2. TOPOGRAPHY

2.1. SITE IDENTIFICATION

The development of a low head hydropower station usually starts with the identification of the site. In the beginning of the works stand topographical map studies to find a suitable location for a low head development. Depending on the region to be investigated, the more detailed the map, the more useful is the determination of possible identification sites.

Based on the desk studies in the office, a preferable site should also be visited in the field. If information is available regarding the hydrology at the river, such as gauge readings and discharges, a first estimation of available power generation can be done. The field visit confirms the possibility of a hydropower development of a site identified on the map.

The purposes of the field visit can be summarized as follows:

- To find topographically and geologically adequate locations for all structures required for the hydropower project
- To investigate the access possibilities to all structural components of the project

In case the field yields a confirmation of reasonable development possibilities, further studies can be carried out. If adequate information is available concerning topographic and hydrographic survey, a preliminary design can be undertaken. If the survey information must be considered as weak, survey works have to be undertaken to ensure a proper layout and design of the low head power station.

2.2. DATA COLLECTION

2.2.1. GEODESY

2.2.1.1. BASIC GEODETIC SURVEY

Basis for the cartographic representation of the surface of the earth are coordinate systems, which describe the site and size of the selected area. The reference of the ground surface to the map projection is given by the marking of control stations in the area, which are geometrically defined by an indicating number of coordinates according to a local net.

There are hardly areas on the earth, for which a coordinate net does not exist. Often the same areas are covered by different local nets, which have been established by not coordinated groups for construction, administration duties, cartographic projects, military aims and so on. It is regrettable that these nets are not kept in good condition after completion of the projects, so that integration for further use is not possible. In the end each civil engineering project has to provide its own survey net. Local nets, even of high precision, can be produced by known and tested geodetic survey techniques with the help of experienced personnel.

Usually low head hydropower developments are placed in wide valleys and in the plains. Therefore access to the sites is considerable good and long-range orientation is possible. This is an important prerequisite for survey works for low heads. Long distances can be covered with the measurements; natural conditions are also appropriate for use of modern survey equipment. In most cases all measuring procedures can be carried out in low head hydropower developments. Different measurement techniques can be used to create a local net of benchmarks, if not available. If ‘old’ nets exist, it is recommended to control the coordinates of the benchmarks so that they may be used for present-day tasks.

To create a local net of control stations the following steps are essential:

1. Creation of a basic net by combining triangulation and optical distance measurement.

2. GPS-measurements for a highly exact definition of the relative position of the control stations.
3. Gyro measurements for the orientation of the local network.
4. Computation of the point coordinates from all measurements in a combined adjustment processing.
5. Permanent control measurements to prove the stability of the reference points.

Common survey procedures have always been used for the production of basic and micro networks. Modern electronic parts and computer-aided procedures further rationalize the surveys. So today the use of electronic theodolytes with an integrated distance measuring device -so called total stations- is standard. The total stations are equipped with standard interface plugs provided for an electronic data flow to adapted computers. With the use of these kinds of instruments survey works for setting up networks of control stations can be done sufficiently.

The common geodetic survey methods are generally important for additional measurements and for applications for which the result of survey is needed without delay at the site.

In contrast to photogrammetry, geodetic survey is a point-by-point measuring method, which is able to determine relatively few, but therefore very exact coordinates of points in a unit of time.

Tachometry needs a reflector at the target for point determination. It is a suitable tool in relatively plain areas, where long distances can be covered only by a few measurements. It is possible, to connect a total station like a digitizer to a cartographic computer program, so that one can see measured points and lines immediately after measurement at the screen of a laptop. This technique requires very well educated and experienced personnel.

2.2.1.2. POSITIONING

2.2.1.2.1. ASTRONOMICAL POSITIONING

The astronomical determination of the latitude and longitude of a point on the surface of the earth is a conventional procedure. It needs extraterrestrial references. The geographical latitude is calculated from measurements of the angle of elevation to known stars. The geographical longitude can be computed from measurements of time with calibrated watches. If the definition in geographical coordinates is not sufficient, the geographical coordinates have to be transformed into a local system of coordinates. At best case, the error of position will be about 10 m.

2.2.1.2.2. BAROMETRICAL ALTIMETER MEASURING

The fact that air pressure drops with increasing height from orthometric elevation, is the physical basis of the barometrical measuring. The pressure drop per unit of height is not linear, but goes down with increasing height. The air pressure also depends on meteorological air pressure variations, on the geographical latitude and, on a small scale, on the humidity. Therefore, in measuring the air pressure only differences in elevations can be determined.
If this procedure is limited by the measurement of elevation differences below 1000 m a.s.l, errors up to 10 m may be expected. Measurements in higher elevations can exceed the above value. For this reason it is not recommended to use this technique in low head developments.

2.2.1.2.3. DETERMINATION OF AZIMUTH WITH GYRO

Highly exact measurements of the azimuth are necessary if several local nets have to be combined. It might be possible in case of low head developments, that the river is the political borderline between two countries, which have different local nets in use. This happens quite often in Europe, where different survey coordinate systems are still in use.

Local nets can also be directed by astronomical direction measurements. The disadvantage of this procedure is given by the fact, that weather can obscure the chosen celestial targets. The correct direction can only be determined after large-scale conversions of the data with astronomical tables and time measurement that are difficult to obtain especially in the dark. The advantage of the determination of the azimuth lies in its high exactness by observing stars.

Foucault (1819 -1868) was not the first to be guided by the wish to determine the northern direction on the earth by using a method, which does not need extraterrestrial targets. The magnetic compass used in navigation and in the early days of geodesy was in the beginning sufficient for certain mapping purposes. This cannot fulfill the demand for accuracy in modern engineering tasks.

In the early 19th century works started for developing the gyrocompass. The first gyro suited for survey was built by Schuler (1921) for the Anschütz Company. With this instrument (weight: 350 kg, measuring duration: 6 h) the azimuth could be determined to ± 6 mgon. In doing so the gyro oscillations ("Schulermittel") were evaluated.

Especially the mining industry gave important impulses for the further development of the gyro technology. The DMT-Gyromat is the most modern survey gyro. It has an average weight of 10 kg and it determines after a measuring time of 7 min the azimuth fully automatically with an exactness of <± 1 mgon.

The measurement, which has to take place in an already established net of control points, is being done in the following steps:
1. Centering the gyro on the network
2. Approximate alignment northwards
3. Aiming of a target
4. Starting the gyro
5. After a short time (max. 7 min.) the azimuth is shown at the gyro's display

The north finding process is fully automatic. The measured north direction is transferred to the alidade of the theodolyte automatically. After finishing the measurement, the azimuth can directly be read by aiming at the desired target.
Particular advantages of using gyros are:
- Automatic, highly accurate measurement of azimuth
- No knowledge in astronomical theory and observation methods is needed
- Measurements are almost weather independent

Main areas for gyro measurements are:
- Geodetic indication of direction in tunnel and canal construction
- Relative and absolute geodetic network orientation
- Positioning for GPS networks
- Setting of reference lines for inertial navigation systems
- North alignment of motion simulators
- Determination of anomalies in the magnetic field of the earth
- Determination of atmospheric effects of refraction.

To orientate a net of control stations a few gyro measurements on selected traverse legs are sufficient. The azimuths are brought together with all other measuring data to a combined adjusted computation of coordinates.

Like any other geodetic measurement the gyro measurement has also to be controlled. This is done either by control measurements with a second gyro and/or by calibration of the instrument on a calibration line. The azimuth of the calibration line is being determined astronomically.

2.2.1.2.4. GLOBAL POSITIONING SYSTEM (GPS)

The Department of Defense of the United States of America demanded in the beginning of the 70th the development of a navigational system for a worldwide exact determination of position. Such an equipped user - it does not matter if stationary or with low or high dynamics - shall receive extremely exact information about his three-dimensional position, his velocity and also about the time everywhere on or near the earth. This information system has to provide always independently of weather conditions. This so called "Global Positioning System" (GPS) was achieved by the simultaneous development of 3 segments.

The space segment consists in the final phase of 24 navigation satellites. 18 satellites are necessary for a full coverage of the earth, the other 6 ones shall serve as a reserve. At the moment 16 satellites are in their orbits. Each satellite carries a beacon giving out coding bursts of radiation and a broadcasting time. These signals are used for high precision survey measurements. The orbits of the satellites are selected in such a manner, that always a minimum of 4 satellites can be received simultaneously at any point on the earth. This constellation fulfills the demand, that a moving user of the GPS can receive, without delay and break, information about his three dimensional position.

The control segment shall supervise the satellites and compute the exact orbits. These tasks are carried out by 5 ground stations, which are positioned near the equator at an equal distance around the earth. All GPS receivers together represent the *user* segment. For survey purposes there are small, lightweight antennas available with accurately defined phase center.

GPS measurements are being related to a global terrestrial coordinate system. In this same system are also defined the ephemeris data of the satellites.
The global terrestrial coordinate system defined as such:

1. The origin of coordinates is the central point of the earth.
2. The earth axis of rotation is the z-axis.
3. The x-axis penetrates the equator at the Greenwich degree of latitude.
4. The y-axis is originated by the rotation of the x-axis counterclockwise of 90 degrees.

This system of coordinates is supported geocentrically and takes part in the rotation of the earth. On the basis of this, the World Geodetic System 1984 (WGS 84) was defined for the description of the ephemeris of GPS satellites with regard to further parameters. It cannot be compared with well-known geodetic systems of coordinates. The GPS coordinates defined in the WGS 84 system afterwards have to be converted by special software into user defined systems of coordinates.

The setting up of nets of control stations and their control nowadays is impossible without GPS. By this procedure, accuracy especially over a long distance can be reached which other survey methods cannot provide. It is also an advantage that the provision of data can be made automatically and to a very large extent independently of the weather. Therefore, the work at the site is restricted to set up control stations and the measurement of the antenna eccentricity. The control stations can be out of sight from each other and can be as far away from each other as necessary.
The practical use can confront the user with different sources of errors. The errors can be caused by the space segment (e.g. orbit of the satellites, disturbances of satellites), by interference (e.g. atmospheric disturbances of the measuring signal) and in the user segment (e.g. disturbances of the receiver, reflections or shading of the measuring signal by unfavourable choice of the place of measurement). Without a nearer description of the errors it can be concluded, that the error budget can be kept lowest for most practical cases by a proper design of the measuring procedures and by a selection of suitable post processing software. In any case, an exhaustive planning of the measurement and also an exact selection of the measuring time is an essential presumption for a successful GPS campaign. It has also to be

taken into consideration that still not all satellites are available at any time of the day because the set up of the GPS system has not been finished yet, which can locally lead to very restricted times for observation.

Out of geometrical reasons GPS measurements have to be made with at least 4 satellites simultaneously. Additionally, to obtain exact results these 4 satellites have to be distributed equally over the horizon. The accuracies as given below only apply for most favourable satellite constellations.

According to use, 5 GPS survey modes can be distinguished. All procedures provide space vectors from measurements of the difference according to WGS 84. Therefore all procedures always need a continuously tracking reference station and at least 1 roving receiver. By an appropriate combination of the space vectors between reference station and roving receiver the coordinates of the GPS control points can be computed (trilateration), which are then transferred in a simultaneous adjustment process into a user defined coordinate system.

With this principal measuring arrangement, errors in measuring based on irregularities of satellite orbits can be balanced.

The five GPS modes are:

Rapid Static needs a permanently stationed reference station and several roving receivers moving from point to point. This mode can be used for any job where many points have to be surveyed quickly. It is suitable for measurements of baselines up to about 15 km with short observation times. The accuracy is about ± 10mm + 1ppm baseline. A minimum of 4 satellites must be available during the whole survey campaign.

Static is the classical method for baseline measurement with highest accuracy. It needs permanently stationed receivers on chosen net points during one observation window. This mode is recommended for the survey of base networks. It needs relatively long observation times but it is more accurate and more economical than traditional geodetic methods. For advanced solutions a minimum of 3 receivers have to be available. The accuracy is about ± 5 mm + 1 ppm baseline.

Stop and Go GPS mode is the quickest way to survey detail points with an accuracy of about ± 20 mm + 1 ppm baseline. This mode needs a temporary reference station which tracks continuously and a roving receiver. The roving receiver stops for a few minutes time on point 1. After data registration it is moved, maintaining lock on satellites, to point 2, stops for a few minutes time... and so on. Stop and Go should be used only in open areas when surveying points are close together and when there is the opportunity to repeat measurements when blunders may occur.
Reoccupation mode is similar to rapid static with the difference that one has to reoccupy a point after at least one hour. That makes this mode insensitive against critical satellite constellations.

True Kinematic is the mode for the location of dynamic systems (e.g. hydrographic survey, registration of exposure points during aerial photo flights). This mode needs like all others a continuously tracking reference station on the ground. The starting point of the vehicle has to be observed for a few minutes time for rapid static fix. Then the continuous movement of the vehicle can be recorded with measurements at selected time intervals. Accuracy for this mode is reported to be about ±10 cm rms.

For first order surveys static mode is recommended. This is the most exact method, but at the same time the most time-consuming method in comparison to other GPS modes. The choice of suitable GPS control points for undisturbed receiving of the satellite signal is also connected with this. Usually in plain areas no objections are expected. Sensible GPS works are done with at least 3 receivers.

Recently different producers offered so called GPS hand held antennas in connection with a programmable pocket calculator for the post processing software. Those small GPS receivers are used e.g. on small sporting boats and have proved their worth for navigational use. These small GPS receivers can be used in the same way as mentioned above (5 GPS modes a.s.o.), but one is confronted with a reduced accuracy.

2.2.2. PHOTOGRAMMETRY

In international literature, "photogrammetry" is mentioned first in 1867 by Meydenbauer, the founder of the first archive of metric photos of monuments and architecture.
The most common use of photogrammetric techniques is to recognize and identify an object by its photographic image and to derive its size and its position in space from the photographs.

Further technological developments today give us the possibility to get images of objects by recording them with special sensors even outside the normal visual range of the film and camera.

The best up-to-date definition of "photogrammetry" is given by the American Society of Photogrammetry:

> *Photogrammetry is the art, science, and technology of obtaining reliable information about physical objects and the environment through processes of recording, measuring, and interpreting photographic images and patterns of electromagnetic radiant energy and other phenomena.*

Today, the best known application of photogrammetry is to produce topographic maps of the earth from photographs and other images based on measurements by means of optical instruments and analytic computations.

The world of photogrammetry can be divided into several categories according to the types and position of sensors and to the process of getting information from the images.

In this paper, photogrammetry is explained according to the technologies of obtaining information from photographic images. In this case, depending on the position of the camera, we can distinguish two categories. The terrestrial photogrammetry where the camera is placed on the ground and the optical axis is nearly horizontal, and the aerial photogrammetry where the camera is mounted in an airplane and the optical axis is vertical.

2.2.2.1. EQUIPMENT

2.2.2.1.1. CAMERAS

Cameras for photogrammetric use must fulfill certain conditions. Photogrammetric cameras, so called metric cameras, differ from normal cameras in such a way, that their interior orientation must be known. The interior orientation defines those parameters, which are necessary for the reconstruction of optical image formation. These parameters are the focal length, the principal point and the distortion. Parameters as such are being defined by calibration. Additionally the construction of the camera must ensure that the focal plane is absolutely plain, that means that all light rays passing through the lens come to a focus in one plane. Metric cameras ensure by their construction that the once calibrated parameters of the Interior Orientation are constant over a long period of time.

The principal parts of a typical aerial camera for metric images in the format 225 mm x 225 mm are:

The body contains the electronic and mechanic components for the camera control.

The lens cone *assembly* is mounted into the body. Lens cone assembly consists of lens, frame and shutter. If a lens with a different focal length is used this part can be exchanged completely. The frame defines the focal plane. It provides for auxiliary information on the film at each exposure (flight height, time and date, navigation signs, film numbers, fiducial marks). An exchangeable electronic shutter and filter can be mounted into the passage of light.

The film magazine houses - of course - two film rolls for exposed and unexposed film, the drive mechanism, and the film-flattening device (typically a vacuum system). Some magazines can be equipped with image motion compensation. These are constructional features providing film movement during exposure at such a rate to compensate for the movement of the photographic images. The image motion compensation allows advanced photographic techniques e.g. photos from high-speed aircrafts or photos at low altitudes or photos with slow speed high definition film. The complete aerial camera equipment has a weight of about 250 - 300 kg

Terrestrial metric cameras are offered for all common film formats. For photos of mountainous areas all metric cameras can be used but the format of the film should not be smaller than 70 mm. Well suited for terrestrial photos in mountainous areas is the Rolleimetric camera system. It combines the advantages of a series-produced professional camera system with the possibilities of photogrammetric evaluations. This light-weight equipment ($\leq$ 20 kg) can easily be transported by one person across difficult terrain. If the camera is mounted on a theodolyte further advantages come out of the design of photogrammetric surveys.

2.2.2.1.2. FILMS
The photo industry offers different emulsions for all photogrammetric purposes. In most cases a black and white film is sufficient. By its manifold possibilities in exposure and processing the most economical and safest solution for successful missions is given colour films are provided as positive or negative material. They demand excellent weather conditions during exposure, but supply with additional information of natural colours.

For special use infrared films are necessary. Black and white infrared films easily penetrate mist and fog . They are also suitable for representation of water bodies. These films have a very high contrast and a relatively poor definition, which may cause loss of information. Colour infrared (or false colour) films are mainly used for photo interpretation works for environmental protection studies. This kind of film helps to visualize diseased vegetation and water pollution.

2.2.2.1.3. ANALYTICAL PLOTTERS
Analytical plotters are used to determine geometric information from metric images. They can be described as computer aided measuring machines.

Metric images are adapted on 2 carriages that are moveable in 2 directions. By an ocular system a spatial view is possible on stereoscopic metric images.

A computer program solves mathematically the relationship between photographic image coordinates measured in the two dimensional photographic reference system and the 3D object coordinates. Interface routines make it possible to communicate with cartographic software, those analytical plotters can be used as 3D digitizers for the on-line evaluation of photos.

With modern accessories it is even possible to reflect the evaluated line map back into the ray path of the analytical plotter, so that the operator can at the same time look upon the stereo model of the object and the cartographic result.

2.2.2.1.4. SURVEY AIRCRAFT
In principle any aircraft can be used for aerial photos. There is no typical survey aircraft. The actual relevant task decides which aircraft is best suited.

Basically a survey aircraft has to provide for the space for pilot and navigator, at more extensive missions also space for the camera operator. This as well as the heavy camera equipment has also to be considered, so that at least a 6 seater is convenient.

2.2.2.2. TERRESTRIAL PHOTOGRAMMETRY
Since its invention the photography has been used for measuring purposes. Because of the original technique with long exposure time and unwieldy devices terrestrial - photogrammetric applications were to the fore.

Instead of the theodolyte the terrestrial photogrammetry uses a metric camera. There also existed application of both, the theodolyte and metric camera, so called phototheodolytes. Both types of cameras were used for taking single pictures.

To determine the coordinates of object points their corresponding image points were measured with comparators and converted into object-coordinates. The object-coordinates computed in this way agree in quality with those obtained by the geodetic procedure of intersection, and are also used in the following processes of data acquisition.

Since the beginning of photogrammetry in the last century, this method was applied for the survey of landscapes and buildings. Modern camera and software developments have created with this kind of photogrammetry an efficient tool for highly-precise remote measuring of marked points.

For cartographic purposes this procedure has the disadvantage that many points have to be measured in many single photos. These measuring data have to be compiled in an extra procedure into graphical data. Additionally, there are difficulties to identify the same point in different photos. Therefore, the stereophotogrammetry is better suited for cartographic evaluation.

In the stereophotogrammetric procedure the photos are taken from two standpoints, so that in the following process a spatial (stereoscopic) view can be evaluated. In this case the dimensioning of the baseline between the two camera stand points has a special meaning. It depends from the spatial eyesight of man and from the geometry of the camera stand points according to the exposed object.

A computer aided measuring machines - the analytical plotter - is making the geometrical evaluation of the metric photos. By the complete analytic formulation of the process of data analysis almost all photos can be evaluated.

Since the development of the first instruments for analysis for terrestrial stereophotos in the year 1911 the meaning of the terrestrial photogrammetry, which lies in largescale-mapping of landscape regions has stayed the same.

2.2.2.3. AERIAL PHOTOGRAMMETRY
Each photo flight is to be planned exactly. The planning of such a flight provides the crew with all needed information to photograph a given area with the desired coverage.

The main use of the metric images should be defined beforehand. Different use results in different requirements to the flight design, e.g. for interpretations, for orthophotos, for mapping special conditions have to be regarded respectively.

The most important initial values for the flight design are photo scale and focal length.

Focal length: In aerial cameras one can distinguish between wide angle-, standard angle- and telephoto lenses. If photo maps have to be produced or interpretations are demanded, longer focal lengths are preferable, because the perspective distortion is smaller. If line maps are to be produced it is better to use a wide angle lens to take aerial photos. In doing so the highest accuracy for measurements of heights can be obtained.

Photo scale: The correct choice for the photo scale depends very much on the demanded evaluations. For photomaps the scale should not be enlarged more than 5 times than the scale of the aerial photos. Bigger enlargements are technically possible, but then the photographic quality of the photos is not sufficient for a good result. For analytic evaluations e.g. for measurement of digital terrain models or for line maps, an enlargement factor up to 1 : 10 between photo and map is possible.

The exact keeping of a desired photo scale imposes on the aircraft crew a high amount of flying ability. The photo scale is defined as the proportion of focal length and flight height above ground. The exact determination of the flight height is not unproblematic in a terrain with big altitude differences. It is e.g. possible that the same distances between flight lines can lead to a loss of the side lap above changing ground, although the flight height is the same. It often cannot be avoided to have a flight design with different distances between flight lines and different flight heights. In any case a suitable terrain height has to be determined as a reference elevation.

It is difficult to describe the further procedure universally valid. It is rather necessary to determine the heading of flight in any special case as dependent on the object and the task.

A further important parameter for planning of the photo flight is the forward overlap. In plain regions a high overlap is not necessary. For stereoscopic evaluation normally a photo pair with 60% overlap is sufficient, but especially when using wide angle photos it can happen that parts of the photographed area are not visible

2.2.2.4. PHOTOGRAMMETRIC PRODUCTS

2.2.2.4.1. PHOTOMOSAIC

Especially at big projects the administration of aerial photos has to be supported by a photomosaic. The photomosaic serves as a better overall view and helps to identify the photos. For the photomosaic contact copies of the aerial photos are laid on touch. The photos are equipped with a clearly readable title. The title should contain date, scale, and the photo number. In the end this original mosaic is being reduced to a useable format by reprography and can afterwards be copied. Along with this mosaic all participating groups can select easily and order the photos they want.

2.2.2.4.2. PHOTOS

Single photos include many possibilities for use because of the multitude of the represented information and because of the reproduction of the terrain-conditions at the moment of exposure.

By stereoscopic examinations the planning engineer has a distinct perspective of the terrain. Interpretations and judgements for selection of project areas can be done with competence.

Important information for example about geological formations, morphology, vegetation, water bodies, buildings, settlements, impairments caused by environmental influences, can be received through interpretation of aerial photos.

Handy are enlargements in a format between 24x24 cm^2 and 50x50 cm^2 to identify objects and control points and to interpret characteristics of the terrain. The smaller format has advantages at the stereoscopic viewing, the bigger one can be used as a first basis for mapping.

If the photos are covered with a transparent sheet, the interesting photo parts can easily be marked. Planning designs have to be realized accordingly. Different transparent sheets, which are laid one on top of the other integrate within different information, which can be combined as desired or necessary. Already by these simple methods the basis for a system of information can be laid, and working steps electronically be understood.

2.2.2.4.3. ORTHOPHOTOS

The central perspective reproduction of objects by photos has for geometrical tasks the disadvantage that photos are not of a homogenous scale. Same sized objects are represented in the foreground bigger than in the background. In the photogrammetrical process of evaluation, the size of objects can be represented in two dimensions correctly by the transfer of the central perspective into a parallel perspective line map. The third dimension has to be represented by constructed information, as there are for example contour lines. The result of photogrammetrical evaluation is always an interpretation of the visible photo information.

At the orthophotomap a parallel-perspective representation of the photo is being generated by a differential transformation from the central perspective photo. A digital model of terrain, which can be produced by stereophotogrammetrical evaluation, gives the basis for that.

For the transformation one single photo is being digitized by scanner and disassembled in as many as required picture elements (pixels). Computer programs are now transferring each pixel to its place in the model of terrain, whereby its projection into the map is done.

By further procedures of digital image processing in addition certain parts can be emphasized or suppressed. Assemblies out of some photos are possible.
The - preliminary - result is the exposure of the transformed raster image on film.

The production of orthophotomaps cause about 30 - 50% of the costs for conventional line-maps.

On the basis of the production of orthophotos necessary digital model of terrain, additional information can be produced such as contour lines, profile lines etc., and can be intersected with the image information.

In further working steps hybrid maps can be realized as a combination out of photographic, geometric and semantic information and can be cared for and worked upon in so called information systems by computer.

2.2.2.4.4. DIGITAL MODELS OF OBJECTS AND SURFACES

In a digital model the surface is defined by a certain number of points. The X, Y and Z coordinates of each point are measured with an analytical plotter. There are computer programs that support this process of measuring. The better and more exact the surface has to be described the bigger will be the number of the points to be measured. For exact representation of the shape of the ground (> 1:2000) some hundred points per square kilometer have to be measured.

The measured points are transferred as primary data to special computer programs. These programs solve surface functions from adjacent points. Based on this further evaluations can be made such as are computation of contour lines, profile constructions, deformation analyses, computations of volume and surface, steps of declivity, maps of water flow direction etc.

If the result of planning is given digitally, it is also possible to visualize the planned object in combination with the digital model of the terrain as a computer animation. With large-scale projects such visualizations often helped to get knowledge about purpose and future prospects.

2.2.2.4.5. MAPPING

The presentation of the actual conditions in an understandable and visualized form is the main task of the mapping process.
Civil engineering projects have their own requirements on the mapping process:

- Large-scale maps are mainly required.
- The maps often contain additional information which are normally not included in topographical maps.
- The maps have to be produced quickly and cheaply.
- Actualization and revising have to be possible on the job.
- The mapping concept should be independent of the scale to a very high degree, so that the geometric information which is valid for one scale is transferable to another one.

Modern mapping techniques can fulfill these requirements if all working steps can be made computer aided.

The representation of plain regions in maps is considered as relatively easy in cartography. E.g. pure contour line presentations of plain areas often lead to quite reasonable results, since the difference in contour lines is not too much. A low-cost solution is the combination of a digital orthophoto with planimetric line maps to a hybrid cartographic concept. Proper software can operate this hybrid information in such a form that according to use either the photographic or the line information can be emphasized. Such a technique can be realized in certain parts also independently from the scale.

Some advantages of hybrid cartographic systems are:

- Hybrid cartographic systems as a combination of picture-like information with line drawings are superior to all other concepts, especially for planning tasks in areas with reduced cartographic preconditions .
- First results for interpretation purposes with still reduced geometric accuracy can be produced quickly and with favourable terms during the first planning phase
- The feedback got from interdisciplinary working methods leads object-related optimized visualizing techniques, which are freed from unproductive ballast.
- The complete electronic data storage makes it possible to work with a computer network not bound to local places.

Based on this, various mapping products can be offered for engineering projects:

1. If there are absolutely no cartographic fundamentals or if only - as most usually - maps are available in small scales like 1 : 250 000, then for a first presentation and general idea, scenes resulting from satellites can be produced. For this purpose the following satellite systems are suitable: Spot, Sojus Karta and the metric camera missions of Space lab. This data material is exceptionally suitable for maps up to a scale of 1:25 000. If the existing satellite scenes for the desired map segment are not available the required scenes can be ordered from Spot and Sojus Karta with a time of preparation of approximately 6 - 8 months. The satellites then are maneuvered into the necessary photo positions. The geodetic ground control for geometric orientation of the satellite scenes is appropriately produced by GPS supported surveys. Maps resulting out of these data are extremely useful for the evaluation of geomorphologic conditions and localization of proper construction sites. It is often sufficient to use the stereoscopic view of the satellite scenes. They are also very helpful at field works.

2. In a next step of data processing vertical and/or oblique photos from survey aircrafts can be used. Those photos can be practically evaluated for all desired map scales. Additional terrestrial photos guarantee the complete representation of the site. Based on this, maps can

be produced as they are actually needed. Further information can be added without further field work.

3. By digital storing of all cartographic information special representations can be produced. e.g. for representation of location lines (utility lines, communication lines a.o.) often combinations of ground plan and sections on one map sheet are required. Relieves of terrain e.g. for visibility tests can be realized on the basis of a digital terrain model with different perspectives.

2.2.3. GENERAL SURVEY WORKS

Low head development might be carried out in areas, where topogrraphic information is sometimes weak. Since available topographical maps are not accurate enough for hydropower development, comprehensive survey works are needed at the identified site and its locations for structures. Mainly three different survey methods can be distinguished:

- Conventional survey by triangulation and optical distance measurement
- Photogrammetry
  - Aerial, with optical axis vertical
    - Satellite
    - Air plane
    - Helicopter
  - Terrestrial, with optical axis parallel or inclined
- Global Positioning System (GPS)

To achieve accurate results with the conventional method the coordinates of at least two measurement points have to be known. Since locations of hydropower development might be far away from local survey nets, this method might not be applicable due to constraints in manpower and time. However, this method is reliable if appropriate controls are carried out simultaneously.

In case of photography the horizontal position and altitude of at least one point should be known. Of course, the more coordinates of objects on the photo are known, the more reliable is the determination of coordinates of other points. Moreover especially aerial photography is very expensive.

In recent years with increasing use of technology the processing of satellite images becomes more and more important in survey works. The technology has reached a standard, allowing the resolution of Landsat images having a square grid of 30 m length. Of course, this can not be utilized for detailed survey works, but might be useful in connection with location of structures, and geological weak formations might be identified. Similar to other aerial photographs, survey coordinates of objects must be known for a reliable use of so called georeferenced images.

Global Positioning System can be considered as an appropriate tool in survey works in context of hydropower developments. The position of the actual measurement point is determined with help of the satellites in the area of field measurements. The position and altitude of the point is given in a world coordinate system, which can be converted to local coordinates systems. GPS can also be combined with all other mentioned survey methods. It can be considered as highly accurate survey tool. Once a reference bench mark is determined by single point measurement with GPS, a survey net can be easily established on a high level of accuracy by measuring long distances with static measurements. The local net of established bench marks can be kept in global coordinate systems or transferred in local coordinate systems. It can also be combined with classical tachymeter survey methods for detailed surveys in a small area.

2.2.4. HYDROGRAPHIC SURVEY

For any hydraulic/hydrologic calculations of the river or a proposed reservoir, the geometry of the river can be considered as the most decisive parameter. For this reason the geometry of the river has to be measured accurately in the horizontal and vertical dimensions. By using the measuring techniques and instruments mentioned above, a position next to the river can be determined.

For hydraulic calculations of a river, the cross-section and the longitudinal section are needed. While the cross-section determines the area of flow, the longitudinal section gives the slope of the bed. The longitudinal section can also be determined by a sequence of measured cross-sections. Since three dimensional effects are of importance with respect to the hydropower development, the course of the river in the reach upstream and downstream the weir should be measured. Secondary flows, vortexes and other three dimensional effects are of special interest for the design of structures for hydropower development.

The principle of measuring the cross sectional profiles at a special discharge consists in measuring the water depths at different equispaced verticals of the river. The number of verticals depends on the size of the river. Sufficient points shall be measured to describe the shape of the river. The cross-section should be measured right-angled to the flow direction and the coordinates of the reference points at each side of the bank should be known. A leveling of the water level has to be conducted to determine the elevation of the cross section points.

The simplest method of measuring the cross sectional profile is to take the depth of the water with a stick. This method is only appropriate at shallow rivers or canals. The survey coordinates of each measurement point must be clear in the outline. Usually a tag line is used for smaller water bodies. Plane tables, theodolites and GPS are used to survey larger areas. The distance to any point in a cross section is measured from an initial point of the bank. It is also very important to keep a record of water levels in order to be able to refer the survey data to the same datum. Especially at low head developments, the width of the river might be so great, that the measurement of one cross-section takes considerable time. This is also due to the use of equipment such as boats, ropes etc.

To get good results measurements should be carried out during low flow periods. During flood, it might not be possible/too dangerous to measure due to high velocities. If possible, several measurements should be carried out in several years. A regular measurement of cross-sections at the same locations should be intended to record possible changes in the geomorphology of the river.

Furthermore today echosounding systems are used in hydrographic survey. This technique is only applicable in great rivers with relatively mild slopes. The echosounding systems are combined with measurement boats, which measure the water depth and can be moved over the river in such a way, that cross sections as well as longitudinal sections are taken. The measured data can be processed with help of CAD software, which take data for the establishment of cross-sections and three-dimensional geometries of river reaches.

2.2.5. SURVEY DURING CONSTRUCTION AND AFTER COMPLETION

Though this kind of surveying is not directly connected to the steps for implementation of hydropower projects, it is an important part in the monitoring of construction phase and secure measurements after completion of the project.

Surveying is needed for the permanent control of construction progress to avoid any problems due to inaccurate working. During the construction structures have to have the same position in nature as planned, otherwise problems in operation might occur.

After the completion of the project, bench marks are used to control any kind of movement in horizontal or vertical direction. This is of absolute priority for structures as dams etc. New measuring devices have been developed during the last decades. Movements can occur due to seismic events and tectonic activities.

2.2.6. FIELD INVESTIGATIONS

First all available information of existing bench marks of i.e. the Survey of Pakistan nearby location has to be selected as the main horizontal and vertical control station for the project. After this, reference points have to be established, which should be done with help of GPS survey equipment. Thus a primary GPS network consists of the control station and the different reference points. The reference points should be established next to the location of the main structures, such as powerhouse, weir, intake, headrace canal and tailrace canal etc.

During work with GPS it is necessary, that a minimum of four satellites are available during the collection of GPS data. The observation should be long enough to gain reliable co-ordinates and elevations of the control measurement.

After the GPS network is established, a detailed topographic survey is carried out from the reference points using Total Stations. The Total Station is a tachymeter, which records the data on memory cards. The cards are then regularly dispatched to a computer, where the data processing and error checking is carried out. The data processing is discussed in the next paragraph.

2.3. DATA PROCESSING

2.3.1. GPS DATA

Using the GPS Survey suite of softwares carries out all the GPS data processing. Since GPS data are in the WGS84 format, data have to be converted to the local map co-ordinates. The necessary steps are briefly described below:

- Collection of GPS data at the site using the GPS receivers
- Download of data to computers using gpload software
- Post-processing of data from the known and unknown station using a WAVE baseline processor. All internal computations within the software take place in the WGS84 system. The output contains co-ordinate data for each point in WGS84 format
- Conversion of WGS84 co-ordinates into local map-coordinates by using special software. Correction of any mistakes takes place before conversion. This requires the specification of a reference from GPS laterals and longitudes into the respective Cartesian N-E-Z co-ordinates.
- Conversion of all points to local grid system including horizontal and vertical adjustments

2.3.2. TOTAL STATION DATA

The data processing of total station data first involves the downloading of the field data into the computers through an interface. Each survey data file is then transferred into the program database. The next step is the checking of each file in terms of future code errors and co-ordinate / elevation errors. Once any existing errors are removed, the files are processed for feature codes which help to build up a plot of the surveyed area. These plot files are then sent to CAD software for final setting and plotting.

2.3.3. CONTOUR DEVELOPMENT AND MAPPING

The converted Total Station data are further processed with CAD software. Today there are special applications with digital terrain modeling software for production of contours. One DTM software is MOSS (Modeling of Surface Systems), which is the world industry standard for formation of digital terrain models. Once contours at the required interval had been developed on MOSS, they can be fed to a CAD software in form of contours. The information can be used for the production of a map, showing both the topographic details and features as well as contours.

2.3.4. HYDROGRAPHIC SURVEY

The survey of the cross-section of the river at different locations upstream and downstream the proposed low head development is important for hydraulic and hydrologic calculations. The measured points will be processed in form of drawings showing the cross-section at decisive locations i.e. dam site and the longitudinal-section. Both type of information can also be processed in form of tables, giving the distance from a reference point of the bank to the measuring vertical and the corresponding water depth at that point. Then they are used as an input data for further calculation of sedimentological data processing with the hydrological data bank DBHYDRO.

2.4. APPLICATION

With help of the processed topographical digital maps, detailed information is available for the layout and design works for the development of high head hydropower. With this information, the design of structures can be adapted to the exact site conditions. Geometrical dimensions of the layout can be planned in detail.

Moreover the designed structures can be implicated into the CAD drawings to ensure a proper presentation of planned design. Locations of different components of high head developments, such as headworks and appurtenant structures, alignment and dimensions of penstocks and tunnels etc. can be implemented into the contour drawings.
Especially survey works are needed in high accuracy to ensure proper alignment and design of proposed tunnels. Errors in measurement will have a dramatic impact on the success and the costs of the project.

With the exact hydrographical survey at important locations, such as weir, intake etc. a preliminary as well as detailed design of the structures and especially its dimensions can be elaborated. Furthermore hydrographical survey shall be used for numerical and physical modeling purposes. Together with the hydrological informations at the gauge readings and information concerning bed material, both models can be calibrated and different layouts might be tested before detailed engineering is applied.

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