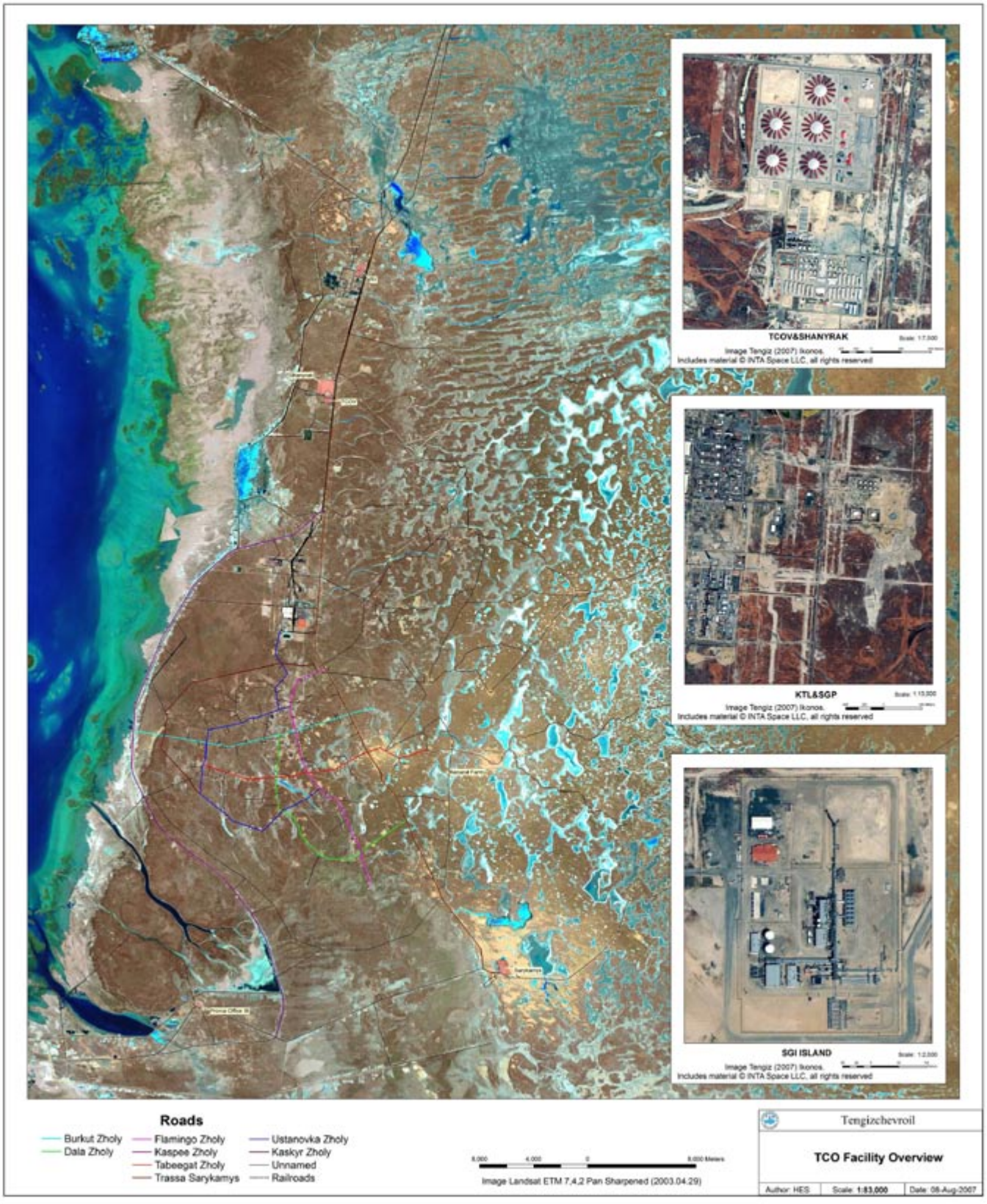
Satellite Monitoring of Tengiz

President Nazarbayev endorsed a governmental program on the development of the space activities in Kazakhstan for 2005-2007 by signing Decree # 1315 on January 25, 2005.

The main objective of the Government Program is the space industry development which contributes to the national and informational security strengthening, social economical and scientific development of the Republic of Kazakhstan by means of effective use of technology. To achieve the indicated objective it is necessary to implement a number of tasks, including:

- *development of the National space monitoring system of the territory of the Republic of Kazakhstan including the environment condition;*
- *development of the professional education and staff training system required for the space industry development;*
- *improvement of legislation and economical support for the space industry development.*



Considerable work has been performed in Kazakhstan over the last few years in the use of satellite imagery. One of the important objectives of using satellite data is to help ensure environmental protection of the Republic.

Tengizchevroil supports the Republic of Kazakhstan program on development of space industry activities as approved by the Order of President Nazarbaev as well as the use of such cutting-edge technologies in support of our production activities. Remote sensing of the Earth – utilizing satellite imagery - is one example of such technology.

Tengizchevroil uses remote sensing to help monitor the potential impacts from implementing large-scale oil development projects and in support of environmental actions executed by the company such as Tengizchevroil's Land Remediation Program. For example, to determine the baseline state of soil and vegetation before implementing the Sour Gas Injection and the Second Generation Project (SGI/SGP) a hyperspectral survey of the Tengiz territory was carried out using satellite imagery. This data will be used to compare against future surveys to determine if changes in the environment have occurred.

Specialists of Tengizchevroil's Geographic Information System Group demonstrate the company's remote sensing activities at international conferences and participate in joint studies with other Kazakhstani scientists with a view to share experience and to expand our understanding on the effective use of new types of satellite imaging technology.

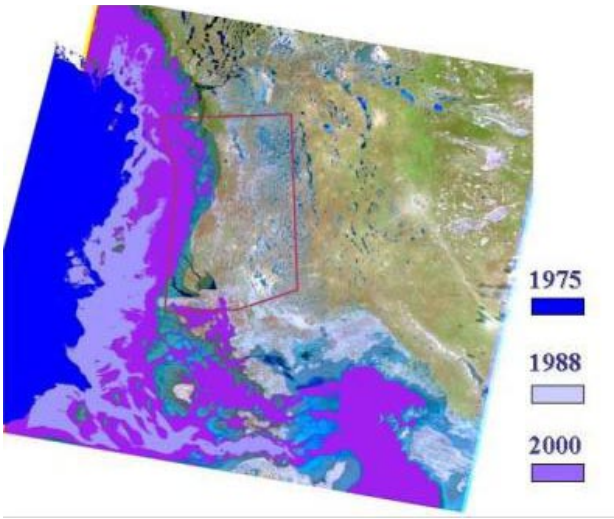
Todd Levy,
TCO General Director

Vegetation and soil maps are developed based on satellite images. These satellite images are used in developing different projects, especially Environmental Impact Assessment (EIA) projects to carry out reclamation of the disturbed lands, develop green belt planting projects and for other purposes. TCO is following the main principle – minimize the environmental impact when constructing new facilities such as roads, pipelines, buildings and landfills. Satellite images allow documenting of the earth surface state before and after construction works, as well as planning land use activities. Satellite images are also useful tools in reclamation and recovery of land resources that take place upon completion of the works and prior to returning the land to the state fund.

The other important use of remote sensing is the monitoring of shoreline conditions due to its immediate proximity to Tengiz infrastructure facilities and to analyze the vegetation cover on the whole territory of North-Eastern Caspian Sea. This issue is solved jointly with RoK Space Research Institute using weekly images since 2001.

Rzabek Artygaliev,
General Manager Deputy
Operational Excellence/Health, Environmental and Safety Department

Caspian Sea level rise and shoreline change near Tengiz



Change of the Caspian shoreline near Tengiz

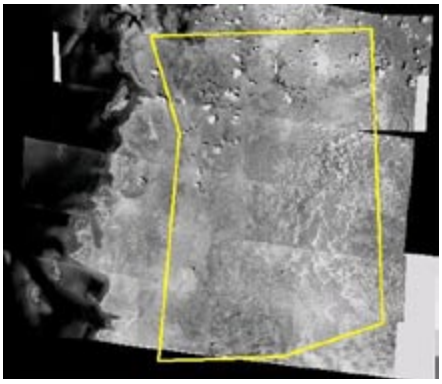


Image from Corona satellite, 1972

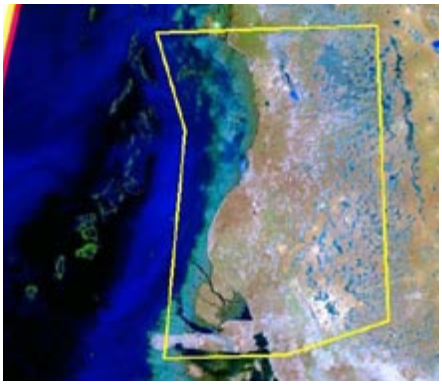
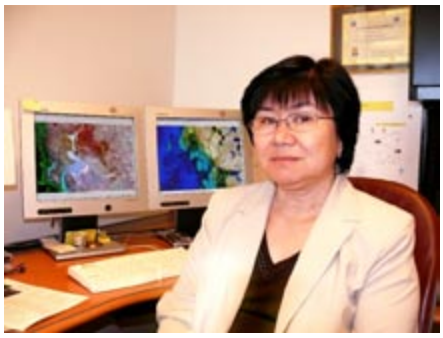


Image from Landsat 7 satellite, 2000

One of the distinctive advantages of satellite monitoring is that satellites can provide continuous information for decades affording an opportunity to conduct comparative analysis, which is the main objective of a long term monitoring program.

Rise of the Caspian Sea from 1978 to 1996 produced a commensurate rise of adjoining groundwater levels and accentuated the effect of storm surges on near-shore oil fields, threatening existing pipeline infrastructure, roads and other facilities. 'This Whole History' continues down to 2000 when it was officially stated that the sea level rise has stopped, and it is kept in archives of satellite images.



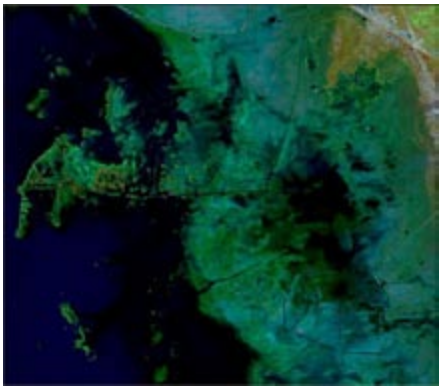
Tengizchevroil utilizes almost all known and commercially available types of satellite images. They all have specific technical characteristics and determine efficiency of their use in solving different issues challenging TCO.

In IT department we have created a large database of space imagery from images of 60s and up to date. The value of such an archive is difficult to overestimate. Historical data can be compared with modern setting up of issues on land protection, inventory of production facilities and geometry of new construction is estimated. Satellite images also help in making any decision associated with spatially distributed information.

Nurgul Amanova,
candidate of technical sciences
Earth Science Applications Support Group Supervisor
Information Technology Department

Remote sensing is studying of Earth surface with airborne and space crafts, equipped by various types of imaging tools. Operational diapason of imaging sensors covers wavelengths from fractions of micrometers to meters: ultraviolet, visible, near infrared, short infrared, thermal infrared, microwave. Data remotely sensed from satellites or space stations considerably depend on atmospheric transparency. That is why multispectral sensors are being used on satellites, which simultaneously measure electromagnetic radiation in different spectral diapasons, called spectral bands. Hyperspectral sensors employ more than 100 spectral bands.
Spatial resolution is another important characteristics of the image. Ability to separate closely spaced objects on an image or photograph. Spatial resolution depends on design of scanning instrument and on satellite's orbit altitude. Commercially available images such as Quickbird and Ikonos have the highest resolution of 61 centimeters and 1 meter correspondingly; it means objects of that size can be distinguished on Earth surface.

Tazhigali field in 1986



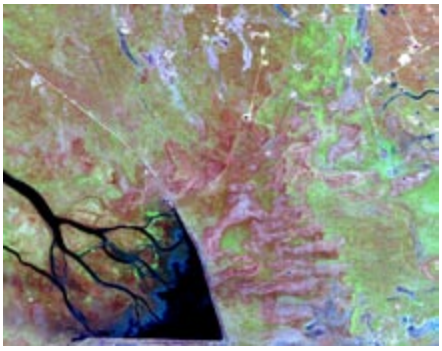
Tazhigali field in 2000

Studies with use of photography from Corona satellite, which operated during 1963 - 1972, and multispectral medium resolution imagery of 1975-2003 from satellites of Landsat series, revealed the following:

"Oil production infrastructure near Tengiz field is shown on early imagery of 1960-1970. Although Caspian advance caused major reduction in area of vegetated lands, considerable depletion of vegetation cover occurred during 1985-1989 caused by active infrastructure development in former Soviet Union".

Seismic acquisition of 1998: vibrator wheels' traces on soil

Vibrator wheels' traces on image of 1999



Vibrator wheels' traces on image of 2002

Vibrator wheels' traces on image of 2003

System	Spectral range, mm	Bands	Band width, mm	Spatial resolution
AVHRR	0.58-12.5	5	0.1-1.0	1000 m
MSS, Landsat 1,2,3	0.50-12.6	5	0.1-2.2	80 m
TM, Landsat 4,5	0.45-12.5	7	0.06-2.1	30 m
ETM+, Landsat 7	0.45-12.5	8	0.06-2.1	30 m
SPOT XS	0.50-0.89	3	0.50-0.89	20 m
MODIS	0.62-14.35	36	0.01-0.5	250-1000 m
ASTER/EOS	0.52-11.65	14	0.01-0.5	15-90 m
IKONOS	0.45-0.90	5	0.06-0.45	1-4 m
QUICKBIRD	0.45-0.90	5	0.06-0.5	0.61-2.8 m
HYPERION	0.40-2.50	220	0,01	30 m

Scanning systems

Shoreline fluctuations in Northeast Caspian during 2002-2006 on TERRA/MODIS imagery

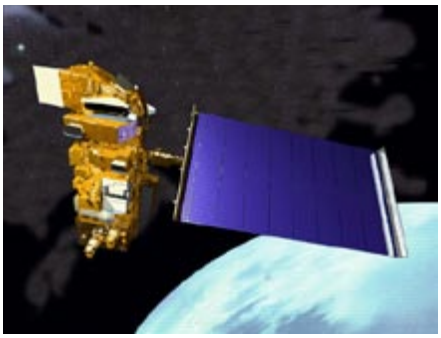
Natural climate peculiarities of Northeast Caspian lowland cause favorable conditions for developing positive and negative shoreline movements during strong wind. Effective height of elevation to a few meters produce commensurate shoreline movements up to 30-50 km in some directions.

Because Tengiz field and major TCO's objects of oil infrastructure are situated close to Caspian shore and potentially exposed to threat of flood in the case of unfavorable scenario of sea level fluctuations, the regular observations of Northeast Caspian region are being conducted with satellite imagery on a weekly basis.

Space Research Institute, RK, is TCO's Partner in this study. The Institute employs its own receiving station in Almaty for daily image acquisitions from multispectral MODIS sensor on TERRA satellite. We have been conducting this monitoring of shoreline fluctuations since 2002, for the period of March-November each year.

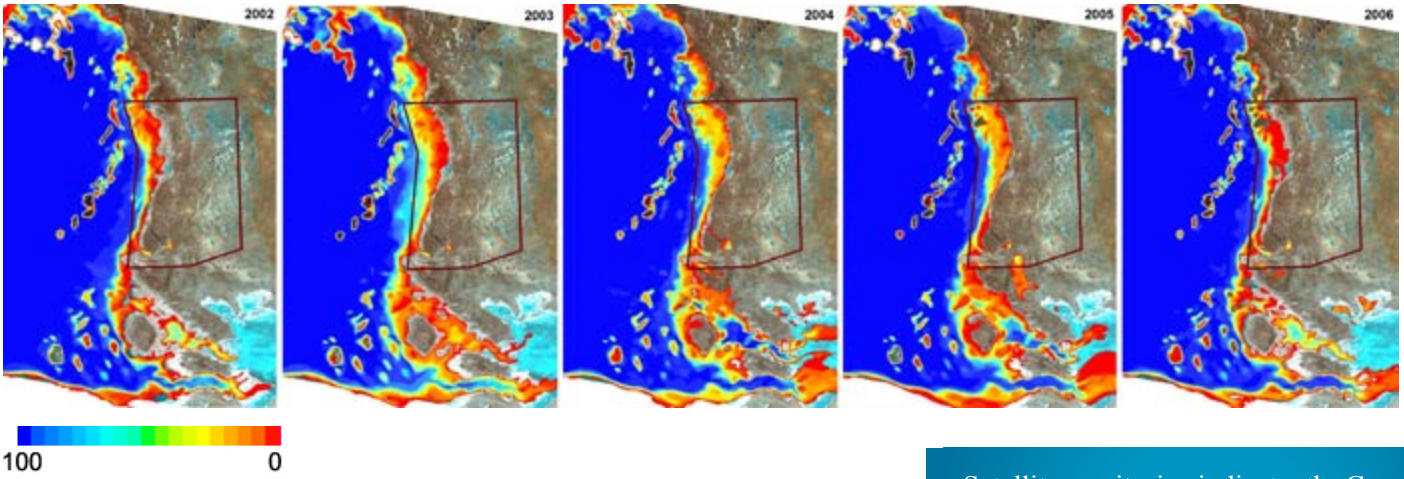
Near shore territory of Northeast Caspian easily can be divided by 2 classes on satellite images: sea surface and land surface. Spectral characteristics of these two classes significantly differ in visible and near infrared spectral ranges. The gentler the shore, the larger is spatial amplitude of the shore line. The shape of the shore line during the period of positive and negative shoreline movement depends on wind strength and direction.

Spatial characteristics of wind conditions can change, that is why shapes of shore lines vary considerably in time. Every year from the beginning of March to the end of November, we receive 32-34 weekly images showing location of Caspian shoreline. In figure below, the color code indicates percentage of events, when in particular grid cell of the Earth surface water was detected: blue color means in 100% events, while red color in 0% events.



TERRA satellite

TERRA/MODIS receiving station at Space Research Institute, RoK, Almaty



Shoreline monitoring with TERRA/MODIS

Satellite monitoring indicates the Caspian Sea shoreline is not encroaching towards Tengiz operations.

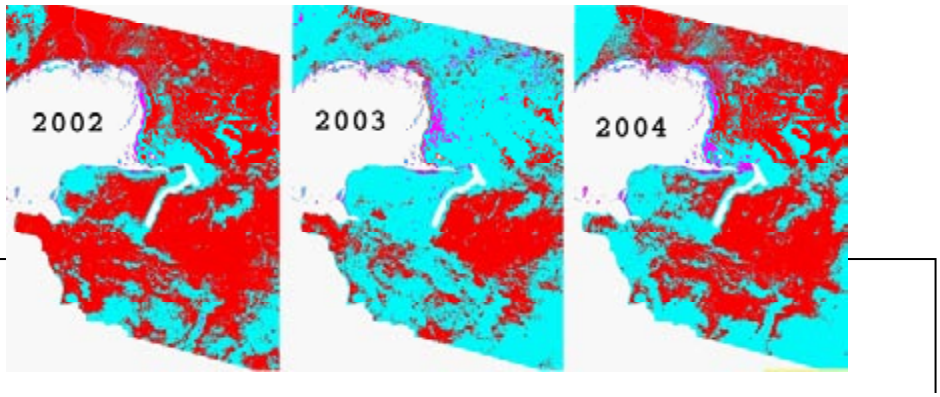
Vegetation status in Northeast Caspian on weekly TERRA/ MODIS imagery

Positive and negative Caspian surges make for ecological balance in the region in many respects. Intensive processes of loose materials transported with shoreline movements, are capable to dynamically change topography and impact on vegetation status within coastal zone.

Plants appear green to human eyes because blue and red light (0.45 and 0.75 mM) are preferentially absorbed, while green light (0.55mM) is reflected. This fact is a base for vegetation index creation for vegetation status evaluation with satellite and airborne images.

Using MODIS imagery, our partners, scientists from Space Research Institute, calculate and build time series vegetation indexes and study the dynamics of changes thereof for main plant communities representative of the region so that to determine duration throughout the start and end of the vegetation season. Those studies help TCO in planning the vegetation planting for rehabilitated sites and compare the condition of the vegetation cover over several years. Apart from those purposes, regular monitoring by MODIS enables TCO in determining the time interval of vegetation peak of main types of plant communities. Based on image analysis, vegetation dynamics could be subdivided into three types: with spring, spring-summer and summer maximum. Spring maximum is typical of dry areas where lack of water makes vegetation use moisture accumulated in winter most effectively. Ephemeral vegetation quickly develops in spring period within 2-3 weeks. Summer maximum is typical of mostly grass meadows and coastal and solonchak areas, characterized by sufficient summer moisture for vegetation development. The third type of dynamics is a transitional type between the above two types. Below shows the results of classification of the whole territory in the vegetation seasons of 2002 - 2004 according to the above three types of vegetation dynamics.

Considerable differences in the areas of vegetation dynamics with pronounced spring minimum in the seasons of 2002, 2003 and 2004 were caused by different factors. The most important factor was weather conditions at the beginning of vegetation period. Another factor, local and influencing only on the lowest parts of Caspian lowlands, is the Caspian surge phenomena, which was especially active in spring and at the beginning of summer 2003 and 2004.



Distribution of three types of vegetation dynamics in Northeast Caspian

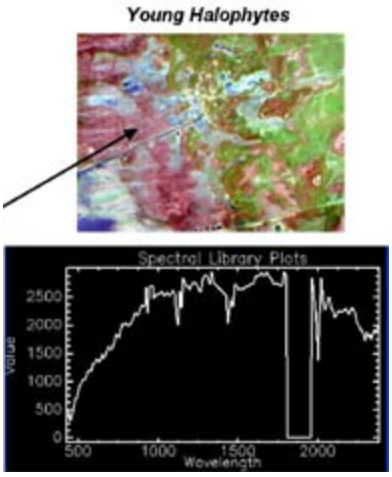
Spring maximum vegetation

Spring-Summer maximum vegetation

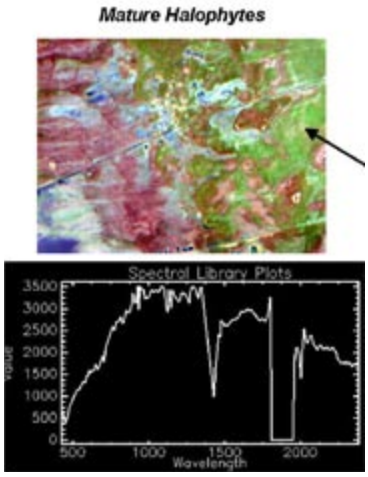
Summer maximum vegetation

Analysis of vegetation dynamics during 2002-2006 based on satellite monitoring allow acknowledging variations of weather conditions and intensive sea setup as the strongest natural climatic factors considerably impacting on vegetation status in the Northeast Caspian coastal zone.

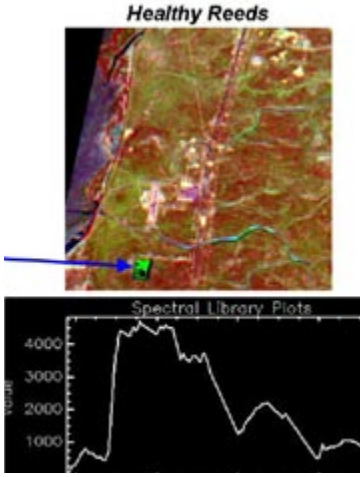
Hyperspectral imagery and land cover classification maps



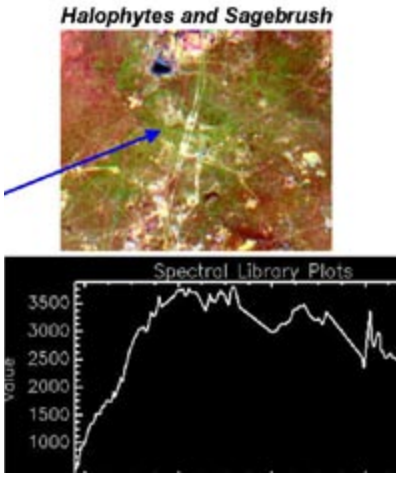
Spectral signature of young halophytes



Spectral signature of mature halophytes



Spectral signature of healthy reeds



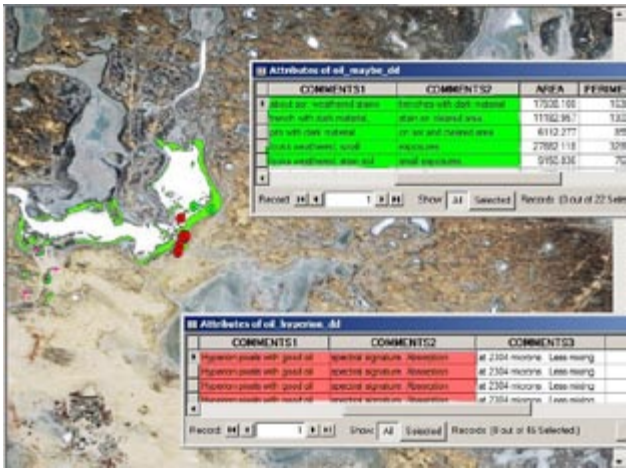
Spectral signature of halophytes and sagebrush community

As you know, TCO is close to completion on the SGP/SGI Expansion Project. Most of the construction works are complete, and TCO has already begun large-scale actions on land reclamation.

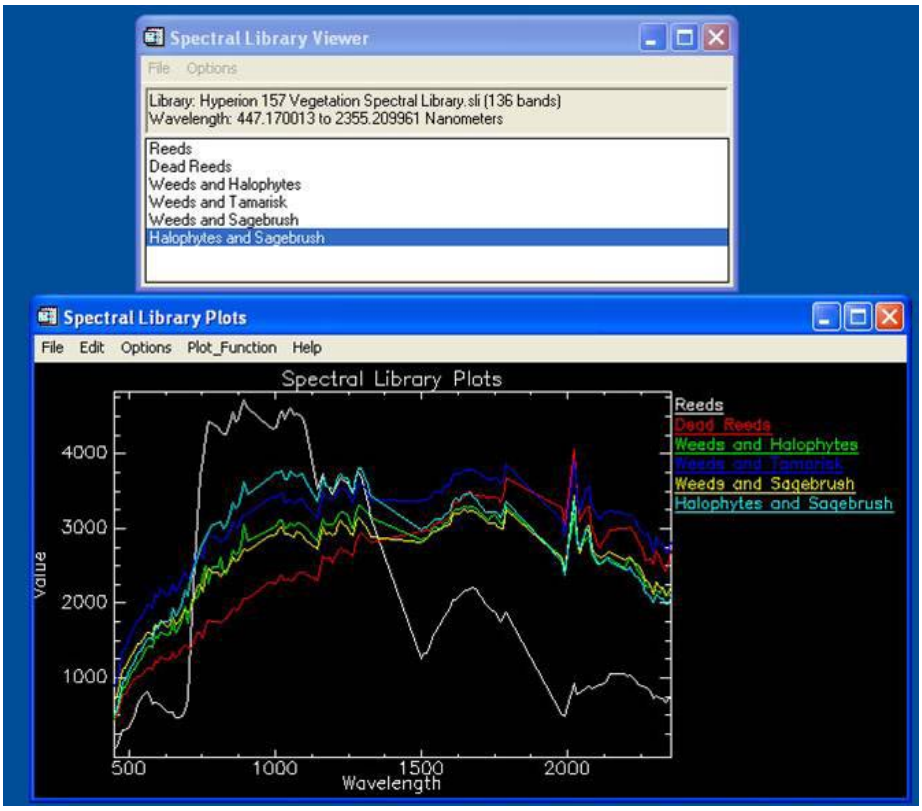
To determine status of vegetation and soils within Partnership territory as of 2002 at the beginning of SGP/SGI projects, special image acquisition was ordered with the use of Hyperion hyperspectral sensor from EO-1 satellite and detailed mapping of all land cover materials was completed.

Hyperspectral sensors differ from multispectral sensors because they measure the intensity of reflected solar energy across a continuous span of wavelengths, recording visible light comprising short blue, green and red wavelengths, as well as longer visible near-infrared and short wave infrared. Hyperspectral sensors area unique in that they have sufficient spectral resolution to identify different surface materials based solely on spectral signatures.

Hyperspectral sensors can detect onshore oil spills and oil-stained ground, because oil has unique spectral characteristics. Oil detection, as well as mapping of vegetation communities, soils, salinity of sors, was an integral part of an environmental baseline in 2002 for Tengiz.



Oil detection with hyperspectral imagery



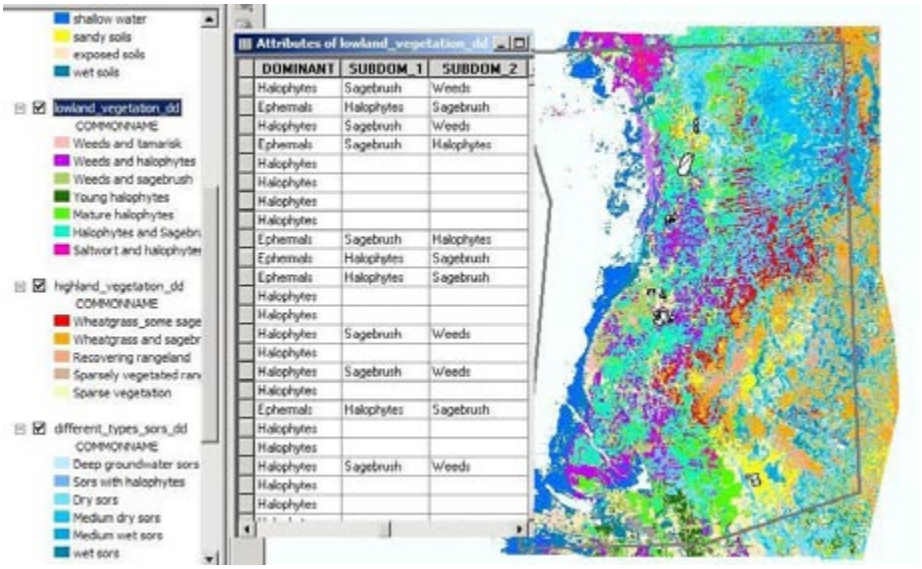
Part of spectral library

Hyperspectral sensors are unique in that they have sufficient spectral resolution to identify different surface materials. But to better interpret the hyperspectral images and use them to map vegetation cover, soil and other surface features, it was necessary to collect ground data about the surface. This data allows "training" the program to process the hyperspectral images of specified training sites for the program to identify other types of the terrain.

The researchers of the Terra Company, Kazakhstan, also gathered considerable ground data for study and for developing landscape maps of Tengiz.

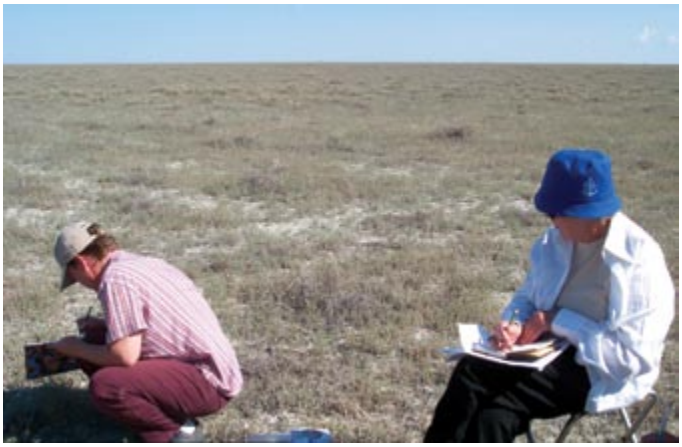
Scientists and specialists from Almaty based "Terra" company, collected and analyzed a large volume of ground data.

We identified 33 classes of various land cover materials, created a library of spectral signatures of all that materials and compiled detailed maps of their abundance within the Partnership territory. Chevron and the Ellis-GeoSpatial companies were our partners in this study.

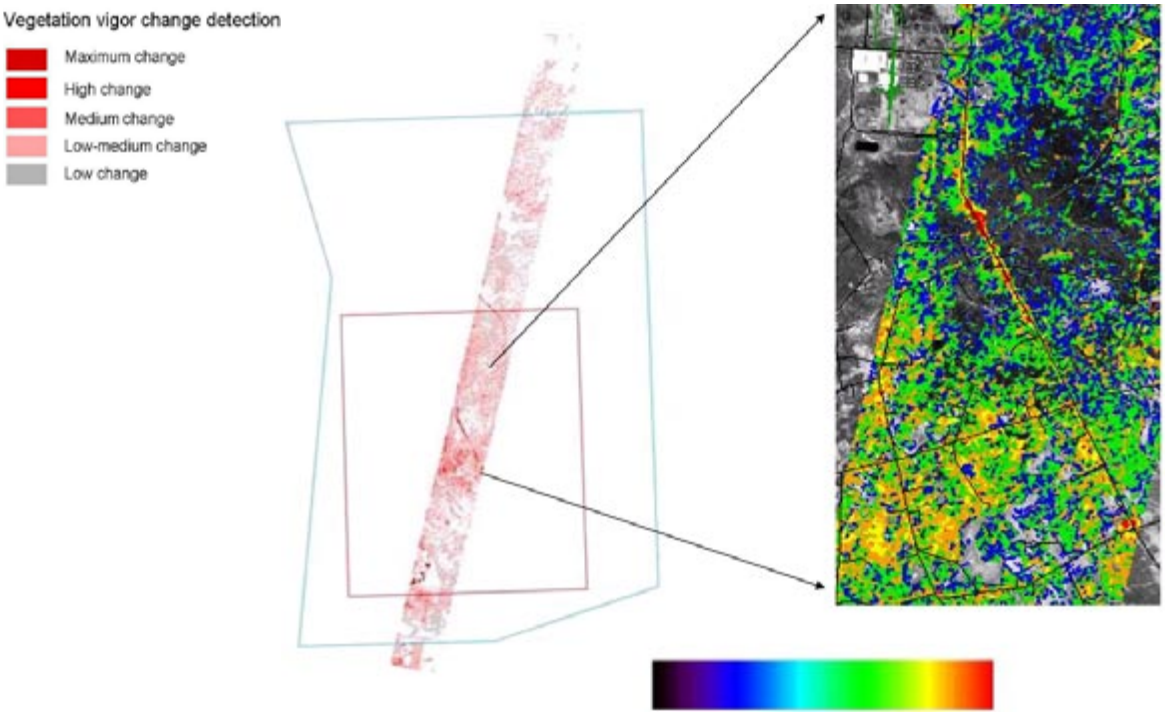


Landcover and vegetation map derived from hyperspectral imagery

Vegetation vigor and soil moisture conditions in the target area rapidly changed from mid May to July 2002, causing the derived maps to reflect the status of vigor and moisture on the day of acquisition. Maps derived from Hyperion imagery during this time frame reveal these differences in the overlap zones. The seasonal reduction in vegetation vigor as the summer progressed was dramatic. This analysis was important for benchmarking natural vegetation vigor in other imagery acquired in different years and seasons. These maps are being used presently in "post-projects" activities for land recovery.



Scientists from Terra are collecting ground data



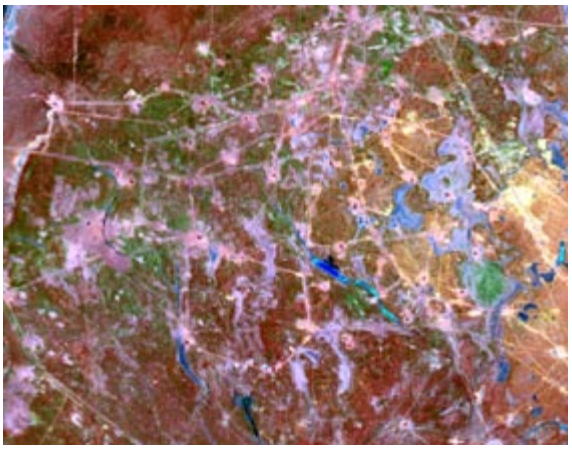
Seasonal dynamics of vegetation vigor on hyperspectral image

TCO specialists use satellite monitoring data in decision-making

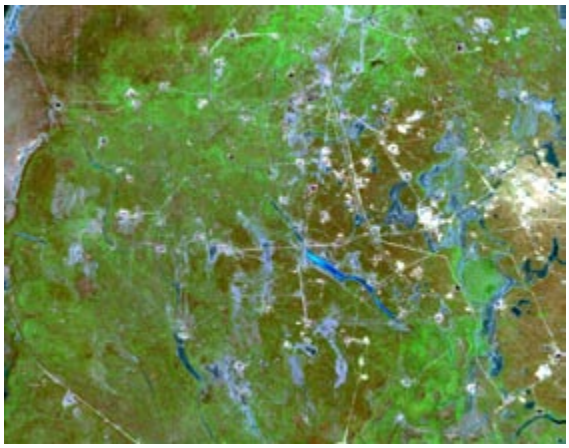
Data from the satellite pictures are used in planning works on recultivation of disturbed lands

Since 1993 Tengizchevroil has been consistently carrying out a Site Restoration Program which has resulted in remediation of environment.

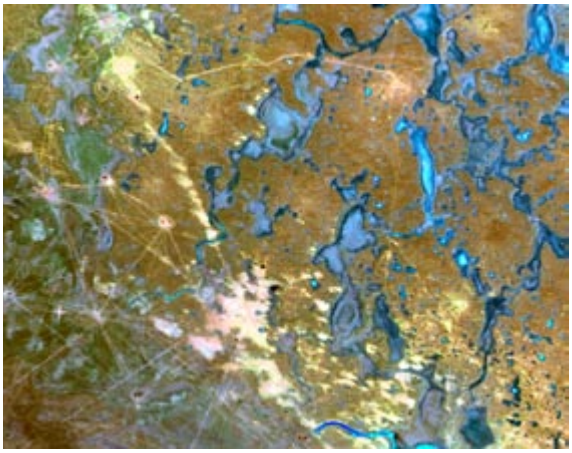
Site Restoration Program includes various activities such as wells sites clean-up, vehicles traffic regulations, sand consolidation by vegetation planting to name a few. This has changed the Tengiz area dramatically. "Before" and "after" views show improvements.



Tengiz field in 1989



Tengiz wells in 2002

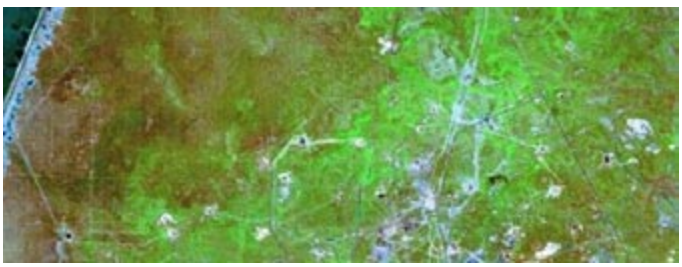


Sand on Sarykamys road in 1986

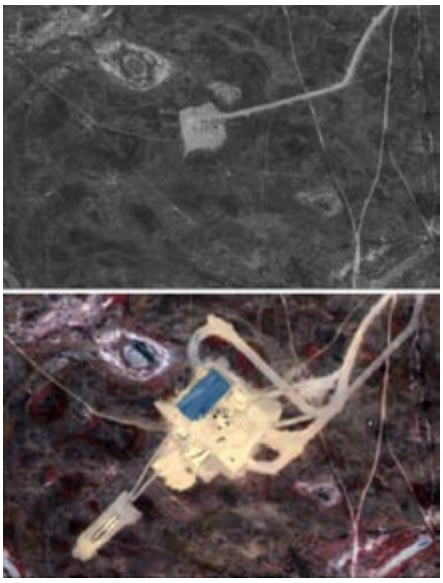
Same part of this road in 2003

Hard-surface roads were constructed in the early years of TCO's existence and off-road vehicle travel was limited to help reduce impacts on the soil and vegetation.

Roads near Tengiz in 1985



Results of traffic regulations in the image of 2002

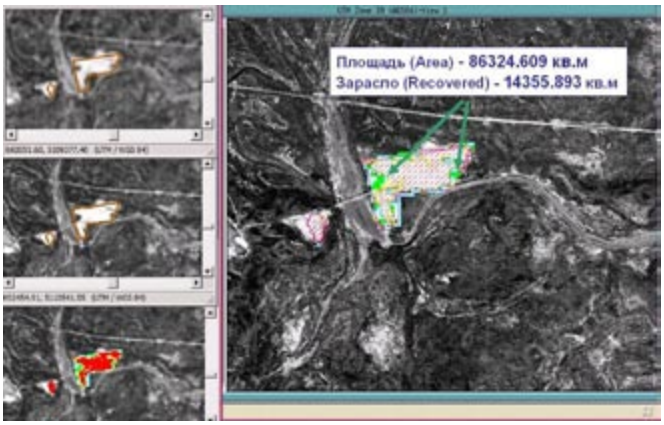


Rapid change in Korolev field during 3 July – 11 August, 2002

Every year we order Ikonos and Quickbird high resolution images for monitoring operational works, constructions and land use in Tengiz.

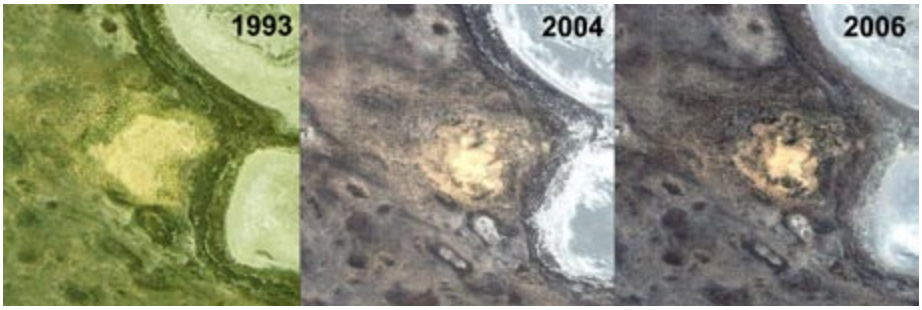
Satellite imagery and aerial photography acquired in different years help doing business in many ways. For example, in calculating acreage of recovered disturbed lands. Mechanical recultivation of the borrow pit by flattening its edges result in revegetation at those edges.

Images are being enclosed when requesting a land allotment for constructions



Result of mechanical recultivation of finished borrow pit, recovery on flattened edge:

a) image taken from the space *b) picture of the same territory*



Borrow pit BP42 existed in 1993, before TCO was created

During the works on BP-42 borrow pit, which have been done in the framework of the Short-term program (2005-2008) for reclamation of technically disturbed and contaminated lands on the territory of "Tengizchevroil" LLP, it was determined that this borrow pit existed in 1993, before TCO was founded.

TCO maintains close cooperation with Kazakhstan scientists and supports knowledge transfer. Chevron specialists assist in such cooperation. In 2003 scientists from CRS&GIS "Terra" received hyperspectral image processing training in Ellis-GeoSpatial Inc.

We regularly participate with co-authored presentations and papers at Kazakhstani and major international conferences for sharing our experience and to learn feasibility and applicability of new remote sensing data and techniques.

Comparative analysis of historical data and recently acquired satellite images indicate that the ecosystems in the Tengiz oilfield have restored to a large extent, as result of consistent environmental policy of our company.

2001

- *AAPG conference, July, Saint-Petersburg*
- *1-st International Oil and Gas Scientific-Practical Conference, Atyrau*
- *International conference "10 years of Space Research in Kazakhstan", Almaty*

2002

- *Applied geologic Remote Sensing, Las Vegas (ERIM)*

2003

- *NASA JPL AVIRIS Earth Science Workshop, US, Pasadena*

2004

- *The Remote Sensing and Photogrammetry Society (RSPS), Annual Conference, UK, Aberdeen*
- *IGARSS-2004, US, Anchorage*

2005

- *3-d Conference "Remote Sensing the Earth from the Space", Russia, Moscow*

2006

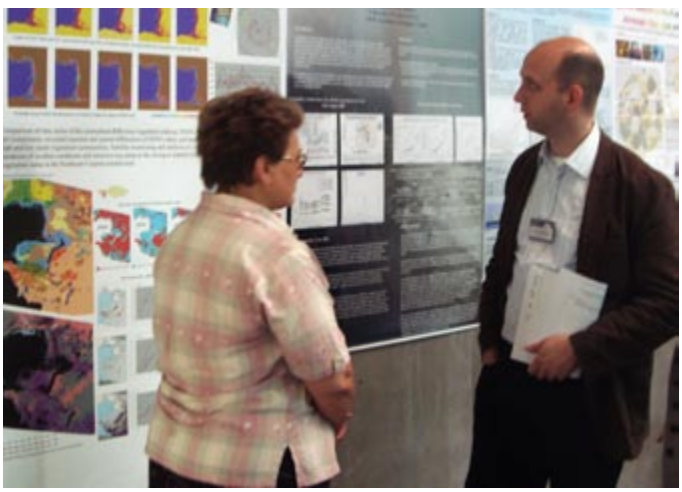
- *Subsoil Use and Law Journal, Almaty*
- *International conference «Independent Kazakhstan: 10 years of Space Research», dedicated to 70-th anniversary of academician U.M. Sultangazin, Almaty*

2007

- *EcoExibition "Ecologically effective and resource-saving technologies 2007", Astana*
- *3-d European Workshop Coastal Remote Sensing, Italy, Bolzano*

Mr. Ron Kasberger, OE/HSE Department General Manager and his deputy Mr. Rzabek Artygaliev with Minister of Environmental Protection Mr. N. Iskakov. International Exhibition "Environmentally effective and resource saving technologies", Astana

Results fo stellite monitoring of Tengiz were highlighted at the exhibition in Astana



Dr. Nadiya Muratova, Space Research Institute, RoK

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OE/HSE Department
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