

Geodetic Contributions to Iwrm-Projects in Middle Java, Indonesia

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Key words: Water resources management, GIS, engineering surveying, cave surveying.

SUMMARY

The district of Gunung Kidul in middle Java is one of the poorest regions in Indonesia. The essential reason is the acute water scarcity in this karst region during the months of the dry season. As a consequence to the poor living conditions many people have migrated away and therefore the development of the region is stagnating. During the last years two projects have been initiated under the theme “Integrated Water Resources Management” in order to improve the water supply situation, both funded by the German Federal Ministry of Education and Research and realized essentially by institutes of the University of Karlsruhe. Geodetic subprojects are integrated in both joint projects. Special surveying works had and have still to be carried out to realize the geometrical basis for several other subprojects. The particular contributions are 3d cave measurements for visualisation and planning, staking out of drilling points and construction axes, the definition of a common reference system, the surveying of the water distribution network and its technical facilities, the setting up and the management of a geographical information system (GIS) as well as different special measurements such as dam monitoring or controlling of a vertical drilling machine. The paper reviews the joint projects and informs in detail about the geodetic activities.

SUMMARY

Der District Gunung Kidul in Mitteljava ist eine der ärmsten Gegenden Indonesiens. Der entscheidende Grund hierfür ist die akute Wasserknappheit während der Trockenzeit. Als Konsequenz der geringen Lebensqualität wandern viele Menschen ab, was zur Stagnation der regionalen Entwicklung führt. Während der letzten Jahre wurden unter dem Thema „Integriertes Wasserressourcen Management“ zwei Projekte initiiert mit dem Ziel der Verbesserung der Wasserversorgung, beide vom Deutschen Bundesministerium für Bildung und Forschung (BMBF) finanziert und im Wesentlichen von Instituten der Universität Karlsruhe umgesetzt. In beide Verbundprojekte sind geodätische Teilprojekte integriert. Spezielle Vermessungsarbeiten wurden und werden noch ausgeführt, um geometrische Grundlagen für verschiedene andere Teilprojekte zu schaffen. Dazu zählen 3D-Höhlenvermessungen zum Zweck der Visualisierung und Planung, Bohrstellen und Bauachsabsteckungen, die Festlegung eines einheitlichen Referenzsystems, die Einmessung des Wasserverteilungsnetzes und technischer Einrichtungen, der Aufbau und die Verwaltung eines Geoinformationssystems (GIS) sowie Spezialvermessungen wie Staumauerüberwachung und Steuerung einer Vertikalbohrmaschine. Das Paper vermittelt einen Überblick über die beiden Verbundprojekte und informiert im Detail über die geodätischen Aktivitäten.

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1. INTRODUCTION

The region ‚Gunung Sewu’ (thousand hills) in the district ‚Gunung Kidul’ of the Yogyakarta Special Province along the southern coast of middle Java is a 1400 km² large karst area, internally composed of hundreds of networked caves. This cave network forms a large underground river system, in which the rainwater is seeping away fast and ending up nearly unused as natural springs at the coastline. The acute water scarcity during the months of the dry season, especially the low drinking water supply, is the essential reason that Gunung Sewu is one of the poorest regions in Java and the whole of Indonesia. As a consequence of the bad living conditions many intellectual people of the population have migrated away and therefore the development of the region is stagnating. In some of the caves the water is dammed up and used by diesel pumping systems, but this cannot meet the growing water demand for private households, trade and agriculture. In addition, such systems are not sustainable from the economical and the ecological perspective. At the turn of the century it was recognized that the development of a sustainable water management system was the need of the hour. As a consequence the German Federal Ministry of Education and Research (BMBF) funded first a feasibility study for the possibilities of an underground water management, carried out by the Institute of Water Resources Management, Hydraulic and Rural Engineering (IWK), University of Karlsruhe (Nestmann et al., 2009). This feasibility study was followed by two other joint projects between institutes of the University of Karlsruhe, the Research Center Karlsruhe (both today merged into the Karlsruhe Institute of Technology (KIT)) and the University of Giessen. In the following the objectives of the joint projects are presented and the geodetic contributions, realized by subprojects of the Geodetic Institute of the KIT (GIK).

2. PROJECT GUA BRIBIN

The BMBF joint project ‚Water Resources Management of an Underground River in a Karst Area, Yogyakarta Special Area, Indonesia’, funded in the years 2003 to 2006, shall realize an underground water reservoir with a volume of about 400.000 m³ in the cave ‚Gua Brabin’. There is a water pipe system in the region existing for the supply of 75.000 people. The discharge in the underground river is sufficient with a minimum available flow of 1.000 l/s during the dry season. 70 l/s could be continuously pumped into a new reservoir, what would be sufficient to supply the publication with 80 l/day of drinking water instead of only 10 l/day in the dry season now. The basic idea is a partial damming of the water flow system by a reinforced concrete dam with an integrated micro hydroelectric power plant and a water-power driven pumping system (pump as turbine plus a water pump at the same shaft), see fig. 1. So regenerative energies and appropriate technologies for operation and maintenance are to the fore.

2.1 Three-dimensional cave surveying

A precise surveying of the cave, beginning at the entrance, along the underground river until the construction site of the weir, was the basis for all the planning tasks and the construction works. The frame for all the secondary measurements was a polygon consisting of 65 points with an underground and an above ground branch, each 1,5 km long. The polygon was



Fig. 1: Schematic section through cave and barrage

measured twice with a Leica TCR1102 – accuracies of 0,5 mgon for the directions and 2 mm for the distances. The weak point of the polygon was a shortest distance of 4 m only near the cave entrance. The high humidity of nearly 100% made the measurements and the handling of the instruments very difficult, especially in the lake regions of the cave, where consoles had been installed at the rock faces (see fig. 2). Nevertheless a sufficient accuracy could be reached, as can be seen from fig. 3: mean point error of 3 cm, a better accuracy above than underground, a relative error ellipse of 20cm/4cm for the drilling shaft in the construction area (yellow ellipse).



Fig.2: Polygon measurement using consoles in a lake area

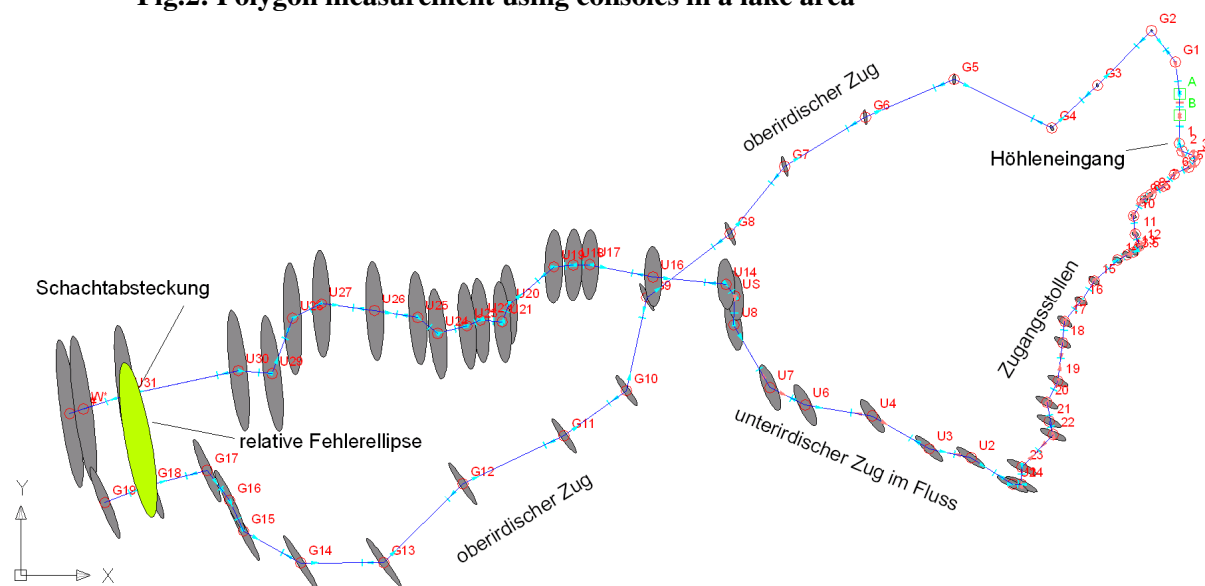


Fig. 3: Polygon Gua Bribin

The polygon design in preparation of the measurements and the adjustment afterwards has been carried out with the software package NetzCG, which has been developed at GIK (Derenbach et al., 2007). From the around 6.000 single points, which have been measured with the TCR1102 in the cave, a cave model was derived with the software Civil 3-D from Autodesk, used for visualisation purposes and volume computation. A lot of details concerning the cave measurements can be taken from Kupferer et al. (2006), Benner et al. (2009a, 2009b).

2.2 Special measurements

The background of the above ground polygon and the relative error ellipse in yellow (fig. 3) was the necessity of drilling a shaft from the terrain surface to the dam construction site in the cave for the transport of building material, machines and workers during the construction phase and later for the operation of the installations. The shaft of about 100 m length should meet the cave side with an accuracy of 20 cm. Therefore a precise staking out of the drilling point at the surface was necessary. For the vertical drilling itself a special machine was developed by the company Herrenknecht, well known for the construction of big horizontal tunnels, see fig. 4. With the size of the relative error ellipse between drilling point and cave of 20 cm in the critical lateral direction, the postulated accuracy could be guaranteed, the reached accuracy after the break through was with only 8 cm even much better. This high accuracy could only be reached by a precise controlling of the vertical direction of the drilling. At the upper end of the shaft two Leica laser plummets were installed and used until a depth of 50 m was reached. The high precise water-level integrated in the plummets made the vertical alignment of the lasers with an accuracy of about 2cm/100m possible. The operator of the drilling machine had to control the position of the laser points on special targets at the machine and to observe the bubble of a special level installed near the steering gear. After 50 m depth consoles were constructed in the shaft for the plummets and their use during the second drilling part. Finally this solution was relatively cheap, simply to operate and precise enough.

Another interesting task consisted of deformation measurements at the underground barrage after its construction and during the filling of the reservoir during the test phase with different geodetic and geotechnical methods, aiming an accuracy in the submillimeter level. The monitoring measurements were tacheometric measurements to single object points, convergence measurements with invar wires and pendulum measurements. Additionally water leakage measurements have been carried out at especially installed drainage tubes. Information about the marking of the points for the different measurements are documented in Benner et al. (2009a). A survey of the monitoring network is given in fig. 5.



Fig. 4: Vertical drilling machine

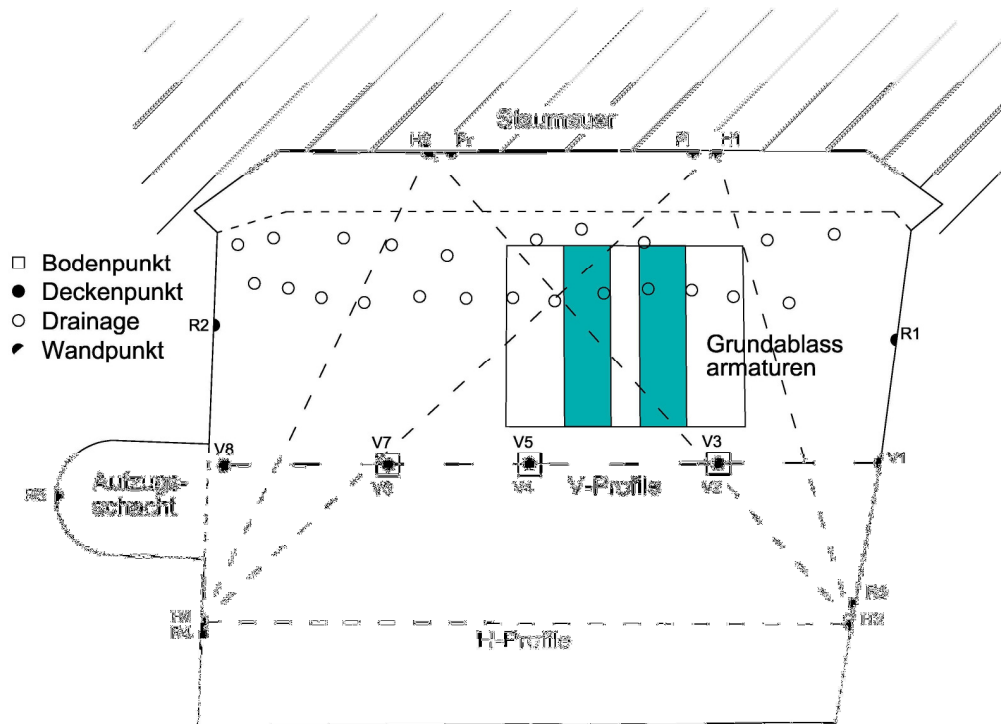


Fig. 5: Geodetic and geotechnical monitoring network of the Gua Bribin dam

Before the test filling of the reservoir a reference measurement was carried out. The polar measurement of the single points took place before and at the end of the filling. Convergence and pendulum measurement were repeated all two or three hours during the filling which needed 48 hours for a build-up height of about 17 m (water flow 1,2 m²/s). The data processing of the polar measurements did not indicate any deformation of the dam and the machine platform. The results of the convergence measurements, carried out with a precise distometer ISETH – precision of distance differences between the profile points better than 0,05 mm - showed uncritical motions below 0,1 mm. For one of the side walls a shift of less than 0,3 mm could be detected. In future a regular monitoring of the long term behaviour of the dam shall be observed (Mutschler and Triantafyllidis, 2009).

The inauguration of the Gua Bribin plant will take place in March 2010.

3 IWRM PROJECT

The success of the project Gua Bribin might have been a decisive reason for the initiation of a new BMBF joint project ‘Integrated Water Resources Management (IWRM) in Gunung Kidul, Java, Indonesia’ (life time from 2008 to 2013), in which the whole region including the town Wonosari is the focus of thematically enlarged studies. The structure of this joint project includes all different aspects such as the acquisition of new drinking water resources, the infrastructure for the water distribution and the waste water disposal under consideration of hydrological, hygienic, ecological, social, cultural and economical conditions, requirements and consequences. It is also necessary to do educational work and training of the population concerning sustainable use of the resource water. The studies shall not be restricted to drinking

water only, they shall be extended to the water supply for municipal workshops and the irrigation in agricultural areas.

3.1 Gua Seropan

The cave Gua Bribin is one more example for an existing small weir and a diesel pumping system for the local supply. Because of a larger height difference than in Gua Bribin following the river course down the weir, an alternative system is planned consisting of a would stave pressure pipeline for local production of electrical energy, to be used for pumping the water from the enlarged existing weir system to a reservoir uphill. One advantage of such a wooden pipeline is the construction down in the cave with local wood, which can be transported through the small cave entrance.



Fig. 6: TLS measurement in Gua Seropan

As basis for the detailed cave measurements served similar to Gua Bribin an underground polygon, here realized with a Leica TCRP1201 – motorized and automatic targeting. Outside the cave differential GPS in RTK modus was used to stake out the above ground point for the test drilling into the cave. The three-dimensional data capture in Seropan was done in August 2009 using a terrestrial laser scanner Leica HDS6000, in order to get a cave model with a very high resolution for the planning of the pipeline and geotechnical studies concerning the geological stability of the cave walls (get an impression from fig. 6). Some details for the TLS-measurements are: 22 instrument positions along 350 m cave length with a height difference of 20 m down; cave breadth between 3 m and 15 m, cave height up to 21 m; measurement during 4 days; scan resolution in 20 m distance $6 \times 6 \text{ mm}^2$; no problems with the high humidity, only disturbing points near a waterfall due to spray. One more impression concerning a special cave cross-section is given in fig. 7 – photo – and fig. 8 – TLS point cloud.



Fig. 7: Cross-section photo

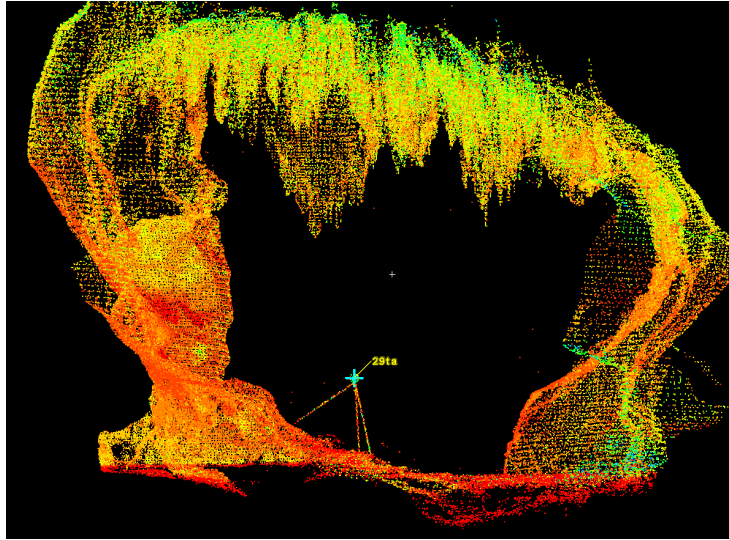


Fig.8: TLS point cloud of the cross-section

3.2 Reference system

The diverse and mostly independent surveying tasks in both joint projects resulted in coordinates and heights in different local systems. These results, the future measurements and the data of all the other project partners should be combined in a common and unique reference system with cm accuracy. Therefore a new reference point network has been realized by static GPS measurements with the Leica system 1200, covering a region of 30x30 km² corresponding to the size of the water distribution networks of Bribin and Seropan. Most of the points are positioned on the roofs of water reservoirs. Criteria have been a homogenous distribution over the project area, stability, free sights, long lifetime and a good approach by car. For the location the UTM-projection on the global GRS80-ellipsoid was chosen with the ITRF2005 as reference frame. The heights have been fixed in a global geoid model, the EGM08. The reached point accuracies were better than 3 cm in position and better than 10 cm in height. Finally for all following measurements and georeferenced data a high accurate reference frame is available.

3.3 GIS

The central task of the GIK in the project is the development of an overall geographical information system, the IWRM-GIS. This GIS shall facilitate an efficient management of all the relevant informations in the water supply systems Bribin and Seropan, concerning water and waste water management and the social and economical aspects. All project related data such as thematic and general maps, reports, pictures, coordinates and object data shall be available to all project partners via internet.

The main components of the IWRM-GIS are the software COSVega and a Oracle database. COSVega is a development of the COS Systemhaus, industry partner of the GIK (see homepage COSVega). On the basis of AutoCAD COSVega has a couple of application modules for different pipe and supply grids (f.e. gas, electricity, water, waste water, district heating, ...). The system for construction and data capture is running on a conventional personal computer, while the information service in connection with the software MapGuide is installed on a separate webserver. The Oracle database as the second core is also installed on a separate server, but has no public linkage to the internet. The database contains in addition to the actual subject informations geometries, topologies and parameters for construction and data capture. Big data blocks like satellite scenes and photos are stored in a document administration as part of COSVega on the webserver. As long the project is running, the collaborators at the GIK are responsible for the administration and the data capture. The adaption of the system functionalities and the application modules to the requirements of the Indonesian authorities occurs in cooperation with COS. After a special training of the responsible administrations the complete system (software and data) will be handed over at the end of the project.

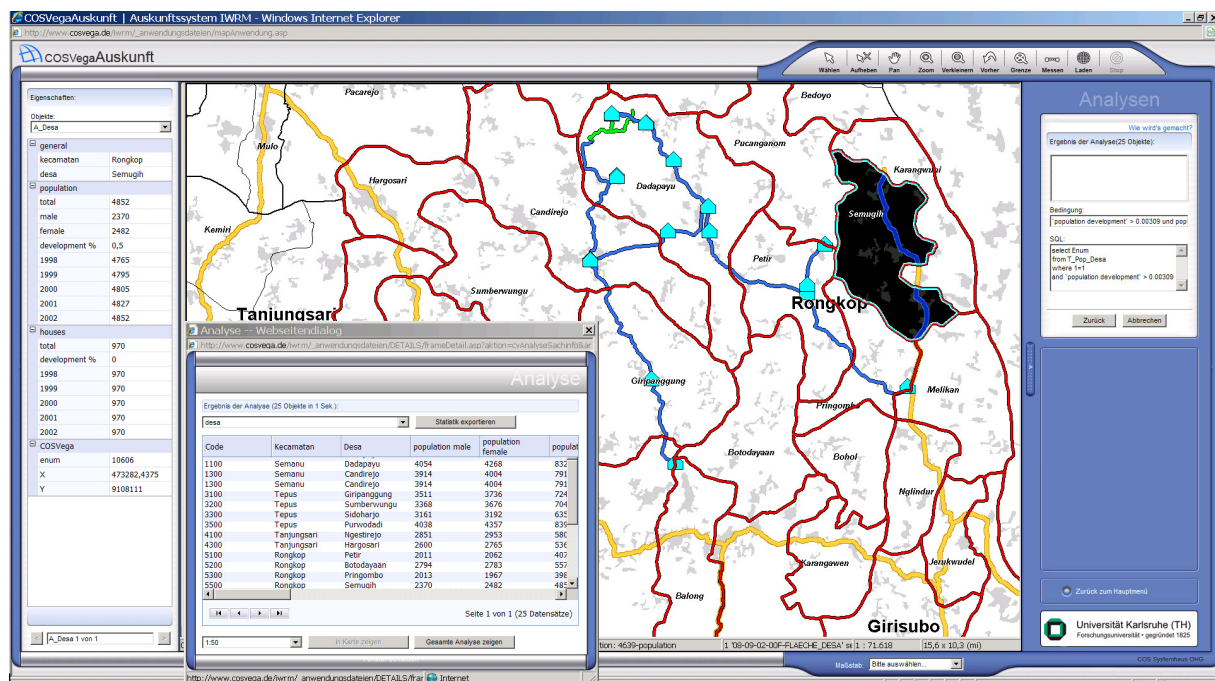


Fig. 9: IWRM-GIS: Enquiry system COSVega

One big block of data acquisition was the registration of the water supply systems Bribin and Seropan, covering a region of $40 \times 20 \text{ km}^2$. The pipe network was measured with GPS in the RTK mode, including building and construction details such as water reservoirs, pumps and slides including additional informations like pipe diameters, material and age. All these informations are needed for a hydrolic simulation model of the supply network for the development of optimization and rehabilitation strategies (Klingel et al., 2009). Partly the measurements have been carried out with students from the Geodetic Department of the Gadjah Mada University (UGM) in Yogyakarta in the sense of capacity building.

The 18 German research and industry partners and the Indonesian IWRM partners are producing during the life time of this joint project a lot of heterogeneous object data. The most time-consuming part of the GIS installation is the collection, preparation and editing of these data, which are mostly unstructured and in different formats. Table 1 is giving an impression about the variety of data which are commonly available in the IWRM-GIS. More information about the data management in the GIS and the access rights of the project partners can be found in Benner et al. (2009a).

	raster data	vector data / coordinates	object data / alphanumeric	object data / documents	integrated software
thematic maps (topography, geology, hydrography, ...), satellite images	x				
water supply systems Bribin + Seropan (pipes, reservoirs, slides, pumps, ...)	x	x	x	x	
hydrological model for the analysis of water supply networks (KANET)					x
administrative boundaries, settlements, streets, rivers, land use, contour lines, ...		x			
statistical data (population, water consumption, buildings, level and distribution of income, ...)			x	x	
measurement results (geodetic + geotechnical surveying, rainfall, build-up pressure, temperature, water flow, ...)		x	x		
chemical (water quality), mineralogical, geological investigations + analyses		x	x	x	
investigations + analyses concerning drinking and waste water treatment		x	x	x	
caves (Bribin, Seropan, ...)	x	x	x	x	
technical plants (pumps, generators, turbines, water power plant Bribin, wooden pressure pipeline Seropan)	x	x	x	x	
meta-data (when?, who?, from whom?, where?, how?, ...)			x		
...					

Table 1: Georeferenced data in the IWRM-GIS

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