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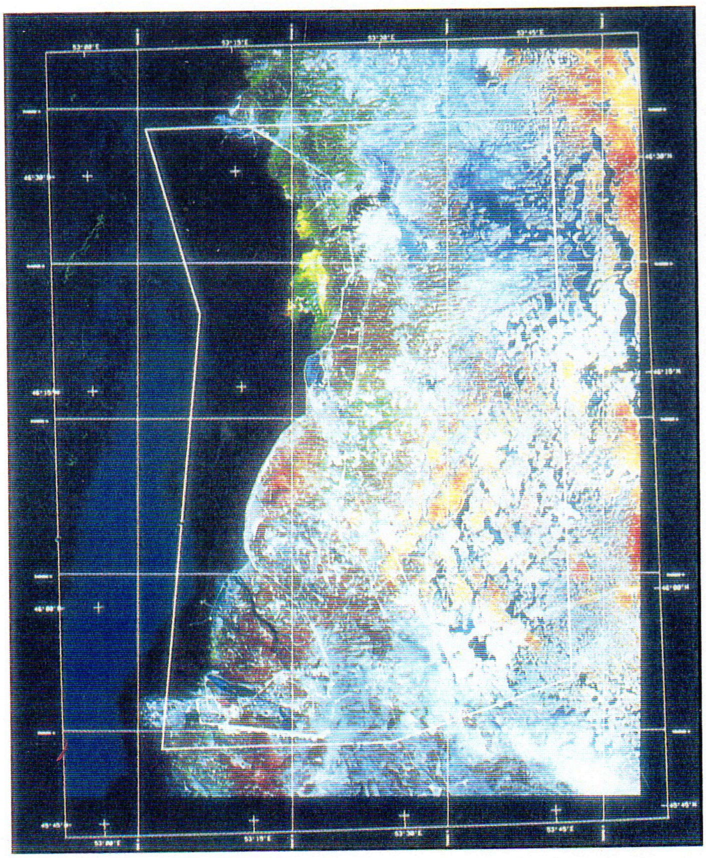
Using Satellite Imagery, CAD, and GPS To Develop an Environmental and Engineering Baseline

By James M. Ellis and Peter B. Goodwin



INTRODUCTION

REMOTE SENSING TECHNOLOGY has been used by Chevron to support worldwide operations for many years. This technology has been used since 1988 to help evaluate and construct basemaps of the Tengiz area of western Kazakhstan because reliable maps from other sources have been difficult to obtain. In 1993 a joint venture was established between Chevron and the Republic of Kazakhstan (Tengizchevroil). Tengizchevroil is effectively using satellite images, computer-aided drafting (CAD), and GPS to provide regional environmental and engineering information concerning facilities and terrain conditions across the J.V. Block.

The region has a steppe/semiarid climate with approximately 10-20 cm of average annual rainfall. Mean daily temperatures range from approximately -15° C in January to +30°C in July. The terrain is below sea level (the Tengiz oil field lies at an average elevation of -24 m below sea level) and has little relief. Elevation decreases about 6 m from east to west across the J.V. Block (approximately a 50 km distance). The region is windswept with well-developed dune complexes and prominent deflation basins. Because the terrain onshore and nearshore is so flat, the location of the Caspian Sea shoreline varies greatly with weather conditions.

The images being used were acquired by Landsat MSS, TM, SPOT panchromatic, and KFA-1000 sensors from 1986 to 1993. Each of the images contributed unique information about the area. The images were digitally enhanced and integrated with image-processing technology and interpreted using CAD workstations.

SATELLITE IMAGES MSS

FIVE LANDSAT MSS images (57 m ground resolution) acquired in 1986-87 were processed at the beginning of this project in 1988 to provide a regional color mosaic (a portion is shown in Figure 2). A 4,2,1 false color IR composite was derived from the MSS data to enhance vegetation, water and man-made features such as towns, roads and developed oil fields.

Interpretation of the MSS images yielded a wealth of regional information. Ancient Caspian Sea shorelines are visible far inland of present-day shorelines. Extensive, very mature dune complexes are aligned in the dominant wind direction. Most of the dunes are stabilized by vegetation. Widespread, fine-grained carbonate sand "playas" (locally called "sors") are developed between the dunes. The sors have a very high reflectance and are clearly displayed on MSS images.

Extensive coastline movement was first detected by

Figure 1: Landsat TM 25 meter data, acquired July 19, 1992 and processed Nov. 19, 1992 is rectified to a grid and later used to create a regional CAD basemap.

Tengizchevroil from the MSS images (Figures 3a and 3b). Acquired about a year apart, these overlapping images show coastal water movement of approximately 40 km in an east-west direction. This shoreline movement appears to be caused by different wind conditions and is probably independent of a documented rise in the Caspian Sea level.

Also visible on the MSS images is a levee constructed on the west side of the Tengiz oil field and some of the road and railroad networks constructed within the oil field. The levee was constructed during the past 10 years to protect the Tengiz oil field from the Caspian Sea and wind-driven storm surges.

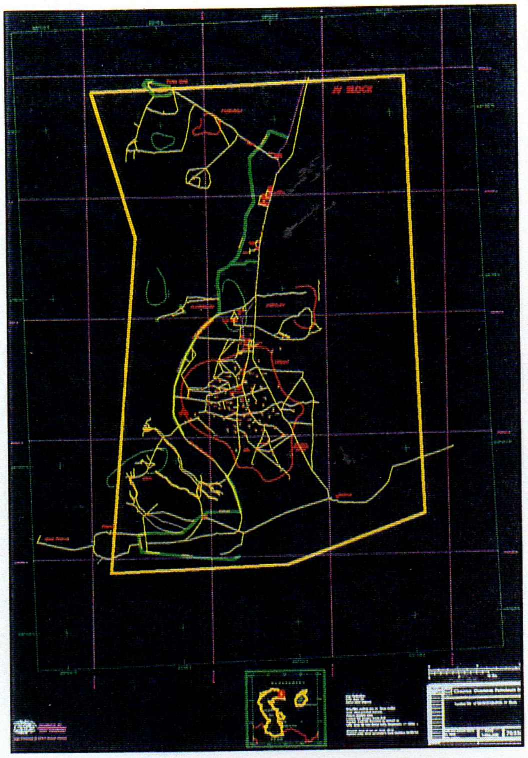


Figure 2: CAD basemap generated from interpretation of satellite images and field work with GPS technology.

SPOT

DURING AUGUST 1989, eight panchromatic SPOT images (panchromatic, 10 m ground resolution) were acquired to provide maximum spatial information about individual well sites, roads (both paved and unsurfaced), pipelines, levees, seismic line traces, and larger facilities. Plots were generated at scales of 1:100,000 to 1:25,000. These plots were used extensively in the field.

An uncontrolled digital mosaic of the eight SPOT scenes was used to create the first basemap of the Tengiz J.V. Block. Ephemeris data from the SPOT images were used to place the mosaic into a latitude and longitude grid. Once this was accomplished, an interpretation was carried out to identify and locate wells, primary and secondary roads, railroad lines, the extent of the levee, and more detailed geomorphologic information.

KFA-1000

OVERLAPPING RUSSIAN KFA-1000 satellite images acquired in July 1991 were obtained as film transparencies. These two, 30 x 30 cm films (approximate scale 1:200,000) recorded light with wavelengths of 570-670 and 670-810 nanometers. The films displayed vegetation as a purplish-pink color. Ground resolution of these KFA-1000 images was about 7 m. The films were digitally scanned for integration with the TM and SPOT imagery. However, a camera model was not available to correct geometric distortions and the Russian data could not be digitally registered to the TM or SPOT images using Tengizchevroil's standard, image-processing software.

TM

A LANDSAT TM IMAGE (28.5 m ground resolution) was acquired in July 1992 to provide improved spectral information of the terrain. Color composites were developed utilizing infrared bands and principal components that accentuated geomorphology (shorelines, water bodies, sors), vegetation, sediment plumes, oil spills, and oil field facilities. In support of faulting, fracturing, subsidence, and environmental studies, TM band 6 (thermal IR) was compared to a Russian interpretation of airborne thermal IR images. The results were inconclusive.

COMPARISON OF SATELLITE IMAGES

CHANGES IN TERRAIN CONDITIONS, both man-made and natural, were readily apparent in a comparison of the older 1986 MSS images with both the newer SPOT images and more recent Landsat TM and KFA-1000 imagery. The 1992 TM and 1991 KFA-1000 images suggest that what was dry grassland with small producing oil fields in 1986 is now an area that appears to be more frequently inundated by the Caspian Sea. The rapid development of the Tengiz oilfield as recorded by road, well, pipeline and railroad construction is also clearly visible. The continued construction and extension of the levee to the north of the J.V. Block between 1989 and 1992 can also be easily mapped with the images. Digital merging of the TM and SPOT through the IHS transformation could not be satisfactorily done because of the significant man-made changes between 1989 and 1992 - extensive road-building, wellpad and facility construction, seismic surveys, shoreline movement, etc.

KFA-1000 data provided the best resolution of man-made structures, such as buildings and storage tanks. However, KFA-1000 images lack the dynamic range we have become accustomed to with SPOT images. Minimal dynamic range hindered the ability to utilize the KFA-1000 data for interpretation of vegetation and geomorphology. However, after digital enhancement of the KFA-1000 films, the increased resolution facilitated identification of unmapped or questionable roads, construction pits, seismic line traces, well pads, and levee extensions.

GENERATION OF A BASE MAP AND IMAGE MAPS

AS THE PROJECT MATURED from 1989 to 1993, the registration accuracy of the numerous images to a specified latitude/longitude grid improved. In 1989 the images were rectified using satellite ephemeris data alone. By 1992 ground control points (GCP's) were established across the J.V. Block using a single, hand-held GPS receiver. These control points were used to rectify the TM image to a grid (Figure 1). After rectification, the images were used to create a regional CAD basemap showing the location of the levees, roads, railroads, facilities, oilfields, oil wells and drainage channels (Figure 2). However, the interpretation produced from satellite images could not

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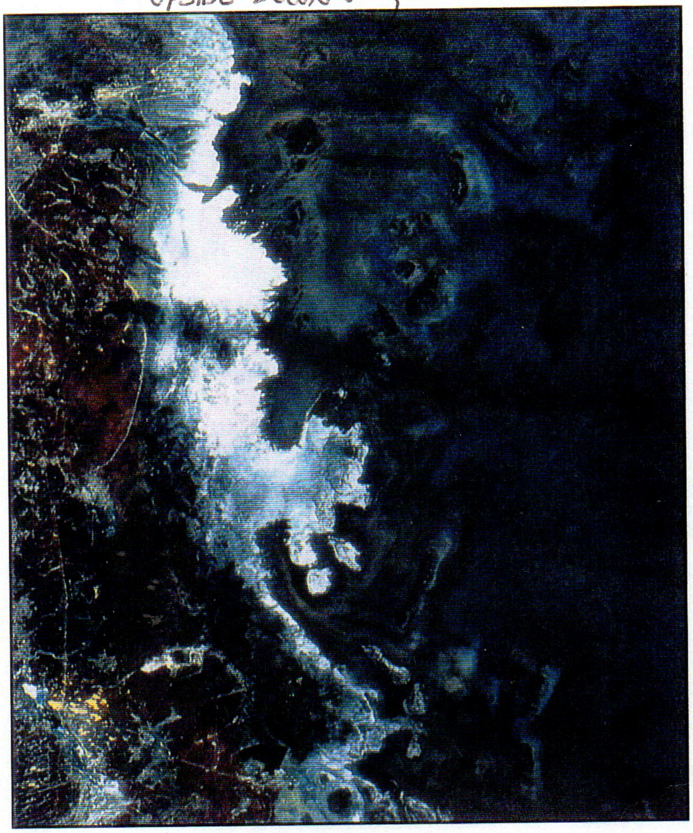

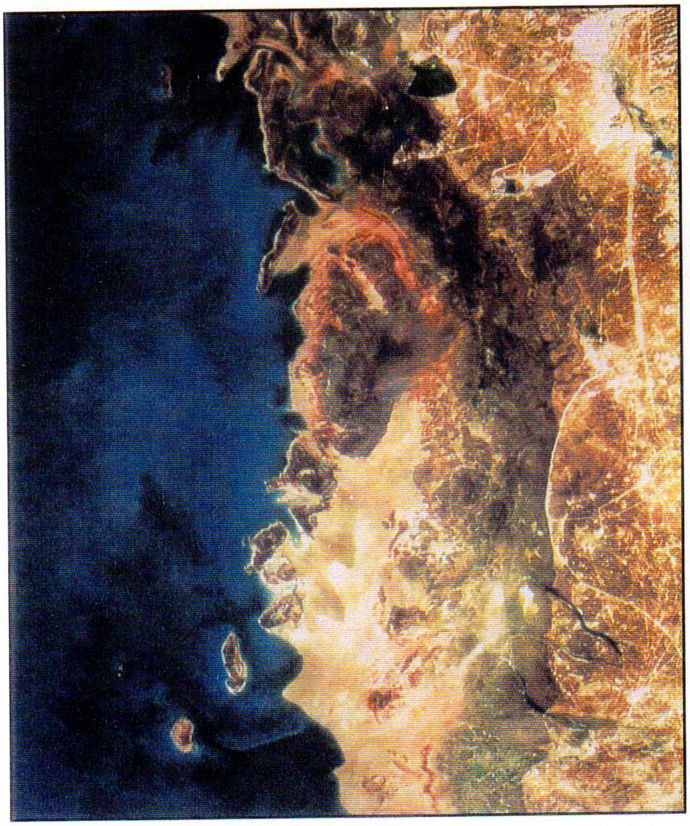

Figures 3a, 3b: 1986 MSS image (above) compared to same-scale 1987 MSS image (below) of Tengiz area showing 20 km east-west changes in shoreline location due to change in wind condition.

discriminate active roads from abandoned roads or determine road type (paved, dirt, gravel). This important distinction was not resolved until field work was carried out in 1993.

Plots of the satellite images at scales ranging from 1:100,000 to 1:25,000 were delivered with matching CAD maps to earth scientists, engineers, and environmentalists working in the field to record sample locations, plan surveys, inventory and map facilities, and describe terrain conditions. Images with CAD maps embedded (Figure 1) were also delivered as digital data sets on laptops and portable PC's with image display software and vector mapping software.

In order to satisfy continuing environmental studies and engineering projects in the oil fields, as well as construction of an environmental baseline over the entire J.V. Block, Tengizchevroil authorized an aerial photography survey in both natural color and color infrared (1:20,000). This survey was completed in August of 1993. Georeferenced satellite images were essential for planning this survey and establishing photogrammetric tie points in the field. In 1994 new satellite imagery will be acquired to assist in monitoring environmental conditions across the 4000 km^2 block. This imagery will be rectified using a highly accurate geodetic control network established in 1993 and GCP's located with geodetic quality, single frequency GPS receivers in differential mode.

SUMMARY

THE GEOTECHNOLOGIES ARE PROVIDING environmental and engineering information concerning facilities, environmental conditions, and terrain conditions. Remote sensing, CAD and GPS have proven to be versatile and cost-effective tools for establishing baselines, improving planning, and guiding fieldwork in Kazakhstan.

ACKNOWLEDGMENTS

WE THANK TENGIZCHEVROIL and Chevron Overseas Petroleum Inc. (COPI) for supporting remote sensing technology and this article. Floyd Sabins of Remote Sensing Enterprises acquired the KFA-1000 films for us in 1992. Scott Hills of Chevron Petroleum Technology Co. provided excellent advice on processing parameters. Mark Choiniere, Hattie Davis, and Pat Caldwell of COPI provided continuous technical support throughout the project.

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Jim Ellis and Peter Goodwin work for Chevron, providing (along with their five associates) remote sensing products and services to company business units located around the world. Jim is the supervisor and Peter is a remote sensing geologist within the group.

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