some restriction on complete photographic coverage due to perceived national security issues which are strictly imposed as no-fly zones by the Bahrain Defence Force. However, most of the development is in the north of the country which can be covered by suitable aerial photography. Besides stereoscopic data capture the images are also compiled into a seamless mosaic. In the most recent (June 2007) project special photography using a 305mm lens has also been acquired over areas of high-rise development in order to minimise occlusion due to the effect of ‘terrain relief’ in the perspective imagery. A sample of this imagery (showing part of the photograph only) is shown in Figure 4a of the Bahrain Financial Harbour precinct. The standard 152mm lens photography of the same area is shown in the sample in Figure 4b. The buildings are 53 stories high [18] and yet the structure causes only minor obscuring of the ground detail. Note that the centre of the photograph is in a very similar location with the towers actually imaged closer to the photograph centre in Figure 4b (but obscuring more ground detail).

The imagery will also be utilised within ESRI Imageserver [19] (formerly MAPS Promptsever). This enables direct, rapid reference to the mapping data and also has a very useful feature enabling the various images to be shown of any particular object of interest. This has been found to be more useful than the simple orthophoto mosaic since the perspective geometry of the photography is exploited whilst still retaining the maximum benefits of the orthophoto process.



Figure 4a: Bahrain Financial Harbour captured using 305mm lens



Figure 4b: Bahrain Financial Harbour captured using 152mm lens

2.10 Pictometry

A further development in aerial photography technology has been the geo-referenced oblique imagery provide by companies such as Pictometry. The advantages of this imagery are the more oblique angle of view which enables full viewing of buildings. Thus these oblique images are very good for visual inspection but full three dimensional data capture is still to be implemented with this technology. It is foreseeable that the integration of such oblique imagery with detailed laser scanning could substitute the need for stereoscopic data collection. However, based on current capability these images are considered complimentary to the conventional vertical aerial photography [20].

Such imagery over Bahrain is to be acquired as part of a combined arrangement with other Ministries subject to a suitable licensing arrangement being finalised with the supplier.

3. Conclusion

Many exciting projects are being implemented by the Bureau to position it as a world class National Mapping Organisation. The involvement of all stakeholders is essential for the success of these projects, which will ultimately enable the Bureau to transfer key responsibilities to the private sector and provide the spatial information foundation necessary for the growing prosperity of the Kingdom.

Acknowledgements

The authors gratefully acknowledge the kind support of;

- H.E. Shaikh Salman bin Abdulla Al Khalifa, Head of Survey and Land Registration Bureau, Kingdom of Bahrain

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