AIRBORNE LASER SCANNER AND LARGE SCALE CARTOGRAPHY IN RISK MAPPING : LANDSLIDES AND FLOODS

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Commission VI, WG VI/4

KEY WORDS: Risk maps, Floods, Landslides, LIDAR, Cartography, Cadastre, Simulation, High-resolution Satellite Imagery

ABSTRACT:

Airborne Laser Scanner - ALS and Large Scale Cartography offer a reliable spatial basis for Risk Maps, recommended to prevent or mitigate disasters in downtown areas. The research method evaluates LiDAR - Light Detection and Ranging data and Cartography in scale 1 : 1.000 (2009) to improve hydrological models development. Also, evaluate Digital Terrain Model – DTM, remote sensing (high-resolution satellite imagery Quickbird, e.g. ortho-rectified, four 4-meter resolution color channel, 1-meter resolution panchromatic, hydrometeorologial data and other information. Proposal includes imagery processing, Geographical Information System (GIS), hydrological modelling. The expected results are thematic maps as an instrument to support stakeholders decision.

1. INTRODUCTION

1.1 Motivation, Aims and Overview

The motivation for research is the high level of recurrent disasters in Santa Catarina´s coast, severe floods and landslides. Since these tendencies are probably be worsened, as a result from the Climatic Change, Greenhouse effect and Global Warming processes. Higher temperatures will increase extreme events, e.g. heavy rains, severe floods, landslides and droughts. Higher levels of prescipitation and severe flash floods, might as well occur, according to IPCC – Intergovernmental Panel on Climate Change and *INPE - Instituto Nacional de Pesquisas Espaciais*; Brazilian´s Climate Reports. However, the vulnerability of coastal areas and towns remains unknown.

Estuaries offer difficulties due to dynamics streams and tides. According to Wolansky (2007) environmental fragility, high level of sensitivity, low geotechnical imbalance and floods as a natural phenomena. Estuaries are also named as “sacrife zones”. Disturbace is a thereshold or “trigger” of coastal, estuarine colapse among other negative consequences. Despite of hydrological modelling, sea level rising processes must be considered. The possible setting according to Brazilian´s *IBGE – Instituto Brasileiro de Geografia e Estatística*, which is linked to GLOSS - Global Sea Level Observing System is that sea level may rises 0,5m in the next 50 years. Glaciology researchers show sea level could rise 1,63m to 4m higher. Vulnerable areas remain unknown. In 2008 60 municipalities from *Santa Catarina* State were affected, which represents more than 1,5 million inhabitants. Civil Protection registered 135 deaths, 22 disappeared, more than 78.000 inh., whose lost their homes, besides other damages. This event is specially relevant due to the highest precipitation level ever registered in *Joinville*´s monitoring since the XIX´s (1851-2009). Abnormal rain occured in Sep., Nov. and December 2008, 335% higher, 900 mm/ month, 25 liters/ m² 24 h, when normal prescipitation is 150 mm per month, (Dias et al.,2009). These extreme events show the relevance of R & D - Research and Development related to the subject. Many gaps in town planning methodologies must be solved. Deforestation and degration are unadvisable because saltmarshes, meadows, swamps, mangrove are buffer zones. Environmental imbalance and disturbance prevention in all those highly sensitive areas is important, otherwise, negative consequences appear, e.g floods and landslides increase. According to Morales (2004) floods and landslides area usually noticed in the area in Spring and Summer, between September and March, when storms and extremely intense rains occur. Silveira and Kobyiama (2007) agree since the XIX Century, when first germans, norwegians, swiss and other foreign immigrants settled in Joinville, several disasters were registered. Moreover, *Joinville*´s Civil Protection does not have precise and reliable Cartography, systems and forecast to support decisions.

This paper is an overview about the doctorate research being developed in *Joinville* municipality, as a case study in Brazil. Since Emergency Preparedness in Early Warning and Emergency Management deal with protection of life, the thesis proposal states the importance of using Airborne Laserscanner data and Large Scale Cartography for several purposes, e.g detect Social Vulnerability within Cadastre. The aim of this paper is to show the potential of Airborne Laser Scanner - ALS and Large Scale Cartography to develop Risk Maps for landslides and floods.

1.2 Large Scale Cartography

According to Erba (2005) and Loch and Erba (2007) Large Scale Cartography represent precisely land information; parcel and building (geographical location, area, type of pavement, limits) and themes as quarters, lakes. Spatial information is represented by 3 type of geometrical elements: a) polygons (infrastructure, e.g water, sewage and energy support, b) lines and intersections, trees and other by c) points. Topographical information may describe the natural and cultural environment. Multipurpose cadastre must be permanently updated and be linked to other spatial information, e.g. Remote Sensing, NTM - Numerical Terrain Models and other. Spatial and tabulated database information can be interrelated, managed within layers in GIS - Geographical Information Systems. The focus is data assessment improvement, reinforcing the importance of georreferenced parcels and urban features as Multipurpose Cadastre basis and other applications.

1.3 Cadastre

Cadastre may prevent disasters, e.g. floods and landslides in towns and built areas, since the tool identify vulnerability in the parcel. Acquire and maintain a complete cadastre of buildings, (blueprint and height), land use and occupation (housing, commerce, industries, services and infrastructure) within detailed cartography enable social losses reduction, including those produced by flow blockage. Townplanning within the cadastral parcel as a unit enables detailed case studies analysis and strategies: a) protect or remove important services and buildings, e.g. schools, hospitals and other to safer areas; b) remove poor people *(favelas)* to safer areas, c) encourage selfprotection for commerce and industries, (Tucci, 2004).

1.4 Airborne Laserscanner potentials

According to Jonas and Byrne (1999) topographical surveying is not recommended in large and isolated coastal areas. Photogrammetrical surveys face difficulties to locate control terrain points and lack of geodetical reference net support. ALS technology is advisable in coastal zones, due to precisely targets in sandy and muddy environment detection. LASER response in sandbanks, mangrove, saltmarshes, swamps, mudflats and other similar environment, in which seatides oscilation occur, is efficient for several purposes. Sensor detects average and maximal sealevel, within almost 100% point cloud density. Accurate morphology, altimetry, themes as vegetation, erosion processes monitoring and coastal line programtion, rivers and dunes monitoring can be detected, shows sample in Fig. 1.

According to Hailea and Rientjieb (2005) topography is one of the critical aspects in hydrological modelling development. Models seem to be developed specially in plain zones, where topography is simple and declivities are low. In this area low-resolution sensors are used for DEM`s - Digital Elevation Models in-put and hydrological simulations. General DEM are recommended for agricultural areas floods simulations. The problem connected to low-resolution is lack of topographical and physical details detection. DEM´s influence over floods simulation is important for it determines floods patterns, and flows development and evolution. Modelling in steep zones may be a challenge and require high-resolution sensors.

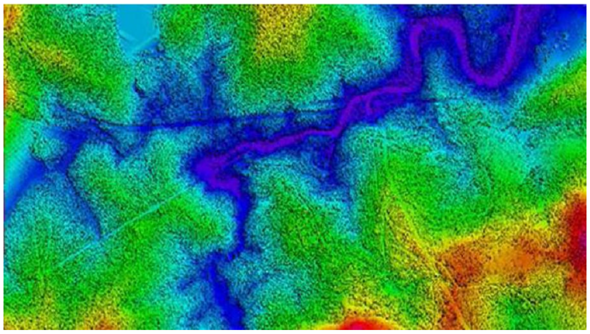

Figure 1. sample – orthointensity image from Airborne Laser Scanner surveying with ALS-60 Leica Geosystem frequency 200kHz and innovative technology MPiA - Multiple Pulses in Air. Source : Aeroimagem Engenharia e Aerolevantamentos S/A. no scale.

Topography affects the flood wave propagation in both riverstreams and buffer zones. Geometrical properties may cause blockage or increase flow. Since hydrological models out-puts are influenced by DEM - Digital Elevation Model resolution, detail levels as declivity índex, declivity gradient, declivity layers and drainage density, among other aspects interfere. Even though, hydrological modelling is a focus, without precise and detailed spatial information out-puts can fail. Many issues are required. e.g. understand the relationship between flood levels, flow velocities and flooded extention areas, isolated effects, critical meteorological conditions and their relationship. DEM´s scale and DEM´s resolution affect hydraulic rugosity indexes and modelling out-puts. DEM´s low-resolution generalisation results incoherent flow patterns.
ALS surveying is an advantage to acquire altimetry data (3D) for Topography and Cartography purposes. LASER Pulses transpose vegetation and detect ground heights precisely. ALS is a low-cost solution to detect targets efficiently even in dense vegetated environment. Also, improves land cover thematic classification within detailed and automatizated detection.

According to Verwey (2001) altimetry surveying within LASER pulsing swepping sensors improves cartographical refinement, precision and exactness in hydrological modelling, due to much better filtering, classifying and relationship between blockage and flows.

DEM´s resolution affects hydrological modelling. As a result, diferences between data sources resolutions is a problem. The model is favoured within large elements in grid. In this case processing time is reduced. Model calibration and sensitiviness analysis enable to acquire almost a near real-time flood forecast. On the other hand, low-resolution in-puts is not recommended for small scale or details losses, which affect flood propagation. In DEM´s sampling, low and high resolution data, topographical details are important. Generalization influence models performance and simulations, as a consequence out-puts reliability must be quantified. Moreover, generalizations must be avoided to prevent relevant information losses.

Flood models can simulate flood patterns within a Digital Surface Model - DSM basis. Beyond that elevation and reduction of flood levels monitoring, as flood velocities, routes, and duration and flooded areas might be simulated and be helpful to evaluate possible potential flood losses.

According to Hailea and Rientjieb (2005) a detailed model, which provide accuracy simulate near real settings and flow blockages, topographycal gradients that affect hydraulic gradients and flow, as velocities and routes. Misunderstandings in topographical representation in towns, for example, may cause many problems for stakeholders. ALS technology may solve problems related to erroneous topographical representation. ALS potentials help to develop maps within 15 cm altimetry accuracy depending on landcover and 1 m spatial resolution. ALS hastening surveys in valleys for many purposes, both spatial and topography monitoring. Though, the most important aspect involved is the resolution required.

Small scale hydraulic processes can be improved within high-resolution models. Once in-put data is reliable models improve floods simulations in meadows, dams and other. Meanwhile, DEM´s in-put for hydrological modelling, in general, is developed with low-resolution data. Post-control samples with LiDAR data are used to prevent important information losses, for example, for landcover and dams. Field work support is required as a surveying control. Also, in case of hydraulic structures, as bridges, buildings heights among other data topographical surveying is needed. Rugosity other specific information must be observed in the study area.

Sensor selection and resolution required must be preceded by purposes evaluation; time and a coherent grid. If low-resolution DEM´s is used generalization control is advisable to avoid relevant information losses. High-resolution DEM´s require time for computational processing.

2. MATERIALS AND METHODS

2.1 Materials

The materials available are Cartography in scale 1: 50.000 from *EPAGRI - Empresa de Pesquisa Agropecuária e Extensão Rural e Santa Catarina S.A* and Cartography and Aerial Color Ortophotos scale 1: 1.000 (2009); Digital Terrain Model – DTM from Joinville´s City Hall - *Prefeitura Municipal de Joinville*, developed by *Aeroimagem Engenharia e Aerolevantamentos S/A*, high-resolution satellite imagery Quickbird, e.g. ortho-rectified, georreferenced, 4-meter resolution (Red, Green, Blue, Near Infrared),1-meter resolution panchromatic, Thematic Maps, e.g. Soil Aptitute, Geological Hazards, Potential Resources, developed by Gonçalves (1993) in scale 1 : 50.000; Measurement from maps and data available, e.g. Impermeabilization tax; Occupation tax; Prescipitation and other pre-existent information. Also, ALS point cloud is being contested in PMJ and Aeroimagem Engenharia e Aerolevantamentos S/A.

2.2 Methods

Method comprises photo and image interpretation and analysis from Aerial Photographs and Quickbird´s imagery, development of thematic maps, identifying *Cachoeira´s* basin urban patterns, separating landcover themes (streets, pavement, buildings, green areas and open spaces). Also, vectorization of geological maps developed by Gonçalves (1993) and eventually Baggio (1998) research about subterranean water resources.

Large Scale Cartography support to produce thematic maps, identify sub-basins limits, types and landcovered areas and occupation and other physical parameters. Hydrological modelling and simulations, settings, considering topography, areas, heights and thematic maps. Compare hazard areas (very-high, high, medium, low, very-low) with land use and occupation plans, e.g Masterplans.

3. CASE STUDY

3.1 Location and Relevance

Joinville´s location is Northeastern *Santa Catarina´s* State between 23°00‘ and 26°00‘ S and 48°45‘ and 49°10‘ W. *Cachoeira*’s basin is a large plain, within 84,82 km² and comprises other 7 smaller basins, Fig. 2. *Cachoeira´s* basin drains to the largest most austral South America´s mangrove. *Babitonga´s* Bay is influenced by tides, as a result there are saltmarshes, swamps, mudflats and other environmentally fragile ecossistems important to ecological processes, estuarine and oceanic food webs in South Atlantic.

3.2 Environmental Degration

According to Morales (2004) urban sprawl and high-level of landcover worsen floods and landslides. However, precise information about river flows remains unknown, (1-3 and 5 m³/s). Low *Cachoeira´s* the largest amount of discharge has a tidal origin. High level of degration, deforestation, water contamination and eutrophication due to pollution; high levels of organic (sewage, garbage, efluents) and chemical pollution (Cr, Ni, Cu, Pb, Zn, Fe), erosion (sediment discharge of more than 0,6 milion m³ each decade). Population in the basin is 212.777 inhabitants; 25,69 inhabitants/hectare. *Companhia Água de Joinville* (2008) recognizes sanitation attends only 15% inhabitants. Rain has an orographic origin, from interceptation of *Serra do Mar* mountains leans and maritime humidity of 85% brought by East wind. Cachoeira´s main stream has 15 km draining several neighbourhoods and downtown areas. If high tide occurs, riverflow is inverted and saline flows into firth reaching 7,5 Km headstreams. Low heights near firth, high tides blockage effect, plus heavy rain in clay, sand, peat cause frequent floods in *Cachoeira* Basin.

3.3 Water Resources

According to Knie and Lopes (2002) *Cachoeira´s* headstreams 40 m height and firth sea level; estuary. *Saguaçu* lagoon and *Babitonga´s* Bay are influenced by high tides. Hermann (2007) and Silveira and Kobyiama (2007) identify geo-hydro-morphology is important to high vulnerabilities exposure; severe river and sea floods, severe landslides. Oliveira (2000) analyses progressive advance of saline flows into aquifers is a consequence of human settlements. *Cachoeira´s* affluents are *Morro Alto, Mathias, Jaquarão; Bucarein, Bom Retiro and Boa Vista*. Basin´s location is entirely downtown, see Fig. 3. *Cachoeira´s* basin is influenced by tides, so, sea level rising processes must be considered. Many authors have been studying settings for the future, as Scheel-Yberta et al (2009), Angulo (1992), Bigarella (1976) and Oliveira id. show indicators useful for this research, e.g. variation for sea level in Brazilian´s coast in last 7.000 years.

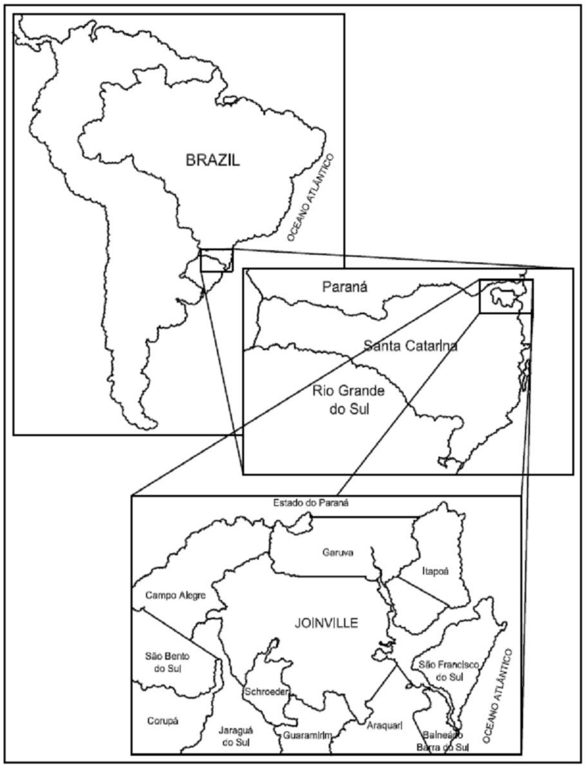

Figure 2. Joinville´s location in *Santa Catarina* State, South Brazil and South America.

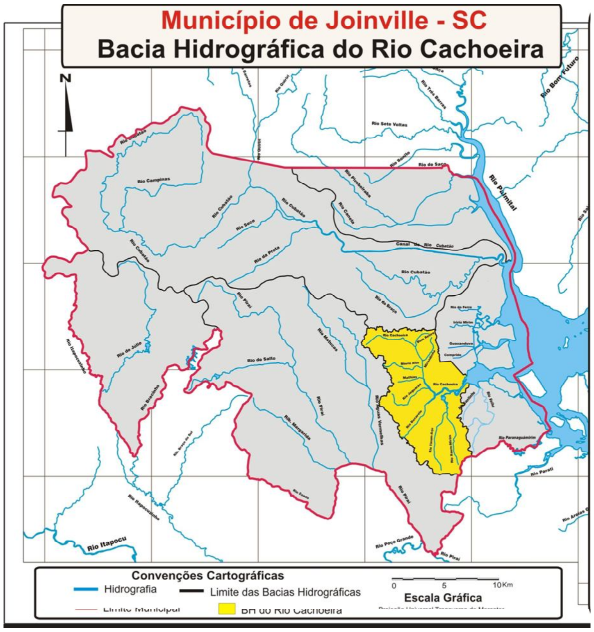

Figure 3. Joinville´s location in *Santa Catarina* State, South Brazil and South America.

3.4 Geology and Geomorphology

According to Angulo id, Bigarella id. and Oliveira, id. coastal floodplain´s comprise transgressive Holocenic barriers, regressive Holocenic barrier, Holocenic estuary, holocenic estuarine canal, Cenozoic continental sediments, Pleistocenic sediments, Pleistocenic barrier and cristaline basement. Sandy terraces are built with combination of wind and sea processes.

Sandy terraces are important to basins disposal control, river flow and aquifers flow directions in coastal floodplains. Aquifers in the area are shallow and highly vulnerable to saline flows advance if overdrainage occurs. Geomorphology comprises three major systems; *Serra do Mar* (900 m height), Floodplains (10 m height or less) Estuarine and Lake Complex – *Babitonga*`s Bay and Saltmarshes, whose connection are water resources. Gonçcalves (1993) geological survey identified average 13 m of clayey soil (5-30m depht) from Holocenic barrier or Holocenic paleo-estuaries. Ângulo (1992) detected sandy terraces (12,6; 4,6 and 1,8 m depht) appear parallel and along coastline (SW-NE), 0,5and 6,0m depth and Peat between 0,5 and 4,5m depth.

3.5 Previous Hydrological research

Benetti and Ramos (2005) detected 4 monitoring stations in *Joinville*, Fig. 4, from governmental institutions *Agência Nacional de Águas – ANA, EPAGRI – SC - Empresa de Pesquisa Agropecuária e Extensão Rural de Santa Catarina S/A, Estação Meteorológica UDESC-UNIVILLE Universidade para o Desenvolvimento do Estado de Santa Catarina* and identified lack of a dense monitoring net and difficulties for rain intensity detection, evaluate duration and frequency of intense prescipitation events or heavy rains detection. Authors used Filling Failures Method and Consistency Analysis (Double Masses Method) and produced information about Prescipitation (Time and Space variation), Total Prescipitation, Monthly Average, Annual Average, Spatial Average Prescipitation, Annual Series Frequency Analysis, Daily Maximal Average x Return Time - RT, Annual Total Prescipitation Variation, Table 01. Monthly Total Prescipitation, Prescipitation Index, Average Rainy Days, Daily Maximal Average x Return Time-RT (Method : Probability Distribuition of Gumbel).

Station	Prescipitation /year
2648014	1547,7
2648034	3105,9
2648036	2360,9
2649060	2276,0

Table 1. Average Total Annual Prescipitation. Adapted from Benetti and Ramos (2005).

Another emphasis was lack of temporal and spatial database to draw or tabulate information, useful for civil protection and water resources planning improve, management and other purposes. Differences depend on geographical position and height compared to sea level. Theoretical concepts were confirmed, e.g Station 2648034 (*Estrada dos Morros*) registered the highest prescipitation levels due to settlement near Serra do Mar. Also, emphasized temporal and spatial database to improve civil protection, water resources planning, management and other purposes.

Heemann and Hackenberg (2003) state run-off index and maximal flow research provide support for for civil protection, town planning, land use and land occupation legislation, water resources management decision.

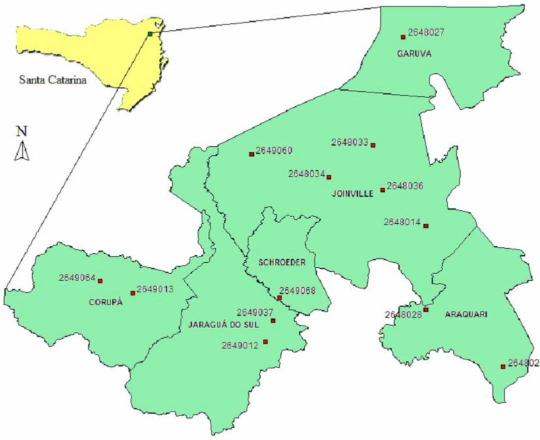

Figure 4. Monitoring Stations in Joinville,
Source : Benetti and Ramos (2005).

Authors detected run-off increase in *Joinville*, which is worsened during heavy rain events. Landcover quantifying is improved using Cadastre, large scale cartography and aerial photos. Several downtown quarters had been surveyed and compared between 1994 and 2001. Vectorization is needed, when Cartography is not uptodate. *Joinville´*s landcover index stands between 30 to 75% increasing run-off, riverflows. Other negative consequences were noticed, e.g. erosion, undermining, side erosion processes and river sedimentation. Between 1994 and 2001 landcover changes occurred, deforestation, restoration and construction. In 1994 landcovered area was 638.837,38 m² or 61,05% downtown *Joinville*. In 2001 landcovered increased to 66,30%. In 1994 were quantified 72.393,47 m² of green areas, 6,01% downtown, however, green areas were reduced in 2001. Downtown area has 1.046.342,60 m², however, only 49.220,58 or 4,70% m² is green. Authors acquired topography in *Joinville´*s Drainage Department, using each corner heights to draw drainage direction, identify buffer zones and limits of the fourteen sub-basins, each one less than 1 Km². Authors concluded downtown area run-off increased 35 %.

According to Tucci et al. (1995) research about Run-off offer challenges as hydrological aspects, e.g. soil type, landcover and land occupation, humidity, prescipitation intensity. Generalisations alike using only one average index for a whole basin is not a realistic hypotesis.

4. EXPECTED RESULTS

4.1 Preliminary statements

The challenge to face floods and landslides, and also other types of disasters is the reaction to phenomena. Disasters must be a turning point. The key concept seems to be change approach in order to solve the problems; prepare for the future, prevent and deal with future disasters, as states Gruber (2008) and EIRD – International Strategy for Disaster Reduction and other issues give priority to non-structural approach (land use, settlements, legislation and fiscalization). For Raschky (2008) disasters are connected to : institutions level of preparedness or how to deal, which efficient adapting solutions are available.

ALS and Large Scale Cartography improve Risk Maps development, representing with much more details hazard areas, limits (very high, high, medium, low, very low).
These tool is needed to detect vulnerability, endangered areas and populations, support floods and landslides zoning. Also, contribute for inhabitants awareness, instruments to provide Early Warning and support operational skills of Civil Protection, and humanitarian aid, as Red Cross.

4.1.1 Expected results

Thematic maps as Geology Map; Declivities Map; Hydrography Map; Land Occupation and Land Use Map; Built Areas Map (types of landcover layers); Modelling in-puts and testing. *Cachoeira´*s basin topographical evaluation; research about tides influence over floods and landslides; hydrological modelling; produce thematic maps; analysis of geomorphology, hydrology patterns, land use and occupation relationship; simulations out-puts. e.g probably flooded areas, floods depht according to return time - RT; verify conflicts between land use and occupation x hazards and reinforce the importance of townplanning and water and land management considering water resources and disasters prevention.

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6. ACKNOWLEDGEMENTS

A Universidade Federal de Santa Catarina – UFSC and Programa de Pós-Graduação em Engenharia Civil, Florianópolis, Santa Catarina, Brazil. Università degli Studi di Trento, Trento, Italy. Brazilian *Conselho Nacional de Desenvolvimento Científico e Tecnológico – CNPq* and *Fundo Setorial de Recursos Hídricos – CT HIDRO* for the scholarship and approval of grant for Project 480651/2007-8 from *MCT/CNPq 15/2007 - Universal / Faixa C* Call. European Union. Erasmus Mundus – ISAC - Improving International Skills Across Continents for the scholarship, health insurance, fees and travel expenses. Brazilian Advisor Professor Dr. Carlos Loch. Italian Advisor Professor Dr. Corrado Diamantini. Other Professors and Researchers from both universities. Msc. Eduardo Dalbosco, Joinville´s Secretary for Planning, Budget and Management Affairs, Msc. Patricia Becker and Msc. Celso Voos Vieira from Joinville´s Geoprocessing Department. Civil Engineer Antônio Luiz Codespoti Teixeira de Freitas, Head-Director of Aeroimagem S/A, Dr. Everton da Silva, Msc. Roberto Elizeu Preosck, Survey Eng. Suely Bárbara Laskowski and Msc. João Norberto Destro.