# ACQUISITION GUIDELINES FOR DIGITAL IMAGERY AND TERRAIN DATA FOR THE SAN DIEGO REGION

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# INTRODUCTION

# INTRODUCTION

Member agencies of the San Diego Regional GIS Council have a continuing requirement to acquire updated digital imagery and terrain data. The high acquisition costs and complexity of these projects have led to the formation of image acquisition partnerships between Council members. After considering the lessons learned from these acquisition partnerships, the Council formed the Imagery Subcommittee to address the need for regional coordination and to define actions that will facilitate a cooperative approach to future imagery and terrain data acquisitions.

The purpose of the Acquisition Guidelines for Digital Imagery and Terrain Data for the San Diego Region is to provide guidance on the issues and complexities related to imagery and terrain data acquisitions and to suggest a framework for future coordinated acquisition projects among local agencies in the San Diego region. In addition, this document describes the benefits of coordinated, multi-agency acquisition projects; documents typical issues that need to be considered when acquiring digital imagery or terrain data; outlines the major tasks associated with successful acquisition projects; and provides a history of regional and subregional imagery and terrain data acquisitions.

The imagery subcommittee also has prepared a companion document entitled Acquisition Plan for Digital Imagery for the San Diego region. This document provides a framework, schedule, and budget estimates for future coordinated imagery acquisitions. The Acquisition Plan for Digital Imagery for the San Diego region is the document local agencies are encouraged to use and adopt for their imagery acquisition needs. Adoption of this document will assist in the planning and budgeting for future image acquisitions, and lead to a coordinated, systematic approach to obtaining up-to-date imagery on a more frequent basis. Acquiring digital imagery through coordinated, multi-agency partnerships will provide significant savings to individual agencies.

Another companion document may be prepared related to cooperative efforts to acquire higher resolution terrain data for the region. The need for better terrain data for the region continues to exist; however, acquiring significantly improved data for an area as large San Diego may be cost prohibitive. To date, it has been difficult to justify the costs of a better terrain model, particularly if used solely for imagery orthorectification purposes. Justification will become even more problematic if commercial vendors obtain and utilize better terrain data to prepare commercially available regional-scale imagery. If this occurs, then a regional-scale terrain data project may need to wait for a dramatic drop in acquisition costs or for a collaborative effort funded by federal, state, and local agencies.

The Council anticipates that this document and the Acquisition Plan documents described above will be updated after each coordinated, multi-agency imagery or terrain acquisition project, or as needed to keep current with technological changes in the industry.

# GUIDELINES

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## I. PURPOSES AND GOALS

### A. Statement of Purposes

The purposes of the Acquisition Guidelines for Digital Imagery and Terrain Data for the San Diego Region are to inform agencies about the issues related to acquiring digital imagery and terrain data, provide a framework for coordinating imagery and terrain data acquisition projects, facilitate procurement of digital imagery products which best meet the needs of regional and local agencies, and facilitate and promote sharing of digital imagery among multiple agencies in the San Diego region.

### B. Goals

- To reduce individual agency acquisition costs for digital imagery and terrain data by sharing workload and costs.
- To reduce data redundancy by promoting local, state, and federal cooperatives and partnerships.
- To promote regional coordination by sharing information, methods, and data related to digital imagery and terrain models.
- To standardize the process for acquiring imagery and for generating terrain data.
- To provide a common set of terms and standards related to digital imagery and terrain data.
- To provide an historical account of cooperative efforts for obtaining digital imagery and terrain data.

### C. Benefits

- Partnerships allow for economies of scale to be realized while lowering the cost to individual agencies.
- Partnerships may allow for digital imagery or terrain data to be obtained on a more frequent basis, thereby providing more up-to-date information to support homeland security, natural disasters, and other efforts where information recency is of critical importance.

- Image or terrain acquisition projects that are cost prohibitive for one agency may be feasible through the use of partnerships.

- Without partnerships, many image or terrain data acquisition projects may not occur.

- In general, partnerships and pooling of funds and resources allow acquisition of higher quality data with a broader area of coverage, thereby making the data useful to more agencies and applications.

- Acquisition project tasks such as research, procurement, evaluation of final products, and distribution of final products can be shared among partnering agencies, thereby reducing the burden to any single agency.

- The interagency collaboration of partnerships provides for a broader use and acceptance of the imagery and terrain data obtained and promotes data sharing between agencies.

- A greater understanding of terminology, concepts, and acquisition procedures for imagery and terrain data will lead to a greater appreciation of the activities related to successful acquisition projects, and will reduce the time required to educate, discuss, and plan for future projects.

- A greater understanding of the past history and future direction of regional and subregional imagery and terrain data acquisition requirements will provide agencies with information to inform their staff and to facilitate financing strategies for future acquisitions.

# II. BACKGROUND ON PREVIOUS IMAGE ACQUISITION PROJECTS

## A. Regional Image Acquisition Projects

It is generally cost prohibitive for all but the largest and well-funded agencies to acquire high to very-high spatial resolution (3-foot to ½-foot) digital imagery to cover large areas of the San Diego region. Therefore, multi-agency partnerships are essential to funding large-scale image acquisition projects. In addition to cost savings, partnering to acquire digital imagery for an area as large as the San Diego region usually allows a higher resolution product and a broader area of coverage to be obtained.

As the use of digital imagery in the region has grown and become more sophisticated, the demand for more frequent, timely, higher resolution, and higher accuracy products has increased. In addition, there are now more competitive sources from which to obtain digital imagery. These sources include: satellites (which are making higher resolution image products more readily available), conventional capture by analog film and subsequent conversion to digital products, and more recently, image capture via digital cameras or imaging radiometers (e.g., scanners) flown on low altitude aircraft. Any high to very-high resolution image acquisition project for the region will be expensive. Costs increase significantly as spatial resolution and accuracy requirements increase.

Cooperative acquisition of digital imagery in the San Diego region began in the mid 1990s with a partnership formed to fund the acquisition of SPOT satellite imagery for use in updating land use vector databases. Partnerships to acquire the USGS DOQQs focused on providing local funding to obtain complete regionwide coverage and/or to create value added image products useful to the partnering agencies and local GIS community. Usable DOQQ imagery products sometimes were provided to the local GIS community two years after the date of image capture.

With the exception of the CIR digital imagery partnership in 2000, historical regional imagery acquisition projects have not represented the true costs to acquire broad-scale regional imagery. This is generally because partnerships were formed to acquire existing digital imagery and did not pay for the cost of acquisition, the cost of scanning film to digital format, or for project administration and overhead. In addition, the agency responsible for taking the lead role was not reimbursed for managing the partnership and consultants. The resources required to lead a successful partnership are significant and include partnership outreach, writing Requests for Proposals (RFP), managing consultants, evaluating and proofing final imagery products, determining fair pricing structures, invoicing, and distributing final products to the partners (see Section IV, Roles and Responsibilities of an Acquisition Partnership, for more details on specifics concerning an acquisition partnership).

## B. Subregional Image Acquisition Projects

There have been a number of very successful subregional partnerships to acquire very high resolution digital imagery and terrain data to support the work programs of cities and water districts. These occurred in 2001 (an effort led by the San Diego County Water Authority), 2004 (an effort lead by the City of Chula Vista for areas in the South Bay), and the largest occurred in 2005 (spearheaded by the City of San Diego and facilitated by SANDAG). All of these partnerships obtained 3-inch to 6-inch resolution imagery with accuracies between 1:1,200 and 1:2,400 and terrain data to support the generation of 2-foot contours. The areas of coverage varied for each of these subregional partnerships based upon the area of coverage required by the participating agencies. The 2001 effort covered 215 square miles, the 2004 effort covered 275 square miles, and the 2005 effort covered 820 square miles.

These partnerships came about by one agency's need for updated imagery or terrain data, and that agency outreaching to others. No one agency represented the partnering agencies, although the agency with the need for updated imagery or terrain data did take the lead in issuing the RFP and selecting a consultant. Each agency that participated in the partnership negotiated its own contract and desired products with the selected vendor, and was responsible for proofing the final deliverables.

Significant cost savings were realized by all agencies participating in each of these partnerships.

Appendix A provides more details on each of the historical regional and subregional image acquisition partnership efforts that occurred in the San Diego region.

# III. TECHNOLOGICAL ADVANCEMENTS AND CHANGES

Over the last few years, significant advancements have occurred in capturing imagery using digital cameras versus traditional analog film-based cameras. There are a number of different types of digital cameras on the market successfully being used to acquire imagery. Digital cameras have a number of advantages over film-based cameras, including: eliminating the need to scan the film to digital format, ability to capture color infrared images at the same time as true color imagery, better radiometric information, and reduction in time between capture of imagery and delivery of final products to customers.

Initial digital camera technology used push-broom sensors to capture imagery, similar to satellites. New advancements in digital cameras now employ frame-based systems. The advantage of frame-based systems is that the procedures for orthorectification of the imagery are similar to those that have been in place for film-based cameras. This allows for easier, more rapid adoption of the new digital systems by traditional orthorectification firms.

Use of digital cameras to acquire imagery is becoming more commonplace, has been proven as a viable alternative to film-based image capture, and is increasingly becoming very cost competitive.

# IV. ROLES AND RESPONSIBILITIES OF AN ACQUISITION PARTNERSHIP

## A. Project Organization

Each acquisition project is unique, will require a lead agency or champion, and should be managed by a project team. The lead agency most likely will be the agency that is in need of a particular image product, and most likely will be the prime point of contact for the partnership and the contractor. The project team will be comprised of some or all of the partnering agencies and will assist in defining the specifications for the imagery, the methodology for the project, QA/QC protocols, the roles and responsibilities of the lead agency and partners, and oversee the entire image acquisition project. It is expected that all partners will share an equitable portion of the project administration costs, although one or more agencies may function as the lead and be responsible for many of the tasks. In addition, it is possible to hire a consultant to facilitate this process and help solidify the partnership, although this will add an additional cost to the project. This method has been used successfully in other areas of California. Listed below are the typical tasks required for an acquisition project. The ordering of these tasks may differ for each image acquisition project.

## B. Forming the Partnership

### Partnership Outreach

The project team will prepare a project charter that includes a description of the acquisition project, imagery or terrain product, partnering agencies, and defines agency roles and responsibilities. It is extremely important to have the image specifications in writing to minimize misunderstandings about the image products being proposed and solicited for partnership. The project team will solicit responses in an effort to determine the level of interest, the scope of the project, and an approximate budget for the project. In addition to defining their imagery needs, the project team also should determine the needs of other agencies to see if the imagery product can be modified to be more useful to a larger number of agencies. It is a good idea to reach out to local, state, and federal agencies, and, if appropriate, universities, community colleges, utilities, and private firms. This phase may require several iterations over a period of a few months.

### Define Image Products

The image product being acquired needs to be defined clearly to eliminate misunderstandings from the partners or the consultant hired to create the image product. Product specifications include defining the type of imagery, method of capture (digital vs. film), resolution, accuracy requirements, and other factors which are described in more detail in Section C.

### Formalize and Finalize the Partnership

Once the scope of the project and image products have been defined through the outreach effort, the partnership needs to be formalized and finalized. At this point, the project team should have a fairly solid budget for the project, firm commitments from potential partnering agencies, and a plan on how cost will be split between participating agencies. Costs per agency should be simple to implement and be based on required area of coverage. Agencies may be able to participate in the partnership by contributing in-kind services in lieu of a monetary contribution. Additionally, the roles and responsibilities of each agency in the project team and agencies in partnership should be clearly defined. Formalization of the partnership can be handled through a Memorandum of Understanding that stipulates a funding commitment from each agency.

### Obtain Funding Commitments and Identify Per Agency Costs

The last step in establishing the partnership is to get a standardized formal letter of commitment for funding from each participating agency. The letter should come from a person who has budgetary discretion and authority to commit the agency to the partnership. If any agency decides not to participate at this point in the process, the per-agency costs of the remaining agencies will increase and will need to be recomputed. In addition to finalizing and legalizing the cost commitments, this document also can serve as a mechanism to describe the final image products that each partnering agency will receive. This will help ensure that there are no surprises to the partnering agencies at the end of the project.

## C. Consultant Selection Process

The project team will draft a Request for Proposal (RFP) for the desired image acquisition project. The RFP should contain as much detail as possible on the desired specifications of the imagery (type, resolution, positional accuracy, area of coverage, etc.) and the scope of the project. The project team will assist in reviewing the RFP, submitted proposals, and selecting the final contractor/consultant. Below are some of the topics that should be considered when drafting an RFP.

### Define Image Specifications

Defining the specifications of the desired imagery is an important step. They should include image type (e.g., panchromatic, true color, color infrared), image resolution, positional accuracy requirements, desired rectification (e.g., true orthos or simple rectification), image formats, and coordinate system. They also should define requirements for color/radiometric balancing, mosaicking, desired compression scheme, and acceptable compression ratios. In addition, the project team may want to specify the type of image acquisition method (e.g., conventional aerial camera, digital cameras/sensors or satellite remote sensors); describe the types of uses for which the imagery will be used; and if it is important to the project, the optimal time of year for image capture. This may help potential proposers to better understand the image acquisition project and end user needs to assist in recommending a particular type of image product.

### Define Quality Assurance and Quality Control Procedures (QA/QC)

A QA/QC plan needs to be fully described, documented, and followed throughout the project. The plan should contain a schedule, the responsibilities for QA/QC by the contractor and the project team, the scale at which reviews will take place, and minimum standards that the contractor must meet. The imagery partners also must fully understand and agree to the QA/QC standards so that they are aware of the acceptable limitations/artifacts that may be contained in the final image products. The QA/QC plan establishes the expectations for the project and can be the difference between what is perceived as a good or poor imagery product. Everyone involved must fully understand these expectations.

### Define the Final Image Products to be Delivered to the Partners

The imagery products to be delivered to the lead agency and ultimately to the partnering agencies must be clearly defined. This includes defining the issues described previously in the image specification section, as well as technical specifications defining the final image products partnering agencies will receive. These include whether the final image products will be compressed, the desired compression scheme, the tiling structure, the area of coverage each agency will receive, and the delivery media.

### Project and Product Metadata

Complete metadata on the project and imagery products also should be specified in the RFP as a deliverable at the end of the project. The project metadata should consist of documentation on the specific procedures followed on the project, including imagery creation, rectification, and QA/QC procedures. The metadata also should include documentation on the positional accuracy of the imagery, the method used to derive the accuracy measures, and a discussion of any known issues or limitations to the imagery.

### Define Licensing Structure

The partners must consider what type of licensing structure is acceptable. The terms of ownership and distribution rights also must be established. All partners must fully understand these rights and adhere to them. Many times a licensing structure is suggested in the contractor's proposal or can be negotiated during the contract award.

### Select an Imagery Consultant

The project team should independently review and rank the proposals that best fit the needs of the imagery project. The project team should discuss all proposals with greater emphasis focused on the most qualified proposals, and a determination should be made as to which proposal is most suitable for the project.

### Award a Contract

The project team can begin contract negotiations with the first ranked firm. If an agreement cannot be reached with this firm, then the next ranked firm should be contacted.

## D. Manage Imagery Consultant (Lead Agency(s) or Third Party)

In order to receive a high quality and timely product, contract and consultant monitoring is essential. The process should include a project kick-off meeting to allow face-to-face introductions amongst the project parties. Other meetings related to project milestones also should occur in person, if possible. Regular communication with the contractor should be established up-front and maintained throughout the project. Biweekly or monthly progress reports from the contractor are a good way to accomplish this and should be required in the contractual agreement. Progress reports provide information on work accomplished to date, identify whether the project is on, ahead, or behind schedule and reasons why, identify problems and suggested remedies, and describes work scheduled for the next period, including resources or information required from the lead agency or project team.

Delays in imagery acquisition from aerial or satellite sources can be expected due to the weather. Although San Diego is known for its great weather, coastal haze, high clouds, or thunderheads in the mountains can delay the image acquisition and, therefore, the entire project schedule. The lead agency needs to work with the vendor to ensure that they are ready to go when the weather is suitable. This will be slightly more difficult with satellite imagery.

Once the imagery is acquired, it is a good idea to conduct a pilot project for a small area. For the pilot, the contractor should provide a sample of the raw imagery and a representation of what the final image deliverable will be. This should include georeferenced, rectified, mosaicked, and color balanced imagery, as well as samples of compressed imagery at various compression ratios (if final image products are to be delivered in a compressed format). This allows the contractor and the project team to have a mutual understanding of what is expected for the final image products and allows the contractor to identify and address any concerns up front. In addition, the resultant imagery from the pilot project can be provided to the partners in order for them to have a firm understanding of what to expect from the final products. In the case of a regional project, it is beneficial to pick a few pilot areas that cover different urban and environmental regimes.

For each milestone in the project, the contractor should provide a short report that summarizes work completed for that portion of the project. The reports should identify problems encountered, solutions for overcoming them, and modified timelines for completing the remaining steps of the project (if necessary). The lead agency or project team should sign off on these milestones so that the contractor knows they are heading in the right direction.

Additionally, it is the responsibility of the lead agency or project team to pass along pertinent information, such as delays, product adjustments, and samples to the other partners. It is in the best interest of the project team not to surprise any of the partners with products that they were not expecting.

## E. Perform QA/QC

As previously stated, the QA/QC plan sets out the expectations for the project and can define the difference between what is perceived as a good or poor product. The QA/QC procedures outlined in the contract should be followed by both the contractor and the agencies involved in the review process. This means that reviewing agencies should not critique the imagery at a scale larger than specified in the contract, nor should they expect the contractor to correct issues unless they are within the contractually agreed upon tolerances. Image attributes that should be of concern to the reviewing agencies conducting QA/QC analysis include: positional accuracy, overall color consistency, uniform image brightness, tile-to-tile color balancing, image hot spots, vignetting, and feature matching along frame edges.

It is a good idea to ensure that the contractor has done its required QA/QC process before providing the images to the project team for review. Hopefully, the contractor will catch many of the errors before the client ever sees the product. There may be artifacts in the final imagery that the contractor may not be able to fix which are within the acceptable tolerances defined for the project. For example, recent cut and fill or landscape grading operations that are not reflected in the terrain model may cause roads to have a wavy appearance; bridges along mosaic seamlines may not line up because their height is not recorded in the terrain model; or the vignetting is so strong on some images that it cannot be totally eliminated. In these and other cases, the project team will have to negotiate with the contractor on what can and cannot be fixed within the scope of the contract. This can be a very contentious time during the contract and emphasizes the necessity for a good, agreed upon QA/QC plan to be established early on in the project.

Hiring a qualified, third party, independent contractor to QA/QC final image products will eliminate the need for the lead agency(s) or partnering agencies to proof final deliverables. The independent QA/QC consultant will use the QA/QC procedures outlined in the RFP and/or the contract as the framework for evaluating the imagery products. This method has many benefits, but may increase the total cost of the project by about 5 to 15 percent.

## F. Distribute Data to Partners

Although product distribution sounds like an easy part of the project, it takes a bit of up-front planning so that an undue burden is not placed on the lead agency(s). Depending upon the size of the project, final image products can be gigabytes or terabytes of data. For regional projects, it is best to distribute images in a compressed format, such as MrSID or ECW, which can significantly reduce image file size by 80 percent or more.

Decisions also need to be made on a simple, easy to implement tiling structure for compression and distribution to partnering agencies. These tiling systems can be defined as standard windows, jurisdictional or other geographic boundaries, or unique user-defined areas. In addition, system file size limitations need to be considered when defining the tiling structure. The project partners should be consulted on where the splits are made. Additionally, an acceptable common standard data transfer media needs to be found that will work for all partners. Currently, DVD media and external hard drives are the most common transfer methods in universal use.

The lead agency(s) might consider including a provision in the contract making the contractor responsible for distributing the data to the partners. This is an especially good idea if the partners desire individual image tiles or unique user-defined compressed images. Writing large amounts of data to tape can consume significant amounts of time and network resources.

## G. Distribute Data to Non-Partners

It is very important for the partners to set up and agree on a pricing structure and policies for distributing the data to other agencies not involved in the partnership. Typically, inquiries about obtaining the imagery follow soon after product distribution to the partners. Historically, many of these inquires have come from agencies that were included in the outreach efforts but did not participate in the final partnership.

There are many options related to distributing the image products to non-partners. Some of these are listed below.

- The lead agency, project team, or partners could decide to have the contractor hold the licensing and resale rights to the imagery;

- The lead agency or one or more members of the partnership could be responsible for distributing the imagery to non-partners by inviting others to join the partnership after the fact, paying equivalent costs incurred by partnering agencies;

- The lead agency or one or more members of the partnership could distribute the imagery for the cost of time and materials;

- The lead agency or one or more members of the partnership could distribute the imagery free of charge, or

- Acquisition partnerships can include the USGS as a partnering agency and allow the USGS to serve up the data (raw or resampled) in the public domain.

Each option has advantages and disadvantages. For example, having the contractor hold the licensing and resale rights to the imagery might be an easy solution to absolve any one agency from the responsibilities of distributing the imagery after the project is completed. Inquiries simply can be referred to the contractor. However, this method can severely limit the partnership's ability to distribute the data to consultants working on projects for them, and may add an additional cost to the project, although some contracting firms may lower the price for the initial image acquisition if they think they can profit from future sales of the licensed imagery.

The lead agency or partnership can hold the license to the imagery and take on the responsibility to distribute the data by charging a partnership fee to those who request the data after the fact. The agency can use those additional fees to help support the next imagery purchase, cover some of its cost for leading the project, or distribute them back to the partnering agencies. Distributing the imagery for the cost of time and materials requires time by the lead agency to figure out what is needed for each request and to determine a common, efficient delivery medium. Distributing the imagery free of charge over an Internet imagery server may be appropriate, but would require the lead agency to invest in the appropriate hardware and software. Methods to distribute the imagery free of charge or for time and materials do not encourage agencies to join future partnerships since they know they will be able to acquire the data at a later date for little or no cost.

A partnership with USGS is a viable option given USGS's emphasis on placing current imagery in the public domain. USGS is willing to partner with local and regional agencies and provide funding for image acquisition efforts so long as the imagery, or some higher resolution resampled version of the imagery, can be made available in the public domain. This method of distributing imagery to non-partners eliminates the burden from any one local agency in the region.

## H. Use of a Third Party Consultant for Project Oversight and/or for QA/QC

The partnership may want to consider hiring a third party consultant to manage some or all of the tasks listed above. In this situation, the project team would put out an RFP for an image acquisition project manager. Desirable qualifications include: an intimate knowledge of the different types of available imagery, knowledge of the image processing techniques necessary to create high quality image products, good communication skills, proven QA/QC skills, and proven project management skills.

The use of a third party consultant is useful if there are insufficient resources or knowledge locally to undertake a particular image acquisition project. The third party consultant can work with the project team to establish a partnership, educate the partnership about the types of imagery available, narrow down what types of imagery will work for a majority of the partners' applications, and identify what companies would be best to solicit. They can be responsible for drafting an RFP, managing the entire project, QA/QC of the imagery products, and for distributing the imagery to the partners after the project is complete. Using a third party consultant reduces the burdens on the lead agency and project team but may increase the total cost of the project.

# DIGITAL IMAGERY ACQUISITION GUIDELINES

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Historically, multi-agency digital imagery acquisition partnerships have been regional in nature and have acquired digital imagery with the same spatial resolution across the entire project area. However, spatial resolution and accuracy requirements are generally different for regional agencies (agencies requiring countywide coverage) and subregional agencies (agencies requiring only a portion of the region such as a city, water district, etc.). Therefore, it may be feasible to form multi-agency digital imagery partnerships to acquire multiple resolution image products. These types of partnerships would specify higher spatial resolution imagery for urbanized areas, and lower resolution imagery for non-urban areas, and still obtain regionwide coverage. Separate partnerships for regional and subregional scale imagery in alternating timeframes is another approach. With this approach, the area of coverage for the subregional acquisition partnership would be defined by the participating partnering agencies.

The following two sections describe specifications and issues to be considered when obtaining regional and subregional scale digital imagery.

## I. PLAN A: REGIONAL SCALE IMAGERY

Generally, most regional agencies in San Diego now require high spatial resolution imagery to support their work efforts and they usually require imagery that covers the entire 4300+ square miles of the region (and sometimes areas outside of or adjacent to the region). These image products range from the public domain 1-meter DOQQs to higher resolution image products available from commercial vendors or defined on spec. Although regional agencies may require lower resolution imagery than subregional agencies, the need for regionwide coverage tends to make the higher-end resolution image acquisition projects costly. Therefore, image acquisition partnerships are essential in reducing the per-agency costs. The extent of inter-agency cooperation will vary based upon the imagery requirements of each agency and budget limitations, but as more agencies are made aware of the specifications and desired frequency of updates, agencies can plan for cooperative image acquisition projects. This section describes the specifications that agencies should consider when obtaining regional scale imagery.

Table 1 provides a brief summary of the historical regional image acquisition projects, costs, and partnerships. Appendix A describes and provides more details on the past regional image acquisition projects and partnerships.

| | Table 1. Historical Regional Imagery Acquisition Projects | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | **General Descripton of Project** | | | **Imagery Specs** | | | | **Cost** | | | |
| | **Date** | **Coverage** | **Square Miles** | **Type** | **Resolu-tion** | **Accuracy** | **Compression** | **Total Project Cost** | **# of Partners** | **Cost Per Partner** | ***Cost per Sq Mi.*** |
| | 1995 | San Diego Region & Tijuana River Watershed | 5,500 | Pan & XS | 10m Pan & 20m XS | 1:24,000 NMAS | No | $ 67,000 | 5 | $13,500 | *$ 12.00* |
| *A* | 1997 | San Diego Region | 4,355 | Pan | 3-foot | 1:12,000 NMAS | Yes, MrSID | $ 115,000 | 30 | $ 2,000 or $10,000 | *$ 26.00* |
| *B* | 1999 | San Diego Region | 4,355 | CIR | 3-foot | 1:12,000 NMAS | Yes, MrSID | $ 55,000 | 30 | $ 2,000 or $ 4,300 | *$ 13.00* |
| *C* | 2000 | San Diego Region | 4,355 | CIR | 2-foot | 1:12,000 NMAS | Yes, MrSID | $ 113,000 | 30 | $ 2,000 or $10,000 | *$ 26.00* |

Notes: All costs are for contractor costs only and do not include costs for the RFP process for consultant selection, QA/QC of imagery, project management, or project implementation. In addition, all of these image acquisition projects were based upon imagery captured by conventional aerial cameras, with the exception of the 1995 project, which was based upon SPOT satellite imagery.

***Footnotes:***

A *Imagery acquired was 1994/96 panchromatic USGS DOQQs. For this project, the partnership also funded part of the acquisition costs, as well as the costs to create value added image products to make the imagery useable by local agencies in San Diego. Value added image processing includes reprojection to State Plane Coordinates, resampling pixels from 1 meter to 3-foot, color balancing, and image compression.*

B *Imagery acquired was 1996/97 false color infra-red USGS DOQQs. This project only funded the cost of creating value-added image products.*

C *First Imagery acquisition project for the region funded from scratch. Costs incurred by partnering agencies for this project do not represent the true costs of a project of this magnitude. Consultant chosen to do this work did not completely appreciate the complexity of the project in San Diego and underbid the project cost, and SANDAG was not funded for the time and effort to lead the project, manage the consultant, QA/QC final products, and distribute final products to partnering agencies.*

## A. Specifications

The specifications described below are guidelines and may vary depending upon individual project needs. These specifications are based upon past imagery acquisition projects and informal conversations with regional agencies. To date, most regional agencies have used digital imagery as a back drop to assist with visual interpretations in updating land cover, vegetation, transportation, and other vector databases by displaying vector data layers contained within a Geographic Information Systems (GIS) database on top of the imagery. Most of the regional image acquisition partnerships focused on obtaining digital imagery captured from traditional aerial cameras rather than digital cameras or sensors.

Imagery captured with digital cameras or sensors can provide multi-spectral information. Multi-spectral imagery contains light reflectance captured from different wavelengths of the electromagnetic spectrum. This information can be used for both visual interpretation as well as automated image processing routines to extract and classify information obtained from the sensors. Automatic feature extraction and classification routines have not been used much in the region because they tend to yield coarser results than what currently are being maintained or desired. But these methods have proven cost effective in generating data from scratch over large areas. In order to maintain the vector databases to the level of detail required by regional agencies, visual interpretation still is the preferred methodology. Visual interpretation techniques generally require higher resolution imagery because human interpreters rely on context, pattern, and knowledge of the area, and less on the variation of reflectance values of the multi-spectral imagery.

### 1. Spectral Resolution:

Desired: Color infrared (CIR) or true color.

Discussion: Regional agencies generally prefer color infrared or true color imagery over panchromatic (black and white) because these products contain more information (both visually and spectrally) than panchromatic and, therefore, support a wider variety of applications and uses.

### 2. Spatial Resolution:

Desired: 1 to 3-foot is preferred.

Discussion: One to three-foot resolution is desirable, but costly, and the cost may affect how often these data are updated. Regional agencies generally can use imagery coarser than 3-foot for most of their needs.

### 3. Temporal Resolution (Frequency of Updates):

Desired: 2 to 4 years.

Discussion: Because of the cost and work effort associated with obtaining regional scale imagery, most agencies may only be able to support updating the imagery every 5 years. Coarser resolution imagery or off-the-shelf image products (described under Section III, Plan C: Commercially Available Imagery Products) could be used in interim years.

**4. Temporal Specifications (Season/Time of Day):**

Desired: For true color imagery, generally between the months of March and October, and between the hours of 10 am and 2 pm local solar time.

Discussion: Seasonality and time of day of image capture affect image quality. Generally, the time of year and time of day where shadows are the longest should be avoided. In addition, in San Diego, spring/summer acquisitions are desirable for discriminating vegetation types but persistent coastal fog poses problems during these months. Imagery captured during the fall season also can be problematic in that the natural vegetation typically is dry, thereby reducing contrast between the natural features.

To make the most use of the digital information in the imagery, it may be best to collect color infrared imagery between the months of May and October. This timeframe will avoid what are typically the wettest and driest periods in San Diego.

**5. Flight Planning**

Desired: Image capture along a north/south flight plan rather than east/west, and capture images with a 30 percent side overlap and a 60 percent forward overlap.

Discussion: Since distortions such as building lean and radial displacement increase toward the edges of an image, capturing imagery with a 30 percent side overlap and a 60 percent forward overlap helps ensure that only the center portions of each image are used in the rectification process and the final deliverables. Flying in a north-south direction reduces bi-directional reflectance problems and provides more even brightness between frames (particularly for frame cameras with rectangular footprints). In addition, the aircraft flying height should be appropriate for capturing the imagery at the desired spatial resolution and map accuracy scale. It would be a good idea to obtain the Global Positioning Satellite (GPS) data for the image center points as a final deliverable, as well as the calibration report for the equipment used to capture the image (e.g., camera, GPS, and Inertial Measurement Unit (IMU). Having the GPS data may be useful for repeat imagery capture at a later date to help with image-to-image co-registration.

6. **Positional or Spatial Accuracy:**

Desired: Every image product/deliverable should contain information on its positional or spatial accuracy and how it was measured as part of its metadata. For regional scale digital imagery, generally accuracies between ± 10 to ± 25 feet are acceptable. These accuracies will be highly dependent upon the date and resolution of the terrain data used in the rectification process. Higher accuracies can be achieved in the flat, low relief areas, but not in areas with high terrain variability.

Discussion: There are many different ways to specify spatial accuracy for orthophotography and many methods to define, calculate, and measure positional accuracy. The National Map Accuracy Standards (NMAS), the American Society for Photogrammetry and Remote Sensing (ASPRS), and the National Standard for Spatial Data Accuracy (NSSDA) are ways to describe positional accuracy. The NMAS and ASPRS methods have been used for years. The NSSDA is a new method that was developed in 1998 by the Federal Geographic Data Committee (FGDC). Although the NSSDA has not been used in the San Diego region to date, it may be utilized more in the future to specify accuracy requirements for digital imagery as more agencies adopt FGDC guidelines. Root Mean Square Error (RMSE) and Circular Error (CE) are standard methods used for determining or measuring the positional accuracy of digital image products. See Appendix C, Definitions and Acronyms, for more information on these accuracy measures.

7. **Radiometric or Color Balancing:**

Desired: Radiometric or color balanced across the entire project area.

Discussion: Most agencies want imagery (even panchromatic) radiometrically or color balanced across the project area. Since the San Diego region is so large and varied (oceans, urbanized areas, mountains, and deserts) image acquisitions may span several days (depending upon the type of imagery) and be comprised of multiple tiles/scenes. Each tile will vary in tonal quality. This is true even for the lower resolution products. Tonal variation within and between frames occurs due to weather conditions, time of day, and to differential reflectance as a function of view angle and type of terrain. Color balancing normalizes the color and brightness within and between image frames. Imagery that is not color balanced across the project area has an unpleasing look when viewed over large areas and detracts from the value of the product.

Radiometric balancing is a time-consuming and difficult process. Imagery usually is balanced locally, with nearby photos, and globally, with all the photos. The balancing becomes more difficult as the number of photos increases, which is influenced by the spatial resolution and area of coverage. Furthermore, the result of the balancing process is subjective to the viewer and the scale at which the data are viewed.

**8. Coordinate System:**

Desired: State Plane Coordinate System for California, Zone VI, US Survey feet, datum NAD83.

Discussion: Nearly all regional and local agencies in the San Diego region use the California State Plane coordinate system (with the exception of some state and federal agencies). If a different coordinate system is desired for special purposes (typically to meet data requirements of state or federal agencies), most GIS software can project imagery to a new coordinate system (although this can be a significant task for higher resolution imagery due to the number and size of images involved).

**9. Metadata:**

Desired: Complete documentation.

Discussion: All new imagery should be accompanied by complete metadata. At a minimum, the metadata should specify the technical specifications of the data, including: the date(s) of image acquisition, spectral resolution, spatial resolution, spatial accuracy, spatial extent, verticle datum, whether the imagery has been orthorectified or simply georectified, brief description of rectification process used, description of the QA/QC procedures used to evaluate the quality of the imagery, tiling scheme, compression scheme (if any), coordinate system, redistribution restrictions or policies, and contact information. Optional information may include camera or digital sensor specifications, and update schedule (if applicable). The metadata should be compliant with the standards developed by the Federal Geographic Data Committee (FGDC). In addition, it would be a good idea to prepare a one or two page summary sheet on the imagery specifications to use when providing the imagery to other agencies or users.

**10. Distribution/Licensing:**

Desired: Each image acquisition partnership needs to define a distribution policy for the end products.

Discussion: Each partnership should consider the benefits and costs of licensing the imagery. Many companies are willing to lower the price of image acquisitions if the company can retain ownership and be permitted to resell the imagery to others. For some agencies, licensing the imagery relieves them of the need to redistribute the imagery in response to requests from non-partnering public agencies, private firms, and the public. Responding to such requests can consume many hours of work. Alternatively, other agencies have no problem with redistributing the imagery. They argue that the information is public and was obtained using public funds and should be made available to them. They also see that providing such data should result in a more informed citizenry and adds to the ability of private firms to compete successfully. A potential drawback to allowing free access to the imagery after the fact is that agencies may not partner to fund these image acquisition projects and these data may not get developed at all.

**11. Compression:**

Desired: All individual image tiles and imagery in a compressed format that is compatible with leading GIS software packages.

Discussion: Most image acquisition projects for the region will involve large amounts of data, depending upon spatial resolution and type of imagery (e.g., single band versus multi-band). Efficient distribution and use of the imagery will require that it also be provided in compressed format. One of the most important considerations for the agencies involved in the partnership is to agree on a tiling scheme for both the tiled and compressed imagery. It is not likely that a single, seamless image can be prepared for the project area.

Currently, several compression schemes are commonly used by local agencies in the San Diego region. These include the multi-resolution seamless image database (MrSID) from LizardTech and ECW from ER Mapper. However, this technology is rapidly changing and other formats are becoming available and may become more commonly used in the future.

### 12. Horizontal and Vertical Control:

Desired: Use of surveyed ground control points or GPS coordinates and an up-to-date terrain model in the image georeferencing and rectification processes.

Discussion: For most orthophotography projects, acquiring or re-using ground control and digital terrain models (DEMs, DTMs) will be required to achieve high degrees of horizontal and vertical accuracy. With the common practice of using airborne GPS units and on-board inertial systems during the time of image capture, no specific requirements or guidelines on the density of control points are used these days. In general, digital imagery with tight vertical specifications will require more control, but not the density of control points that typically have been used in the past. If ground control points are to be used accurately, the epoch date associated with the survey data must be established. If ground control points are used that were collected over an extended period of time, these data may need to be converted to the most current epoch. Computer programs exist that can convert measurements with one epoch date to another. See Appendix C, Definitions and Acronyms, for more discussion on epoch dates.

## II. PLAN B: SUBREGIONAL SCALE IMAGERY

Most cities, water districts, and other smaller agencies in the San Diego region need to obtain more accurate, higher resolution imagery than likely will be obtained from regional scale imagery acquisition projects and partnerships. These agencies can expect to benefit from substantial savings by cooperating with other agencies in acquiring subregional scale imagery. The extent of inter-agency cooperation will vary, based upon the imagery requirements and budgets of individual agencies. But as more agencies are made aware of these specifications and desired frequency of updates, they can plan for cooperative image acquisition projects. The area of coverage for each acquisition project will be defined by the agencies participating in the partnership. This section describes the specifications that agencies should consider when obtaining subregional imagery.

Table 2 provides a brief summary of the historical subregional image acquisition projects.

## Table 2. Historical Subregional Imagery Acquistion Projects

| | General Description of Project | | | Imagery Specs | | | | Cost | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Date | Coverage | # Square Miles | Type | Resolution | Accuracy | Compression | Total Project Cost | *Cost/sq mi* | Costs include topo |
| E | 1992 | City of Escondido | 90 | Pan | 1- foot & 2-foot | ???? | No | $ 150,000 | *$ 1,667* | Yes, 2- & 5-foot |
| | 1992 | City of San Diego | 330 | Pan | 6-inch | ???? | No | $ 1,232,820 | *$ 3,736* | Yes, 2-foot |
| A | 1994 | City of Chula Vista | 127 | Pan | 6-inch | ASPRS Class 1 for 1:1,200 (RMS 1-foot) | No | $ 572,128 | *$ 4,505* | Yes, 2-foot |
| B | 1999 | City of San Diego | 337 | Pan | 6-inch | ???? | ??? | $ 450,000 | *$ 1,335* | Yes, 2-foot |
| | 1999 | Otay Water District | 147 | Pan | 6-inch & 1-foot | ???? | Yes, MrSID | $ 187,450 | *$ 1,275* | Yes, 5-foot |
| D | 2001 | City of Carlsbad | 55 | True color | 6-inch | ASPRS Class 1 for 1:1,200 (RMS 1-foot) | Yes, MrSID | $ 137,043 | *$ 2,492* | Yes, 2-foot |
| D | 2001 | City of Chula Vista | 8 | True color | 6-inch | ASPRS Class 1 for 1:1,200 (RMS 1-foot) | No | $ 40,322 | *$ 4,888* | Yes, 2-foot |
| D | 2001 | City of Encinitas | 35 | True color | 6-inch | ASPRS Class 1 for 1:1,200 (RMS 1-foot) | Yes, MrSID | $ 86,905 | *$ 2,483* | Yes, 2-foot |
| D | 2001 | City of Oceanside | 42 | True color | 6-inch | ASPRS Class 1 for 1:1,200 (RMS 1-foot) | Yes, MrSID | $ 110,303 | *$ 2,626* | Yes, 2-foot |
| D | 2001 | City of Coronado | 8 | True color | 6-inch | ASPRS Class 1 for 1:1,200 (RMS 1-foot) | Yes, MrSID | $ 64,074 | *$ 8,215* | Yes, 2-foot |
| D | 2001 | San Diego County Water Authority (CWA) | 215 | True color | 6-inch | ASPRS Class 1 for 1:1,200 (RMS 1-foot) | Yes, MrSID | $ 599,000 | *$ 2,786* | Yes, 2-foot |
| | 2002 | City of Solana Beach | 3 | Pan | 6-inch | ???? | jpeg ?? | $ 26,365 | *$ 7,754* | Yes, 4-foot |
| | 2003 | MCB Camp Pendleton & NWS Fallbrook | 280 | True color | 6-inch | 1:2,400 | Yes, MrSID | $ 190,579 | *$ 682* | No |
| | 2004 | South Bay | 275 | True color | 6-inch | 1:2,400 | No | $ 313,500 | *$ 1,140* | Yes, 2-foot |
| F | 2005 | City of San Diego & Other Urban Areas | 821 | True color | 3-inch | 1:2,400 | Yes, No | $ 1,012,502 | *$ 1,234* | Yes, 2-foot |

Notes: All costs are for contractor costs only and do not include costs for the RFP process for consultant selection, QA/QC of imagery, project management, or project implementation. It is difficult to compare costs across these projects due to the nuances and variances between projects. The footnotes below attempt to describe unique factors of the image acquisition project.

***Footnotes:***

*A Most of the City was done at 6-inch resolution with 2-foot contours, but some areas were done at 2-foot resolution with 10-foot contours.*

*B Costs were lower than those incurred in 1992 because a new DEM was not created, only 15 percent of the area was updated for this project.*

*D These agencies all partnered under one RFP prepared by CWA, but each agency had separate contracts with the selected consultant.*

*E Urbanized area (approximately 45 sq. miles) at 2-foot contours, outlying areas at 5-foot contours.*

*F Approximately 14 other agencies joined the City of San Diego project in 2005. Each agency negotiated individual contracts and products but received cost benefits due to partnering. With a few exceptions, all agencies partnered to receive the products described in the table above.*

## A. Specifications

Many of the specifications described on the following pages are based upon the consensus of agencies that responded to a survey of image acquisition needs conducted in 2006 by the Image Subcommittee of the San Diego Regional GIS Council. The minimum specification reflects what the respondents typically said would be acceptable. It should be noted that, while survey respondents indicated a need and desire for high resolution, high accuracy digital imagery, the budgets allotted for these products were not always sufficient. Some specifications listed below were not included in the survey and reflect current industry practice.

### 1. Spectral Resolution:

Desired: True color.

Discussion: Nearly all local agencies prefer true color imagery since these products are useful to engineering, public works, police, fire and planning departments. Environmental studies and projects would benefit from color infrared imagery but, since it is not desired by other departments, it generally is not obtained at subregional scales.

### 2. Spatial Resolution:

Desired: 0.25 to 0.5 feet (3-inch to 6-inch).

Discussion: Although it is costly to acquire, nearly all local agencies desire 0.5-foot (6”) resolution imagery or higher. Since the required area of coverage is smaller, imagery with higher spatial resolutions and accuracies work well for most agencies at the subregional scale. In addition, image compression, faster networks, and inexpensive disk storage all make managing and using higher resolution imagery feasible at local agencies.

### 3. Temporal Resolution (Frequency of Updates):

Desired: 2 - 4 years.

Discussion: Most agencies would like to have imagery acquired every 2 to 4 years, although every 5 years would be acceptable. Some agencies indicated that updates every 10 years also would be acceptable since their areas of interest do not change significantly over time.

### 4. Temporal Specifications (Season/Time of Day):

Desired: For true color imagery, generally between the months of March and October, and between the hours of 10 am and 2 pm local solar time.

Discussion: Seasonality and time of day of image capture affect image quality. Generally, the time of year and time of day where shadows are the longest should be avoided. In addition, in San Diego, spring/summer acquisitions are desirable for discriminating vegetation classes but persistent coastal fog poses problems during these months. Imagery captured during the fall season also can be problematic in that the natural vegetation typically is dry, thereby reducing contrast between the natural features.

To make the most use of the digital information contained within the imagery, it may be best to collect color infrared imagery between the months of May and October. This timeframe will avoid what are typically the wettest and driest periods in San Diego.

## 5. Flight Planning

Desired: Image capture along a north/south flight plan rather than east/west, and capture images with a 30 percent side overlap and a 60 percent forward overlap.

Discussion: Since distortions such as building lean and radial displacement increase toward the edges of an image, capturing imagery with a 30 percent side overlap and a 60 percent forward overlap helps ensure that only the center portions of each image are used in the rectification process and the final deliverables. Flying in a north-south direction reduces bi-directional reflectance problems and provides more even brightness between frames (particularly for frame cameras with rectangular footprints). In addition, the aircraft flying height should be appropriate for capturing the imagery at the desired spatial resolution and map accuracy scale. It would be a good idea to obtain the Global Positioning Satellite (GPS) data for the image center points as a final deliverable, as well as the calibration report for the equipment used to capture the image (e.g., camera, GPS, and Inertial Measurement Unit (IMU). Having the GPS data may be useful for repeat imagery capture at a later date to help with image-to-image co-registration.

## 6. Positional or Spatial Accuracy:

Desired: Every image product/deliverable should contain information on its positional or spatial accuracy and how it was measured as part of its metadata. Generally, accuracies of about ± 5 feet are acceptable for six-inch resolution imagery. These accuracies will be highly dependent upon the date and resolution of the terrain data used in the rectification process. Higher accuracies can be achieved with up-to-date high resolution terrain models.

Discussion: There are many different ways to specify spatial accuracy for orthophotography and many methods to define, calculate, and measure positional accuracy. The National Map Accuracy Standards (NMAS), the American Society for Photogrammetry and Remote Sensing (ASPRS), and the National Standard for Spatial Data Accuracy (NSSDA) are ways to describe positional accuracy. The NMAS and ASPRS methods have been used for years. The NSSDA is a new method that was developed in 1998 by the Federal Geographic Data Committee (FGDC). Although the NSSDA has not been used in the San Diego region to date, it may be utilized more in the future to specify accuracy requirements for digital imagery as more agencies adopt FGDC guidelines. Root Mean Square Error (RMSE) and Circular Error (CE) are standard methods used for determining or measuring the positional accuracy of digital image products. See Appendix C, Definitions and Acronyms, for more information on these accuracy measures.

**7. Radiometric or Color Balancing:**

Desired: Radiometric or color balanced across the entire project area.

Discussion: Most agencies want imagery radiometrically or color balanced across the project area. Tonal variation within and between frames occurs due to the weather conditions, the time of day, and to differential reflectance as a function of view angle and type of terrain. Color balancing normalizes the color and brightness within and between image frames. Imagery that is not color balanced across the project area has an unpleasing look and detracts from the value of the product.

Radiometric balancing is a time-consuming and difficult process. Imagery usually is balanced locally, with nearby photos, and globally, with all the photos. The balancing becomes more difficult as the number of photos increases, which is influenced by the spatial resolution and area of coverage. Furthermore, the result of the balancing process is subjective to the viewer and the scale at which the data are viewed.

**8. Coordinate System:**

Desired: State Plane Coordinate System for California, Zone VI, US Survey feet, datum NAD83.

Discussion: Nearly all local agencies (except some state and federal agencies) in the San Diego region use the same coordinate system. If a different coordinate system is desired for special purposes (typically to meet data requirements of state or federal agencies), most GIS software can project imagery to a new coordinate system (although this can be a significant task for higher resolution imagery due to the number and size of images involved). If elevation data are to be obtained, most agencies specify that the NAVD 88 standard be followed. See the section on Terrain Data Acquisition and Management Guidelines for more information on digital terrain model requirements.

### 9. Metadata:

Desired: Complete documentation.

Discussion: All new imagery should be accompanied by complete metadata. At a minimum, the metadata should specify the date(s) of image acquisition and technical specifications of the data, including spectral and spatial resolutions, spatial accuracy, spatial extent of the image, verticle datum, whether the imagery has been orthorectified or simply georectified, brief description of rectification process used, description of the QA/QC process used to evaluate the quality of the imagery, tiling scheme, compression used (if any), coordinate system, redistribution restrictions or policies, and contact information. Optional information may include camera or digital sensor specifications and update schedule (if applicable). The metadata should be compliant with the standards developed by the Federal Geographic Data Committee (FGDC). In addition, it would be a good idea to prepare a one or two page summary sheet on the imagery specifications to use when providing the imagery to other agencies or users.

### 10. Distribution/Licensing:

Desired: Each image acquisition partnership needs to define a distribution policy for the end products.

Discussion: Each agency should consider the benefits and costs of licensing the imagery. Many companies are willing to lower the price of image acquisitions if the company can retain ownership and be permitted to resell the imagery to others. For some agencies, licensing the imagery relieves them of the need to redistribute the imagery in response to requests from private firms and the public. Responding to such requests can consume many hours of work. Alternatively, other agencies have no problem with redistributing the imagery. They argue that the information is public and was obtained using public funds and should be made available to them. They also see that providing such data should result in a more informed citizenry and adds to the ability of private firms to compete successfully. A potential drawback to allowing free access to the imagery after the fact is that agencies may not partner to fund the creation and acquisition of these images and these data may not get developed at all.

### 11. Compression:

Desired: All individual image tiles and/or imagery in a compressed format that is compatible with leading GIS software packages.

Discussion: Most subregional imagery acquisition projects will involve large amounts of data because of the higher resolutions usually required. In addition to the individual image tiles, agencies also may want final deliverables in compressed format to make it easier to distribute and use. The most important consideration for the agencies involved is to agree on a tiling scheme for both the tiled and compressed imagery. It is not likely that a single, seamless image can be prepared for any sizeable area. Once the tiling scheme is agreed upon, then a determination regarding compression schemes can be made.

Currently, several compression schemes are used by local agencies in the San Diego region. These include the multi-resolution seamless image database (MrSID) from LizardTech and ECW from ER Mapper. However, this technology is rapidly changing and other formats are becoming available and may become more commonly used in the near future.

### 12. Horizontal and Vertical Control:

Desired: Use of surveyed ground control points or GPS coordinates and an up-to-date high resolution terrain model in the image georeferencing and rectification processes.

Discussion: For most orthophotography projects, acquiring or re-using ground control and digital terrain models (DEMs, DTMs) will be required to achieve high degrees of horizontal and vertical accuracy. With the common practice of using airborne GPS units and on-board inertial systems during the time of image capture, no specific requirements or guidelines on the density of control points are used these days. In general, digital imagery with tight vertical specifications will require more control, but not the density of control points that typically have been used in the past. If ground control points are to be used accurately, the epoch date associated with the survey data must be established. If ground control points are used that were collected over an extended period of time, these data may need to be converted to the most current epoch. Computer programs exist that can convert measurements with one epoch date to another. See Appendix C, Definitions and Acronyms, for more discussion on epoch dates.

## III. PLAN C: COMMERCIALLY AVAILABLE IMAGERY PRODUCTS

There are a number of aerial photography vendors that produce digital image products for San Diego on an annual basis. The specifications and area of coverage for these commercially available, off-the-shelf imagery products are defined by the vendor; the end user has no control over the final image product. These products tend to be available every year, have a quick turnaround between the dates of image capture and product delivery, and are relatively inexpensive. However, historically these products generally have not had a rigorous rectification process to provide the positional accuracy required by most agencies, often did not contain rigorous color balancing procedures, did not provide regional coverage, or did not provide options for multi-agency purchases. In addition, the majority of this type of imagery is captured during the months of January and February, when shadows are most noticeable, and is available only as true color imagery.

However, the commercially available, off-the-shelf imagery products are improving. Resolution and accuracies have improved over time and area of coverage has expanded (some years countywide imagery has been available). In addition, at the time of this writing (Spring, 2007), some vendors may offer multi-agency purchasing options and may be utilizing a current, high resolution terrain model in the rectification process rather than the 1970s USGS 10-meter DEM, thereby increasing the positional accuracy of the image product. With these improvements, some of these commercially available off-the-shelf image products may satisfy the needs of regional agencies, making regionwide imagery acquisition partnerships unnecessary.

# TERRAIN DATA ACQUISITION AND MANAGEMENT GUIDELINES

# TERRAIN DATA ACQUISITION AND MANAGEMENT GUIDELINES

Digital terrain data can be created using a number of production methods, including: manual profiling from photogrammetric stereo models, stereo model digitizing of contours, digitizing topographic map contour plates, converting hypsographic and hydrographic tagged vector files, performing autocorrelation via automated photogrammetric systems, and utilizing remote sensing systems such as Light Detection and Ranging (LIDAR) and, more recently, Interferometric Synthetic Aperture Radar (IfSAR). Regardless of the production method, digital terrain data can be compiled to reflect surface conditions (including vegetation and structure heights) or bare-earth conditions. Typically, the former is called a digital surface model (DSM), while the latter is called a digital terrain model (DTM). Once compiled, digital terrain data commonly are stored in a digital elevation model (DEM). A DEM is a raster data file of terrain elevations at regularly spaced horizontal intervals. An alternative data format for storing terrain data is a triangulated irregular network (TIN).

Common supplemental information used to compile a digital terrain surface includes spot elevations, breaklines, edge effect lines, and hydrographic features such as lakes, shorelines and rivers. Once a terrain model is complete, one of the most commonly produced outputs is contours. For many agencies, the contours are the most important deliverable for use in cartography and for terrain analysis. DEMs also are a critical deliverable for many agencies since they may be used in the generation of three-dimensional graphics displaying terrain, slope, aspect (direction of slope), and terrain profiles between selected points. DEMs also support applications such as modeling terrain and gravity flows for use in hydrologic and storm water runoff modeling, calculating the volume of proposed reservoirs, and determining landslide probability.

Terrain data are essential in the production of digital orthorectified imagery to mathematically remove displacement caused by terrain relief, to enhance the visual information for data extraction and revision purposes, and to create aesthetically pleasing and dramatic hybrid digital images.

In general, two different scales of terrain models exist for the San Diego region: regional and subregional. Due to the vast size of the region, rugged relief, and the large expanses of undeveloped, unpopulated land, agencies find it difficult to justify the cost for a very high resolution terrain model for the entire region. However, the urbanized areas (jurisdictions, water districts, etc.) have acquired very high resolution terrain data to meet their business needs and to prepare very accurate, very high resolution digital imagery. Therefore, these two scales of terrain models fulfill the different agency requirements throughout the region. For discussion purposes, this section is divided into two parts, each focusing on regional and subregional terrain data used and available throughout the region.

# I. REGIONAL SCALE TERRAIN DATA

Until recently, the only regional scale terrain data available for the San Diego region were two public domain DEMs: the USGS 30-meter DEM and the 10-meter DEM generated by San Diego State University from the USGS 1:24,000 scale 7.5 minute topographic map contours. Both of these DEMs represent the bare earth surface of the region as it existed in the early 1970s. Topography in many areas of the region has changed significantly since then. However, these two DEMs have been used extensively by regional agencies since there is not a more current or higher resolution DEM available. Historically, due to the coarse scale of the regional DEM, there was not a need to update these data as frequently as imagery or subregional scale terrain data since only large scale grading projects had an effect on these terrain surfaces. Therefore, a 10 to 20 year update timeframe was appropriate for regional scale DEMs. Given that an increasing number of agencies, even regional agencies, are working at higher resolutions and are requiring more accurate GIS data, having higher resolution terrain data with more frequent updates has become critical. Since 2003, two other regional scale terrain models have become available: the 2003 National Oceanic and Atmospheric Administration (NOAA) 3-meter DSM and the 2005 Intermap Nextmap 5-meter DEM. Table 3 summarizes sources for regional scale terrain data for the region.

In 2003, NOAA contracted with Earth Data Systems to create a DEM using IfSAR RADAR technology. This acquisition included a first return (X-band) and bare earth (P-band) representation for the coastal counties of southwestern California, including San Diego. The X-band acquisition results in elevation values that represent the first return reflective surface (DSM), including elevations of tree tops, buildings, and bridge overpasses, etc., rather than bare earth surface elevations. The X-band DSM has a ± 1-meter vertical RMSE and a ± 2.5-meter or less horizontal RMSE. The project cost for creating the first return (X-band) DSM was approximately $250,000. However, NOAA placed the data in the public domain and it is now available through various federal websites.

The NOAA product is a digital surface model (DSM) not a bare earth terrain model. As mentioned previously, bare earth DEMs are more useful for modeling applications, emergency management, and transportation and land use planning. A bare earth elevation model can be created from the NOAA DSM by post processing the X- and P-bands. However, NOAA did not contract with Earth Data Systems to create bare earth models because the results of a pilot for the Santa Barbara region proved unsatisfactory. They found severe abnormalities in the P-band acquisition, resulting in blurring and smoothing and subsequent degradation in the accuracy of the elevation data. Therefore, NOAA representatives and the contractor determined the data were not suitable for generating a bare earth DEM. However, the DSM may provide useful information for natural resource planning and 3-D visualization and mapping.

In 2005, InterMap Technologies, Inc. released the NextMap digital terrain product, which also was created using the IfSAR RADAR technology. This product includes a digital surface model (DSM) and a digital terrain model (DTM), or bare earth DEM. Both of these products have a 5-meter resolution and a ± 1-meter vertical RMSE and a ± 2.0-meter horizontal RMSE. As opposed to the X- and P-band processing associated with the NOAA DEM project, InterMap utilizes a manual processing methodology to process the X-band in conjunction with various other datasets, resulting in a 95 percent bare earth product. Counties throughout California have purchased the product but, as of this writing, no agencies in the San Diego region have acquired this product due to the high cost. The Nextmap terrain data costs roughly $275,000 for a single agency purchase, has severe product and licensing restrictions, and does not allow for multi-agency purchases. Currently, there is a considerable uplift charge for additional agencies to purchase the NextMap product.

Regional agencies have a desire and need for an updated, high resolution terrain model for the region. Because of the high costs associated with acquiring a high-resolution DEM for the entire San Diego region, a partnership effort may be the only viable way to obtain this data. In addition, a consortium formed to acquire this data likely will necessitate participation from federal and/or state agencies. Options for future acquisition include a Federal LIDAR-based project currently under discussion and continued negotiations with Intermap Technologies to permit multiple agency purchases/licenses. Regardless of the approach, the effort to update the digital terrain data for the region will cost at least several hundred thousand dollars and probably require a multiple agency consortium.

## II. SUBREGIONAL SCALE TERRAIN DATA

Higher resolution terrain data do not exist for the entire San Diego region. Subregional scale terrain data or contours have been produced and maintained by several jurisdictions and water districts over the years as needed, on a project-by-project basis, or as part of a digital image acquisition project. Typically, subregional scale terrain data are in the form of contour lines (versus terrain models) generated during an orthophotogrammetric data collection effort. Recently, some agencies have acquired LIDAR terrain data as part of image acquisition projects and these have been processed to generate a surface model (DTM, DEM) and/or contours. Contours at 2-foot intervals are typically a common deliverable for subregional agencies. The contour data are primarily used by city engineers for site-specific project design. DEMs can be created from contour lines.

Historically in the San Diego region, subregional scale contours generally were produced at intervals from 2 to 5 feet. Table 4 summarizes the historical subregional terrain data generated for local agencies. Information for this table initially was obtained from an informal survey of local jurisdictions conducted in January/February 2003 and updated with information collected from a survey conducted in early 2007. The purpose of the 2007 survey was to provide an inventory of and document the most recent topographic data collected for each subregional agency, including detailed metadata and spatial extent of the terrain data. This information, along with the actual terrain data, can be provided to vendors and used to prepare new orthorectified imagery, thereby significantly lowering the cost of future image acquisition efforts since no new terrain data will be needed.

A number of agencies acquired digital terrain data in 2004 or 2005 and all of these efforts were associated with an image acquisition project. In 2004, digital terrain data and 2-foot contours were produced using traditional photogrammetric methods. In 2005, LIDAR was used by many agencies to produce a terrain surface sufficient for orthorectification. Many of the agencies also contracted to have the LIDAR data processed to generate either a DEM, DTM, or 2-foot contours.

Continued growth in the San Diego region likely will necessitate more frequent updates to the subregional scale digital terrain data. Based upon past practices, the updates can be expected to be associated with image acquisition efforts. The inventory and documentation of subregional terrain data in the region should facilitate focusing future terrain updates on areas where topographic changes have occurred. Since the terrain data in many areas of the region do not change, future image acquisition efforts may make use of the latest DEMs to assist in the orthorectification of new photography in these areas, thereby providing a significant cost savings since no new terrain data will need to be acquired. New terrain data still may be required for areas of topographic change in the form of site-specific projects or spot area updates. Such an approach will be more efficient and cost effective than completely recreating the terrain data, the approach that has generally been taken in the past.

No agency surveyed indicated a plan or desire to initiate updates to subregional scaled digital terrain data separate from an image acquisition project, so it is reasonable to assume that such updates on a subregional scale will be associated with image acquisition efforts. In fact, some agencies indicated that they would update terrain data only in areas of change when new imagery is obtained.

| Table 3. Historical Regional Terrain Inventory | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **General Description** | | | **Topography Specs** | | | | | |
| **Date** | **Coverage** | **# Square Miles** | **Type** | **Resolution** | **Source** | **Distribution Restrictions** | **Updates Desired** |
| 1970 | San Diego Region | 4260 | DEM | 30-meter | USGS 1:24,000 scale contours | No | Yes |
| 1970 | San Diego Region | 4260 | DEM | 10-meter | USGS 1:24,000 scale contours | No | Yes |
| A 2003 | San Diego Region | 4260 | DSM | 3-meter | EarthData, IfSAR | No | Yes |

***Footnotes:***

*A Digital Surface Model, containing above ground features such as buildings, trees, etc. Generated by EarthData International by IfSAR X-Band technology. This product is not useful for hydrologic and surface flow modeling or for orthorectifying imagery.*

## Table 4. Historical Subregional Terrain Inventory

| | General Description | | | Topography Specs | | | | |
|---|---|---|---|---|---|---|---|---|
| | Date | Coverage | # Square Miles | Type | Resolution | Source | Distribution Restrictions | Updates Desired |
| | 1989 | City of Santee | | Contours | 2-foot | Orthophotography | No | Yes |
| E | 1992 | City of Escondido | 90 | Contours | 2-foot & 5-foot | Orthophotography | Unknown | Yes |
| | 1992 | City of San Diego | 336 | Contours | 2-foot | Orthophotography | Yes, SanGIS policies | Yes |
| | 1992 | City of Vista | | ??? | 5-foot | Orthophotography | No | Yes |
| A | 1994 | City of Chula Vista | 127 | Contours | 2-foot | Orthophotography | No | Yes, Areas of Change only |
| B | 1999 | City of San Diego | 336 | Contours | 2-foot | Orthophotography | Yes, SanGIS policies | Yes, Areas of Change only |
| D | 2001 | City of Carlsbad | 55 | Contours | 2-foot | Airborne GPS & AeroTriangulation from Orthophotography | Unknown | Yes |
| D | 2001 | City of Chula Vista | 8 | Contours | 2-foot | Airborne GPS & AeroTriangulation from Orthophotography | No | Yes |
| D | 2001 | City of Encinitas | 35 | Contours | 2-foot | Airborne GPS & AeroTriangulation from Orthophotography | Yes | Yes |
| D | 2001 | City of Oceanside | 42 | Contours | 2-foot | Airborne GPS & AeroTriangulation from Orthophotography | Maybe | Yes |
| D | 2001 | City of Coronado | 8 | Contours | 1-foot & 2-foot | Airborne GPS & AeroTriangulation from Orthophotography | No | Yes |
| D | 2001 | San Diego County Water Authority (CWA) | 215 | Contours | 2-foot | Airborne GPS & AeroTriangulation from Orthophotography | Unknown | Maybe |
| | 2002 | City of Solana Beach | 3 | Contours | 4-foot | Orthophotography | No | No, City doesn't change much |
| | 2003 | MCB Camp Pendleton & NWS Fallbrook | 280 | DEM | ?? | LIDAR | ?? | ?? |
| | 2004 | South Bay Partnership | 185 | DTM & Contours | 2-foot | Airborne GPS & AeroTriangulation from Orthophotography | No | Spot Updates in Areas of Change |
| F | 2005 | City of San Diego | 377 | Raw LIDAR Data | 5-foot | LIDAR | Yes | Spot Updates in Areas of Change |
| F | 2005 | City of Carlsbad | 41 | DEM & Contours | 3-foot DEM, 2-foot contours | LIDAR | Yes | Spot Updates in Areas of Change |
| F | 2005 | City of Del Mar | 2 | Raw LIDAR & Contours | 5-foot LIDAR & 2-foot contours | LIDAR | No | Spot Updates in Areas of Change |

## Table 4. Historical Subregional Terrain Inventory

| | General Description | | | Topography Specs | | | | |
|---|---|---|---|---|---|---|---|---|
| | Date | Coverage | # Square Miles | Type | Resolution | Source | Distribution Restrictions | Updates Desired |
| F | 2005 | City of Encinitas | 32 | Raw LIDAR, DTM & Contours | 5-foot surface models, 2-foot contours | LIDAR | Yes | Spot Updates in Areas of Change |
| F | 2005 | City of La Mesa | 9 | Raw LIDAR, DEM & Contours | 5-foot surface models, 2-foot contours | LIDAR | Unknown | Spot Updates in Areas of Change |
| F | 2005 | City of Lemon Grove | 4 | ??? | ??? | LIDAR | Unknown | Spot Updates in Areas of Change |
| F | 2005 | City of Oceanside | 67 | Raw LIDAR, DTM & Contours | 5-foot surface models, 2-foot contours | LIDAR | Yes | Spot Updates in Areas of Change |
| F | 2005 | City of Poway | 40 | DSM, DEM, DTM & Contours | 5-foot surface models, 2-foot contours | LIDAR | Unknown | Spot Updates in Areas of Change |
| F | 2005 | City of Santee | 16 | Raw LIDAR data | 5-foot | LIDAR | No | Spot Updates in Areas of Change |
| | 2005 | City of Vista | 44 | Raw LIDAR & Contours | 2-foot contours | LIDAR | No | Spot Updates in Areas of Change |
| F | 2005 | Vista Irrigation District | 44 | Raw LIDAR, DTM & Contours | 5-foot surface models, 2-foot contours | LIDAR | No | Spot Updates in Areas of Change |
| F | 2005 | Valley Center Water District | 100 | Raw LIDAR, DEM & Contours | 5-foot surface models, 2-foot contours | LIDAR | Unknown | Spot Updates in Areas of Change |

Notes: Most of these topographic datasets are tied to imagery acquisition projects (see Tables 1 and 2 summarizing historical regional and subregional imagery acquisition projects).

***Footnotes:***

*A Most of the City was done at 6-inch resolution with 2-foot contours, but some areas were done at 2-foot resolution with 10-foot contours.*

*B Costs were lower than those incurred in 1992 because a new DEM was not created, only 15 percent of the area was updated for this project.*

*D These agencies all partnered under one RFP prepared by CWA, but each agency had separate contracts with the selected consultant.*

*E Urbanized area (approximately 45 sq. miles) at 2-foot contours, outlying areas at 5-foot contours.*

*F These agencies all partnered with the City of San Diego, but each agency had separate contracts with the selected consultant.*

# APPENDIX A:
# HISTORICAL IMAGE ACQUISITION PROJECTS

# APPENDIX A: HISTORICAL IMAGE ACQUISITION PROJECTS

## I. 1992 BLACK AND WHITE ORTHOPHOTOGRAPHY – 6-INCH RESOLUTION

The City of San Diego acquired 6-inch resolution panchromatic orthorectified digital imagery to support engineering level planning for the City's water service area. In addition to acquiring digital imagery, the City obtained digital terrain data in the form of 2-foot contours. These datasets cost the City $1,250,000 to acquire. Final image products were provided in GeoTIff and MrSID formats.

## II. 1995 SPOT SATELLITE IMAGERY – 10 AND 20-METER RESOLUTION

This was the first digital imagery acquisition partnership project completed in the San Diego region. Five agencies (the San Diego Association of Governments (SANDAG), San Diego State University (SDSU), the County of San Diego, Caltrans, and the State of California Parks and Recreation) partnered to obtain 1995 SPOT satellite imagery. Both 10-meter panchromatic and 20-meter multi-spectral imagery were obtained for a 5,500 square mile area covering the San Diego region and the Tijuana River Valley watershed. The imagery was used for multi-date change detection projects to facilitate updating land cover vector databases, and as a backdrop to update transportation and other geographic boundaries. A single agency license for this imagery was $48,000. The cost for a five-agency license was $67,000, thereby reducing the cost per agency to $13,500.

## III. 1994/1995 USGS BLACK AND WHITE DIGITAL ORTHOPHOTO QUARTER QUADS (DOQQ) – 3-FOOT RESOLUTION

The 1994/1995 USGS DOQQs provided the San Diego GIS community with its first high resolution imagery of the region. A multi-agency partnership was formed to assist USGS in creating standard USGS DOOQs for the entire San Diego region, and to create value-added digital image products useful to the partnering agencies and local GIS community.

Standard raw USGS DOQQ products are created and delivered in the UTM coordinate system, with meters as the unit of measure, and are not tonally balanced across DOQQ tiles. Because most of the regional and local agencies in San Diego use the California State Plane coordinate system with feet as the unit of measure, the USGS products are not readily integrated into the agencies' geographic information systems. In addition, there can be extreme tonal variation between the imagery of adjoining quads, thereby causing visible seamlines and checkerboard effects during viewing and plotting. The value-added image processing was conducted by a private consulting firm and included reprojecting the DOQQs from UTM to State Plane

Coordinates, resampling the one-meter pixels to 3-foot pixels, balancing the tone or color across image tiles, and creating compressed products.

The total local contribution to this project was about $115,000 for complete regionwide coverage. About 30 agencies provided funding to make this project happen. Individual agency contributions ranged between $2,000 and $10,000, depending upon the phase contributed to and the required area of coverage.

## IV. 1996/1997 USGS COLOR INFRARED (CIR) DIGITAL ORTHOPHOTO QUARTER QUADS (DOQQ) – 3-FOOT RESOLUTION

This digital imagery provided the region with its first high resolution coverage of the region that was not panchromatic. True color and color infrared imagery provides more information and is more useful in visual interpretation.

As part of the U.S./Mexico Aerial Photography Program, CIR photography was flown in 1996 along the International Border. A thirty-agency partnership was formed to fund the third party creation of value-added image products (reprojection, resampling pixel resolution, radiometric balancing, and creating compressed imagery) for the San Diego region from the standard USGS quarter quads. Image file sizes became more problematic in this project because the CIR DOQQs are 3-band images and, therefore, three times the size of the black and white images. It required over 50 gigabytes of disk space to store the raw CIR DOQQs for the San Diego region.

The total consultant cost to prepare the value-added products for this partnership was $55,500. Smaller agencies requiring a smaller area of coverage contributed $2,000 or less, while agencies requiring regional coverage contributed around $4,300.

## V. 1999 BLACK AND WHITE ORTHOPHOTOGRAPHY – 6-INCH RESOLUTION

In 1999 the City of San Diego acquired new 6-inch resolution panchromatic orthorectified digital imagery to provide more up-to-date imagery to support engineering level planning for the City's water service area. In addition to acquiring digital imagery, the City updated the 2-foot contour data in areas of the city where the topography had changed. The cost to update the contours and to prepare new digital orthorectified imagery was $450,000. Final image products were provided in GeoTIff and MrSID formats.

## VI. 2000 CIR DIGITAL IMAGERY – 2-FOOT RESOLUTION

Based upon local agency desires to have higher resolution, more up-to-date digital imagery, and more timely delivery of final image products, an RFP was issued to determine what types of digital imagery, what resolution, and what area of coverage could be obtained for what cost. This was the first project undertaken to obtain higher resolution imagery for the region from scratch according to pre-defined specifications. The prior DOQQ imagery acquisition partnerships were formed to obtain useful products from existing imagery products (such as

DOQQs) and delivery of usable image products was sometimes as much as two years after the date of image capture.

Based upon the proposals received in response to the RFP, a 30-agency partnership was formed to fund the consultant costs for the acquisition and creation of year 2000, color infrared, 2-foot resolution digital imagery for the entire region. The imagery was captured between June and September 2000, and was rectified using the 1996/97 USGS DOQQs as ground control and a 10-meter DEM for elevation control, thereby providing a positional accuracy similar to the USGS DOQQs (+/- 33 feet). Because of the increased resolution, image file sizes once again increased and final digital image products were provided to the partners in the compressed format.

The outside consultant cost of the project was just over $113,000. Individual agency contributions varied, depending upon the area of coverage required. Agencies requiring digital imagery for the entire region contributed $10,000, whereas agencies only requiring coverage for a smaller portion of the region contributed $2,000.

## VII. 2001 TRUE COLOR SUBREGIONAL IMAGERY – 6 INCH RESOLUTION

In 2001, the San Diego County Water Authority issued an RFP to acquire true color imagery and topographic data along the corridor of its major aqueduct system. Before issuing the RFP, the Water Authority solicited other agencies in the region, including water districts and municipalities, to participate in the RFP as an optional area of interest. Five local municipalities agreed to include their jurisdiction within the RFP without obligating funding to the project. Most importantly, the RFP included a public agency clause allowing any public agency in the San Diego region to participate in the award made by the result of the solicitation. Therefore, only one agency was responsible for conducting the solicitation process, and all agencies then could contract with the selected firm to acquire digital imagery for their area of interest. Six agencies negotiated six separate contracts with one aerial mapping firm. These included the San Diego County Water Authority, City of Carlsbad, City of Chula Vista, City of Coronado, City of Encinitas, and the City of Oceanside. The combined area of coverage was 215 square miles.

While this was not a formal partnership, the agencies involved did form a loose relationship and did realize cost savings. The core products of the project for all agencies involved were true color imagery with 6-inch pixel resolution and 2-foot contour data. Final digital image products were delivered to each agency in the compressed MrSID format.

## VIII. 2004 TRUE COLOR SUBREGIONAL IMAGERY – 6 INCH RESOLUTION

The 2004 partnership was different in nature from the 2001 partnership described above. In 2004, the City of Chula Vista had a need for updated imagery and terrain data for the City and outreached to other nearby agencies to determine if others had similar needs. The City formed a partnership with eight additional agencies and they jointly issued an RFP and jointly negotiated a contract with the selected vendor. The City of Chula Vista acted as the lead agency on the project and obtained signatures from all agencies on the final contract and on all contract amendments. All billing and payments were conducted by the City of Chula Vista; the other agencies deposited their funds into a deposit account created specifically for this project. By cooperating in this manner, the partnership did realize cost savings compared to having contracted for the imagery individually. The other agencies that joined the City of Chula Vista's effort included the Cities of Coronado, Imperial Beach, National City, and Escondido, the Otay Water District, the Sweetwater Authority, the Port District, and the Navy. The project covered 275 square miles and the core products for all agencies involved were true color imagery with 6-inch pixel resolution and 2-foot contour data (except for the Cities of Coronado and Escondido).

## IX. 2005 TRUE COLOR SUBREGIONAL IMAGERY – 3/6 INCH RESOLUTION

The 2005 subregional partnership was very similar in nature to the 2001 partnership described above. In 2005, the City of San Diego had a need for updated imagery and terrain data. Based upon the public agency clause in the City's contract and with consent from the City, SANDAG facilitated the outreach to other agencies in the region to determine who else might be interested in participating in the City's project. Again, this was not a formal partnership, but the 15 agencies involved in the project did realize a significant cost savings. The City was responsible for conducting the solicitation process, and all other partnering agencies negotiated their own contracts and products for their areas of interest with the vendor selected by the City. The other agencies that joined the City of San Diego's effort included the Cities of Carlsbad, Chula Vista, Del Mar, Encinitas, La Mesa, Lemon Grove, Oceanside, Poway, Santee, and Vista, Valley Center Municipal Water District, Borrego Water District, San Diego State University, and the San Diego Wild Animal Park. The combined project area covered 820 square miles. With a few exceptions, the core products for the project were true color imagery with 3-inch pixel resolution, a LIDAR generated terrain model with 5-foot horizontal postings, and 2-foot contour data.

# APPENDIX B:
# REFERENCES

# APPENDIX B: REFERENCES


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# APPENDIX C:
# DEFINITIONS AND ACRONYMS

# APPENDIX C: DEFINITIONS AND ACRONYMS

1. **Accuracy (Spatial or Positional)** – Spatial or positional accuracy refers to the location of an object in the imagery or terrain model in relation to its actual ground location in the real world. Positional accuracy often is represented as a statistical error or as +/- units of measure. See CE and RMSE.

2. **CE (Circular Error)** – One of several methods for deriving or calculating the spatial or positional accuracy. CE is a horizontal measurement on the ground defining the radius of a circle within which an object of known coordinates should be found on an image or terrain model. For CE90, the probability of a point in the image or terrain data meeting the recorded accuracy is 90 percent.

3. **Color Balancing** – The process of making the color/tone of individual image tiles look the same across the project area. Individual image tiles/frames will have variable color or tonal quality based upon time of day captured, sun angle, etc. Color balancing minimizes the tonal/color differences across the project area so the resultant images look visually pleasing. Also known as radiometric balancing.

4. **Color Infrared (CIR)** – Typically, this is multi-spectral imagery where one band of the image represents the infrared portion of the color spectrum. Infrared is just beyond the red portion of the visible spectrum of light. Often called false color because colors are different than those seen by the human eye. CIR imagery is particularly helpful in the study of vegetation since healthy vegetation appears as very bright red.

5. **Datum** – The description of the shape of the earth as defined by the National Geodetic Survey. Usually referred to as NAD27 or NAD83 for the horizontal datums and as NGVD29 or NAVD88 for the vertical datums. NAD27 uses surface reference points, whereas NAD83 uses the center of the earth as the reference point.

6. **DEM (Digital Elevation Model)** – A bare earth surface model represented in raster format containing elevation values at regularly spaced horizontal intervals. It provides basic quantitative data for deriving terrain elevation, slope, and/or surface roughness information. DEMs are available from the USGS at 1:24,000 scale (10 meter and 30 meter resolutions).

7. **DOQQ (Digital Ortho Quarter Quad)** – A digital image prepared by the USGS that covers one-fourth of a standard USGS 7.5 minute Quadrangle. Standard quadrangles have been established for the entire United States and generally are at one of two scales: 1:24,000 (7.5 minute quad) and 1:100,000 (15 minute quad).

8. **DSM (Digital Surface Model)** – An earth surface model containing above ground features such as buildings, trees, etc., generated by remotely sensed methods such as LIDAR and IfSAR.

9. **DTM (Digital Terrain Model)** – A bare earth surface model with breakline enhancements, usually in a TIN format, generated from traditional photogrametric methods or remote sensing methods such as LIDAR and IfSAR.

10. **ECW (Enhanced Compression Wavelet)** – A method of compressing digital imagery developed by Earth Resource Mapping, Inc.

11. **Epochs** – The effective date or time of reference of a geodetic measurement, such as a ground control point or GPS, established via a survey. The reason for having an effective date is that the crust of the earth continues to move with time. This movement is significant in California because of continual movement of the underlying tectonic plates and episodic ground movement associated with earthquakes. Computer programs are available to convert survey points from one epoch to another. These programs account for both the gradual movement of the crust and the episodic movements due to major earthquakes.

12. **False Color Infrared** – See Color Infrared (CIR).

13. **Georectified** – The photogrammetric adjustment of one or more images relative to an absolute (fixed) ground reference system. An image or vector layer that is georectified is tied to a geographic reference system such that each pixel or point chosen can be identified by geographic coordinates. This does not mean that the image is orthorectified since a terrain model was not used in the rectification process to control for elevational distortions. Features shown on a georectified image still may be displaced significantly from their true positions on the earth.

14. **GPS (Global Positioning Systems)** – A network of US and foreign satellites that provide highly accurate time and positional information via radio signals that can be used by receivers to measure horizontal and vertical locations on the earth; used extensively in surveying, navigation, rectification processes, and GIS.

15. **Ground Control Points (GCPs)** – GCPs are accurate positions of points on the earth's surface expressed in horizontal coordinates and in vertical (elevation above mean sea level) measurements which usually are obtained from a ground or field survey. GCPs are needed to orthorectify (spatially correct) an image.

16. **Hot Spots** – Bright or very light areas in digital imagery that obliterate or minimize feature recognition in the image; areas appear washed out. These typically are found in the center of an image.

17. **Hypsographic** – Depicting contours.

18. **IfSAR (Interferometric Synthetic Aperture Radar)** – IfSAR is based upon SAR (microwave) technology. Specifically, it was developed by HAMM (High Altitude Mapping Mission) Inc. Two antennas, each mounted on the wing tip pods of an airplane, form a long baseline that enables the interferometric processing of two images to derive surface elevation data of relatively high precision. Bare earth terrain models also can be generated using post processing software and manual editing procedures. See SAR.

19. **LANDSAT** – A low resolution (15 to 30 meter) image product produced by EOSAT. Typically low cost multi-spectral products covering a large footprint.

20. **LIDAR (Light Detection and Ranging)** – Very similar to RADAR except that it uses a different portion of the electromagnetic spectrum – light instead of radio wave lengths. In the past several years, LIDAR has become a technology frequently used to acquire surface elevations from sensors on board aircraft. Bare earth terrain models also can be generated using post processing software and manual editing procedures.

21. **MrSID (Multi-Resolution Seamless Image Database)** – A method of compressing digital imagery developed by Lizard Tech, Inc.

22. **Multi-Spectral Imagery** – Digital imagery representing multiple portions of the electromagnetic spectrum.

23. **National Map Accuracy Standards (NMAS)** – One of several methods for stating the spatial or positional accuracy of an image. NMAS accuracy measures were based upon hard-copy maps and although NMAS has less applicability when used for digital imagery it is still commonly used as an accuracy measure for imagery. NMAS accuracy uses an RMS error (RMSE) based calculation in determining positional or spatial accuracy. The RMSE is calculated with a distance equation and is the distance between the input (source) location of a known point (such as a Ground Control Point) and the retransformed location for the same point in the image. NMAS reports the accuracy as +/- feet. This means that features on an image are within the given range of their true position on the ground 90 percent of the time.

24. **National Standard for Spatial Data Accuracy (NSSDA)** – These guidelines were developed in 1998 by the Federal Geographic Data Committee (FGDC) as an update to the NMAS standards developed in 1947. NSSDA is based upon the American Society for Photogrammetry and Remote Sensing (ASPRS) accuracy standards for large scale maps and implements a statistical and testing methodology for estimating the positional accuracy of points on a map and in digital geospatial data (including digital imagery). Positional accuracy is estimated using a Root Mean Square Error (RMSE) methodology and is reported in +/- ground distance units at the 95 percent confidence level.

25. **Orthophotography** – Aerial photography that has been orthorectified. See orthorectification.

26. **Orthorectification** – Orthorectified images are the most positionally-accurate image products. The orthorectification process removes image distortions introduced by the airborne collection methods and the terrain, and resamples the imagery to a uniform ground sample distance and user-specified map projection. A terrain model such as a DEM or DTM is required to produce an orthorectified image.

27. **Panchromatic** – A black and white or gray-scale image. Typically an 8-bit image, meaning it has a potential range of 256 shades of gray.

28. **Positional Accuracy** – Spatial or positional accuracy refers to the location of an object in the imagery in relation to its actual ground location in the real world. Positional accuracy often is represented as a statistical error or as +/- units of measure. See CE and RMSE.

29. **RADAR (Radio Detection and Ranging)** – Remotely sensed data produced when a microwave transmitter focused by an antenna emits a beam of micro or millimeter waves. The waves reflect from the surfaces they strike, and the backscattered radiation is detected by the same microwave antenna, which is tuned to the frequency of the transmitted waves.

30. **Radiometric balancing** – See Color Balancing.

31. **RMSE (Root Mean Square Error)** – One of several methods for deriving or calculating the spatial or positional accuracy of an image. RMS error (RSME) is calculated with a distance equation and is the distance between the input (source) location of a known point (such as a Ground Control Point) and the retransformed location for the same point in the image.

32. **SAR (Synthetic Aperture Radar)** – An active radio sensor that transmits microwave pulses to the surface of the earth and receives the reflected microwave signals to observe the ground elevation and other physical characteristics by performing many different analyses.

33. **Spatial Accuracy** – Spatial or positional accuracy refers to the location of an object in the imagery in relation to its actual ground location in the real world. Positional accuracy often is represented as a statistical error or as +/- units of measure. See CE and RMSE.

34. **Spatial Resolution** – The area on the ground represented by a single pixel in the image.

35. **Spectral Resolution** – The wavelength bandwidth for a portion of the electromagnetic spectrum that is represented in an image. Multi-spectral imagery represents many portions of the electromagnet spectrum and typically is called multi-band imagery. If only one portion of the magnetic spectrum is represented in an image, it is a single band image. Multi-band, multi-spectral imagery can be either true color (colors appear as seen by the human eye) or color infrared. See CIR.

36. **SPOT** – A digital image product produced by a series of earth-orbiting satellites operated by the Centre National d'Etudes Spatiales (CNES) of France.

37. **State Plane Coordinate System (California State Plane)** – The projection and coordinate system most commonly used in the San Diego region. It is based upon the Lambert Conformal Conic Projection. It is one of many projection systems available for GIS data, digital imagery, and terrain data.

38. **Terrain data** – Systematically recorded measurements of the surface elevation of the earth or bare earth. Typically, topography is represented in digital terrain data as digital contour lines with a fixed interval, TINs, or as a raster data set where each pixel is assigned an elevation value.

39. **TIN (Triangulated Irregular Network)** – A data structure used to model earth surfaces (bare earth or above ground surfaces) assembled from a series of data points with X, Y, and Z values in a series of contiguous non-overlapping triangles (called faces). The nodes of each triangle are the elevation or surface points.

40. **UTM (Universal Transverse Mercator Projection**) – One of several commonly used map projections. However, agencies in the San Diego region typically use the California State Plane Coordinate system. Many federal agencies use the UTM projection system.

41. **Vignetting** – a gradual shift in image tone, usually a darkening, from the center outward caused by the reduction of radiation intensity in the periphery of the camera's field of view. Typically, cameras have a reduced capacity to gather light at the periphery of their field of view unless anti-vignetting methods are used.