ANNEXES

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Interested parties are urged to also consult original information sources when considering the information about individual deposits.

Annex I

AUSTRALIA – BEVERLEY

Associated company names: previously: Oilmin, Transoil, Petromin, Western Nuclear, Inc., current: Heathgate Resources Pty. Ltd. (a wholly-owned subsidiary of General Atomics)

Location: South Australia

Period of operation: from 2001 to present

Annual production: average 620 tU, maximum 919 tU (2004)

Total production through 2010: 5584 tU

Current status (12/12): operating

I–1. GEOLOGY

Type of deposit: uranium mineralization occurs in the Miocene Namba Formation in tabular pods within sinuous palaeochannel sands some 9 km in length and up to 1 km in width (Beverley Sands). Ore thicknesses of the original discoveries average about 6 m and the average grade is 0.16% U using a cut-off of 0.026% U, without correction for disequilibrium which could range from 50–100%. The average depth is 110 m. Later mining from newly-discovered ore lenses (Beverley East, Beverley South) occurred in deeper sediments with thinner, smaller orebodies.

Geological ore reserves: 12 370 tU (initial estimate – inferred resource only).

Recoverable reserves: 8 050 tU (initial estimate – inferred resource only).

Area of deposit: 170 hectares.

Mineralogy of U: coffinite is the primary U mineral with subordinate pitchblende; both are fine-grained and form coatings on sand grains.

Number of aquifers: above; minor aquifers within the Willawortina Formation.

below: minor production from the deeper Alpha sands at Beverley East.

Underlying formation, rock type: Alpha mudstone (clay), depth from surface 130 m

Overlying formation, rock type: Willawortina Formation, fanglomerate.

Cut off: grade 0.026%U, GT 0.013 m%U

I–2. FACTORS AFFECTING ISL PROCESS

Lithological composition of ores: mainly quartz with some feldspar and clays

Mineral composition of ore: pyrite and marcasite occur in traces. Organic carbon content ranges from <0.05–0.5%, exceptionally to 2%.

Transmissivity of ores:	50–180 m^2/d
Porosity, effective porosity of ores:	33%
Thickness of productive aquifer:	0–21 m
Depth of orebody:	100–145 m
Depth of static level head below surface:	60 m (typical)
Carbonate content in ore:	0.06% (typical), higher in Alpha Sands
Sulphide content in ore:	0.13% (typical)
Total mineralization of groundwater:	3300–13 200 mg/L
Groundwater temperature:	32^{o}C
Natural groundwater flow:	velocity; essentially stagnant, direction; S–SE (regional trend)

I–3. TECHNOLOGY OF LEACHING

Type of leaching: acid

Leaching agent: H_2SO_4, H_2O_2

Determination of leading process: diffusion from the mineral surface is the rate limiting process.

Leaching agent concentration in operational solutions (average): pH 1.5–2.2

Period of individual wellfields (blocks) operation: 6–18 months

Total dose of leaching reagents (average): 470 ppm H_2SO_4, 85 ppm H_2O_2

I–3.1. Wellfields parameters

Well construction: casing diameter; 80–190 mm

casing material; PVC

grouting; top of ore zone to surface

screening type; rib screen, length; variable, material; PVC with geotextile filter

Well patterns: shapes; 5-spot, 7-spot, line drive

distance between wells; 20–30 m (inj to ext)

ratio between recovery and injection wells; 0.9

Pumping technique: type: submersible, diameters: 4” and 6”

Production well pumping rate: 0.5–5 L/s

Area of simultaneously working wellfields (blocks): ~6–8

Number of simultaneously working wells: ~60–100

Specific consumption of electrical power to pump one cubic meter solution from the well: 1 kWh

Disposal/treatment method excess wellfield solution: Disposal by underground injection into unmineralized or 'mined-out' portions of the Namba Formation.

I–3.2. Processing plant parameters

Volume of processed solution: 1080 m^3/h (peak)

Production capability: 1000 tU/a

Technology of solution processing: fixed bed ion exchange downflow

Ion exchange resin specification: type; strong base (anion) quaternary amine,
trade mark; Dowex 21 kK XLT

loading capacity; 12 g/L WSR

particle size; 500 μm

volume of resin in operation; 240 m^3.

Elution reagent specification: elution reagent; 60 g/L Cl^-

Technology of sorption/desorption: total volume of resin; 300 m^3

Chemistry of: resin regeneration; sulphate (10 g/L H_2SO_4)

final product precipitation; uranyl peroxide NaOH and H_2O_2

Initial load of: ion exchange resin; 200 m^3

Annual consumption of: ion exchange resin; 12 m^3/a

Annual consumption of all other chemicals: H_2SO_4; 18 000 t/a, NaOH; 5000 t/a, H_2O_2; 360 t/a, NaCl; 6 000 t/a

Volume and type of equipment (vessels, pumps, piping): 15 IX columns 3.5 m dia and 4 m high; in 2009–2011 10 of these were relocated to the Beverley North satellites.

Injection and recovery stream storage type: recovery pond (12h), no injection storage

Satellite sorption stations: yes, Beverley North Project, Pepegoona and Pannikan satellites

Process water consumption: up to 140 ML/a (includes camp and road watering)

Steam consumption: nil

Electric power consumption: 3–4 MW

I–3.3. Restoration

Technology of groundwater restoration (proposed): Monitored natural attenuation

Operating period of restoration process: Not yet defined, minimum monitoring period 7 a post-production.

Final groundwater quality: Not usable for stock purposes, nor was the water pre-mining.

Annex II

AUSTRALIA – HONEYMOON

Associated company names: Uranium One 51%, Mitsui 49%

Location: South Australia

Period of operation: from late 2011 to 2013/14.

Annual production: average 300 tU (target)

Total production through 2011: 31 (part-year)

Current status (2014): care-and-maintenance

II–1. GEOLOGY

Type of deposit: ore occurs in the Eyre Formation, a coarse-grained, pyritic basal sand unit of an Eocene to Palaeocene age palaeochannel incised into basement rocks at depths of about 90–130 m. Dimensions of the deposit are approximately 450 by 900 m. The average ore grade is 0.24% U and the average thickness of individual layers 1.7 m.

Geological ore reserves: 1.2 Mt of ore at an average grade of 0.24%U containing 2 200 tU (indicated resource only)

Recoverable reserves: n/a

Area of deposit: 40 ha

Mineralogy of U: autunite (hydrated calcium uranyl phosphate) with accessory coffinite and uraninite.

Number of aquifers: above; 4, below; 0

Underlying formation, rock type: Willyama Formation (magmatic basement), depth from surface; 130 m

Overlying formation, rock type: Namba Formation, mainly clay.

Cut off: GT 0.1m%U

II–2. FACTORS AFFECTING ISL PROCESS

Lithological composition of ores: angular quartz sand and gravel with humic matter and minor pyrite.

Mineral composition of ore: reduced. quartz and kaolinite are major gangue minerals.

Permeability: 5 m/d

Transmissivity of ores: 63 m^2/d

Porosity, effective porosity of ores: 30%

Thickness of productive aquifer: n/a

Depth of orebody: 90–130 m

Depth of static level head below surface: 50 m (typical)

Position of orebody in aquifer: n/a

Carbonate content in ore: n/a

Sulphide content in ore: 7% (pyrite)

Total mineralization of groundwater: 11 000–20 000 mg/L

Natural groundwater flow: velocity; 10–15 m/a, direction; to the north

II–3. TECHNOLOGY OF LEACHING

Type of leaching: acid

Leaching agent: H_2SO_4, $NaClO_3$

Leaching agent concentration in operational solutions (average): pH 2.0–2.5

Period of block start up (acidification, alkalization): Preliminary treatment of leaching patterns to reduce calcium content to < 600 mg/L by above-ground deliberate gypsum precipitation and reverse osmosis is undertaken to reduce the likelihood of gypsum precipitation and clogging during the production phase.

Period of individual wellfields (blocks) operation: 6–18 months

Flow velocity of leaching solution: residence time 1–6 d within mined pattern.

II–3.1. Wellfields parameters

Well construction: casing diameter; 80–190 mm

casing material; PVC

grouting; top of ore zone to surface

screening type; rib screen, length; varies, material; PVC with geotextile filter

Well patterns: shape; 5-spot, 7-spot, line drive

distance between wells; 20–30 m (inj to ext)

ratio between recovery and injection wells; 0.9

Pumping technique: type: submersible, diameters: 4” and 6”

Production well pumping rate: 0.5–6 L/s

Area of simultaneously working wellfields (blocks): ~2–3

Number of simultaneously working wells: ~30 extraction wells

The air-lifts consumption of pressurized air; capacity of pressurized air production: N/A

Specific consumption of electrical power to pump one cubic meter solution from the well: 1 kWh

Disposal/treatment method excess wellfield solution: disposal by underground injection into unmineralized or 'mined-out' portions of the Eyre formation basal sands.

II–3.2. Processing plant parameters

Volume of processed solution: 650 m^3/h (peak)

Production capability: 300 tU/a

Technology of solution processing: solvent extraction; 2 air-pulsed columns

Solvent exchange specification: kerosene (narrow cut, 93%) with cationic and anionic uranium extractants (respectively di-ethyl-hexyl phosphoric acid (DEHPA), 2% and tri-octyl tertiary amine, 2%) and non-polar modifier (tri-butyl phosphate (TBP), 3%)

Scrubbing of solvent: diluted H_2SO_4 and $Na_2S_2O_5$

Stripping of solvent: aqueous Na_2CO_3 strip with subsequent iron precipitate removal.

Chemistry of final product precipitation; uranyl peroxide; NaOH, NaOH and H_2O_2

Satellite sorption stations: none

Process water consumption: n/a

Steam consumption: nil

Electric power consumption: 1.5 MW from national grid.

II–3.3. Restoration

Technology of groundwater restoration (proposed): monitored natural attenuation

Operating period of restoration process: not yet defined, likely monitoring period 5–7 a post-production provided water quality trends are suitable.

Final groundwater quality: not usable for stock purposes, nor was the water pre-mining.

Annex III

BULGARIA – PLOVDIV – MOMINO

Redki Metali operated an extensive network of in situ leaching facilities near the town of Plovdiv. These facilities included 14 000 wells in fifteen well fields, four satellite recovery units, and one resin enrichment facility. Loaded resin from the satellites was trucked to the central enrichment facility where the concentration was increased for truck shipment to the Elesnica uranium mill for final recovery, drying and packaging.

Associated company names: Redki Metali

Location: the Momino district of the Thracian Basin is located in the Plodiv region about 130 km southeast of Sofia on the Maritza River

Period of operation: from 1968–1995

Annual production: average n/a, maximum ~300 tU

Total production through 2008: N/A

Current status (12/09): closed

III–1. GEOLOGY

Type of deposit: uranium orebodies of the Momino district occur as roll fronts in buried fluvial channels incised into flat-lying Pliocene siltstones which rest on Oligocene strata. The productive horizon varies in thickness from 10 to 50 m, while the ore zones range up to 4 m in thickness. Disequilibrium is common. Ore grades were generally in the range of 0.02–0.07% U.

Geological ore reserves: total resources of the Thracian Basin were estimated to be 15 000 tU. Initial resources of the Momino district were estimated to be 10 000 tU.

Mineralogy of U: ningyoite, coffinite and uranophane

Underlying formation, rock type: gneiss

Overlying formation, rock type: siltstone

III–2. FACTORS AFFECTING ISL PROCESS

Lithological composition of ores: weakly cemented sandstone with intercalated siltstone lenses.

Depth of orebody: 250 m

III–3. TECHNOLOGY OF LEACHING

Type of leaching: acid

Leaching agent: H_2SO_4

Leaching agent concentration in operational solutions (average): 7 g/L

Specific consumption of reagents: 430 kg H_2SO_4/ kgU

III–3.1. Wellfields parameters

Well construction: casing diameter; 63 mm

casing material; PVC

Well patterns: shape; hexagonal (7-spot)

distance between wells; 20–25 m

Pumping technique: air lift

III–3.2. Processing plant parameters

Volume of processed solution: 160 m^3/h per column

Technology of solution processing: ion exchange

Ion exchange resin specification: type; anion, trade mark; AMP or Varion AP

loading capacity; 15 kgU/m^3 at satellites, 35–40 kgU/m^3 at the central enrichment facility

Annex IV

CHINA – YINING II

Note on project name: Yining II (deposit No. 512) Kuji'ertai, also spelled Kujieertai

Location: deposit No. 512 is located near Yining in Xinjiang Uygur Autonomous Region of North Western China.

Period of operation: from 1994 to present.

Annual production: average ~175/a tU, maximum ~300 tU (2008)

Total production through 2008: ~2 800 tU

Current status (12/12): operating

IV–1. GEOLOGY

Type of deposit: uranium occurs at Yining as pitchblende in a dark grey, coarse sandstone of Jurassic age with an average thickness of 4 m and an average grade of 0.04% U.

Geological ore reserves: initial estimate ~10 000 tU, 2002 resource 3 000 to 4 000 tU

Area of deposit: the deposit is 5.3 km in length and 300 to 500 m in width (approximately 200 ha).

Mineralogy of U: uranium occurs as pitchblende (about 80 % of U minerals), coffinite (about 20 %), rarely brannerite, or also as U-Ti-bearing magnetite and adsorbed on coal debris and pyrite.

Underlying formation, rock type: mudstone or silt claystone

Overlying formation, rock type: mudstone or silt claystone

Cut off: grade: permeable rocks > 0.01% U
non-permeable rocks > 0.03% U

IV–2. FACTORS AFFECTING ISL PROCESS

Lithological composition of ores: quartzose sandstone, feldspathic (kaolinized) sandstone with some volcanic debris, and sandy conglomerate of fluvial and deltaic provenance are the prevailing host rocks.

Mineral composition of ore: quartz 56.5%, quartzite, silicate and siliceous conglomerate 16%, feldspar 7%, hydromica 1%, kaolinite 14%, organic 1%.

Permeability: ~1 m/s

Depth of orebody: 150–200 m

Depth of static level head below surface: 50 m

Position of orebody in aquifer: roll

Carbonate content in ore: 0.33%

Total mineralization of groundwater: 0.66–1.05 g/L

Groundwater temperature: 15°C

IV–3. TECHNOLOGY OF LEACHING

Type of leaching: acid

Leaching agent: H_2SO_4

Leaching agent concentration in operational solutions (average): 5–25 g/L

Period of individual wellfields (blocks) operation: 3–5 a

IV–3.1. Wellfields parameters

Well construction: casing diameter: 110 mm, 160 mm
casing material: PVC, PE
grouting: ore zone to surface

Well patterns: shape: 5-spot, lines (40 × 20 m)
distance between wells; 25 m
ratio between recovery and injection wells; 1 : 2

Pumping technique: air lifts and submersible pumps (4 inch)

Production well pumping rate: 0.9 L/s

IV–3.2. Processing plant parameters

Volume of processed solution: 420 m^3/h

Production capability: 300 tU/a

Technology of solution processing: ion exchange

Ion exchange resin specification: type: local
loading capacity: 20 g/L
total mass of resin: 440 t

Elution reagent: NH_4NO_3 (60 g/L)

Technology of sorption/desorption: sorption; continual countercurrent flow columns
desorption; fix bed columns
final product precipitation; NaOH

IV–3.3. Restoration

Technology of groundwater restoration: after production (production stops when the pregnant solution has a uranium content below 15–20 mg/L), the aquifer is restored. Restoration comprises the pumping of contaminated water from the aquifer, with the extracted water being re-injected, after addition of lixiviant and oxidant, into production wellfields as leaching solution.

Annex V

CZECH REPUBLIC – STRAZ

Associated company name: DIAMO, state enterprise

Location: North Bohemian Cretaceous Basin, Ceska Lipa region

Period of operation: from 1968 to 1995

Annual production: average 650 tU, maximum 769 tU (1977)

Total production (through 2010): 16 002 tU

Current status: restoration

V–1. GEOLOGY

General description: Type; tabular deposit, Cretaceous sandstone sediments

Grade; 0.056% U (average)

Productivity; 5.51 kg U/m^2

Thickness; 23 m (average) of mineralized ore, 55–60 m aquifer

Resources/reserves: 33 385 tU in category C1

Recoverable reserves: 55% of initial reserves

Area of deposit: 606 ha

Mineralogy of U: uraninite (UO_{2+x}),

ningyoite (($CaU(PO_4)_2$. nH_2O)

hydrozircon ($Zr(Si_{1-x}O_{4-4x}(OH)_{4x}).n\ H_2O$)

Stratigraphic setting (description):

The thickness of the Cretaceous formation in the Straz block is from 200 to 250 m. The basement consists mainly of granitic rocks. The Cretaceous sedimentary complex is formed by two stratigraphic units. The lower Cenomanian formation contains the uranium ore mineralization. At its base freshwater sediments are locally developed (in depressions of the palaeo relief). They are overlain by the fluvial-marine transition sediments with a thickness of 0.5 to 5.0 m. These sediments consist of layers of different composition, grain size and permeability (breccia, sandstones, siltstones, often with admixtures of organic matter and pyrite). They often contain uranium ore mineralization. Above these there is a stratum of the friable sandstones (thickness 10–25 m). These sandstones are of very good permeability and uranium mineralization is also found in their basal. The upper part of the Cenomanian sequence is formed by more compact and less permeable fucoid sandstones (thickness 40 m). The base of the Turonian sequence is formed by a 60 m thick formation of poorly pervious

siltstones and marly limestone. Above them there are permeable thick-bedded sandstones which often reach to the surface.

Cut off criteria: grade 0.015 %U

productivity 1.0 kgU/m^2

V–2. FACTORS AFFECTING ISL PROCESS

Lithological/mineral composition of ores:	mainly quartz, <2% clays, <0.5% iron oxides pyrite and organic carbon only locally (<1%).
Hydraulic conductivity:	2–8 m/d
Porosity, effective porosity of ores	26–30% / 18–22%
Depth of mineralized layer:	160–220 m
Static water table in mining aquifer:	-20 to -80 m
Carbonate content in ore:	< 0.1 %
Carbon content:	0.05 % ($C_{organic}$)
Sulphide content in ore:	0.1–0.3 %
Total mineralization of groundwater:	< 0.2 g/L TDS
Groundwater temperature:	14°C
Natural groundwater flow:	10–30 m/a, SW direction

V–3. TECHNOLOGY OF LEACHING

Type of leaching: acid

Leaching agent: H_2SO_4

Operational phases: acidification: up to 80 g/L of H_2SO_4

operation: ~40 g/L of H_2SO_4

ending: 15–20 g/L of H_2SO_4

Specific consumption of reagents: 24–28 kg of H_2SO_4 per t ore (both mineralized/barren)

Flow velocity of leaching solution: 0.12–0.18 m/d

Total dose of leaching reagent: 2 000–8 000 t/ha

V–3.1. Wellfields parameters

Well construction:	to 1983	
	casing diameter	110/90 mm (both injection and recovery wells)
	casing material	PE (polyethylene)
	grouting	cementation
	screening type	cut slots, length 4–6 m, PE
	from 1984	
	casing diameter	110/90 mm (injection wells)
		218/206 mm (recovery wells)
	casing material	PE (injection wells)
		stainless steel (recovery wells)
	grouting	cementation
	screening type	cut slots, length 4–6 m, PE
		moulded bridge, length 4–6 m, stainless steel
Well patterns:	to 1979	
	shape(s)	tetragonal
	distance between wells	typically 28 m, partly 20 or 14 m
	well density	12–25 wells per ha
	ratio between recovery and injection wells	2: 3
	1980–1983	
	shape(s)	parallel (lines)
	distance between wells	20 × 50 m
	well density	10 wells/ha
	ratio between recovery and injection wells	1: 1
	from 1984	
	shape(s)	parallel, distance of lines 100–120 m
	distance between wells	60–80 m in recovery line

6–8 m in injection line

well density 6–8 wells per ha

ratio between recovery and injection wells 1: 10

Pumping technique: to 1983 airlifting

from 1984 submersible pumps; diameter 6" (155 mm)

Area of simultaneously working wellfields: ~ 400 ha

Number of simultaneously working wells: ~ 6 000

Water balance management: not specific

V–3.2. Processing plant parameters

Flow rate of leaching solution: max. 2 500 m^3/h,

Average uranium concentration in pregnant leach solution: 50–60 mg/L

Technology of solution processing: ion exchange

Ion exchange resin specification: strong basic anionic resin, pyridine type

Varion AP (Hungary), Ostion AU (Czech)

total loading capacity 1.55 mol eq/L,

operational loading capacity 8–12 kgU/m^3

particle size 0.6–1.4 mm

volume of resin in operation 1 550 m^3

Technology of sorption: PP 1: fixed bed, 48 columns, each 18 m^3 of resin

PP 2: continual counter current flow

12 sorption columns, each ca. 50 m^3 of resin

Technology of desorption: PP 1: fixed bed column

PP 2: continual counter current flow

3 regeneration columns, ca. 12 $m^3$of resin

Chemistry of desorption: solution of 1.0 mol/L NH_4NO_3 + 0.25 mol/L HNO_3

Technology of downstream processing: precipitation with ammonia, washing, dewatering, drying

Consumptions: ion exchange resin; ~80 m^3_{WSR}/a

HNO_3; 15–18 kg/kgU

NH_3; 5–7 kg/kgU

Annual consumption of all other chemicals:

- H_2SO_4; 180 000–200 000 t/a
- HNO_3; 12 000–15 000 t/a
- NH_3; 5 000 –7 000 t/a

V–3.3. Restoration

Technology of groundwater restoration: pump and treat

Operating period of restoration process: estimated 30 a

Final groundwater quality: less than 10 g/L of TDS

Annex VI

KAZAKHSTAN – AKDALA

Associated company names: Betpak-Dala (A joint venture between JSC NAC Kazatomprom 30% and Uranium One 70%)

Location: Suzak region of the South Kazakhstan Oblast

Period of operation: from 2001 to present

Annual production: average 754 tU/a, maximum 1 040 tU (2006)

Total production through 2010: 7 543 tU

Current status (2012): operating

VI–1. GEOLOGY

Type of deposit: Akdala is classified as a hydrogenic (groundwater infiltration) type deposit related to regional oxidation. The host rock of the deposit is a grey-coloured sediment of the lower interval of the Zalpak formation. It is an alluvial layer of different sized sands, pebbles and gravel with a thickness of 15–25 m. In total, 3 deposits have been identified. Widths range from 25 to 700 m, and lengths from 5.6 to 9.6 km. In cross-section, ore bodies may be roll fronts, lenses or tabular units. The thickness of ore intervals varies from 0.8–9.0 m. The depth of occurrence is 150–195 m.

The average grade of uranium mineralization at the Akdala-Blizhniy site is 0.057% U, the average productivity coefficient is 6.35 kg/m^2, and the average thickness 6.7 m. The average grade at the Akdala-Letniy site is 0.067%U, the average productivity coefficient 4.53 kg/m^2, and the average thickness is 4.1 m.

Geological ore reserves: Blizhniy: C1 – 11 800 tU, C2 – 386 tU. Letniy: C1 – 370 tU, C2 – 3 460 tU (initial)

As of 31 July 2006:

Proven reserves; 3 981 000 t at 0.057%U for 2 270 tU

Probable reserves; 12 809 000 t at 0.057%U for 7 300 tU

Indicated resources; 17 158 000 t at 0.057%U for 9 780 tU

Inferred resources; 9 683 000 t at 0.062%U for 6 020 tU

Recoverable reserves: recovery mandated by government at 90%

Mineralogy of U: uranium minerals include: coffinite 65% and pitchblende 35%

Number of aquifers: above; Uvanas, below; Inkuduk

Underlying formation, rock type: clay /siltstone, depth from surface; 195 m

Overlying formation, rock type: clay / siltstone

Average operational thickness: total; 20 m

U ore; 10–15 m

Cut off: grade 0.01%U; GT 0.06 m%

VI–2. FACTORS AFFECTING ISL PROCESS

Lithological composition of ores:	ore bearing sands consist of quartz 92%, feldspar 7% and SiO_2 5–7%.

Mineral composition of ore: trace minerals include: selenium 0.001%, rhenium 0.75 g/t, scandium 2.8 g/t, rare earths plus yttrium 70.9 g/t and yttrium 19.4 g/t.

Permeability:	4.2–14 m/d
Transmissivity of ores:	116–284 m^2/d
Thickness of productive aquifer:	20 m
Ratio of effective thickness to ore thickness:	1.3
Depth of orebody:	180–195 m
Depth of static level head below surface:	the hydrostatic head increases from east to west from 17–21 m to 50–53 m above the top of the productive horizon, water table from 64–77 m.
Position of orebody in aquifer:	close to bottom of aquifer
Carbonate content in ore:	0.1%
Total mineralization of groundwater:	4.3–6.0 g/L
Groundwater temperature:	22°C

VI–3. TECHNOLOGY OF LEACHING

Type of leaching: acid

Leaching agent: H_2SO_4

Leaching agent concentration in operational solutions (average): Leaching proceeds in three stages: 1) an oxidation stage utilizing a sulphuric acid solution with a concentration of 20 g/L; 2) a leaching stage utilizing a sulphuric acid solution with a concentration of 6 to 10 g/L; and 3) a final stage within which no acid is added to the leaching solution.

Period of block start up (acidification, alkalization): 40 d acidification

Period of individual wellfields (blocks) operation: 5–6 a

Specific consumption of reagents: confidential

VI–3.1. Wellfields parameters

Well construction: casing diameter; 90 mm (inj), 190 mm (rec)

casing material; PVC

screening type, length; 8–12 m, material; PVC

Well patterns: shape; 7-spot and alternating rows of injection and recovery wells

distance between wells; 7-spot: radius of 45–50 m, row patterns; a spacing of 60 m between rows and 30 m between wells

wellfield area total; average block size 54 000 m^2

ratio between recovery and injection wells; 0.4

Pumping technique: Grundfos, Odessy submersibles, 110 mm

Production well pumping rate: 2.2 L/s

Area of simultaneously working wellfields (blocks): 915 000 m^2

Number of simultaneously working wells: ~660 production and injection

VI–3.2. Processing plant parameters

Volume of processed solution: 1 500 m^3/h

Production capability: 1 000 tU/a

Technology of solution processing: ion exchange

Ion exchange resin specification: type, trade mark; Amberlite 910

loading capacity; 20 kgU/m^3 (actual)

particle size; 0.8 mm

volume of resin in operation; 619 m^3

Elution reagent specification: NH_4NO_3

Technology of sorption/desorption: fixed bed; upflow sorption, U shaped desorption

total volume of resin; 619 m^3

Chemistry of final product precipitation; H_2O_2

Annual consumption of: ion exchange resin; 0.03 kg/kgU

Volume and type of equipment (vessels, pumps, piping): 55 m^3 IX, 55 m^3 U shaped desorption, 30 m^3 denitrification

Injection and recovery stream storage type: sand ponds

Satellite sorption stations: no

VI–3.3. Restoration

Technology of groundwater restoration: natural attenuation

Operating period of restoration process: 10 a (estimated)

Final groundwater quality: to near baseline conditions

Annex VII

KAZAKHSTAN – CENTRAL MYNKUDUK

Associated company names: Ortalyk JV (JSC NAC Kazatomprom 100%)

Location: Suzak region of South Kazakhstan

Period of operation: from 2007 to present

Annual production: average 739 tU/a, maximum 1 242 tU (2010)

Total production through 2010: 2 957 tU

Current status: operating

VII–1. GEOLOGY

Type of deposit: the deposit is classified as the hydrogenic (groundwater infiltration) type related to regional oxidation. The host rock consists of grey coloured sediments of the Mynkuduk formation. It is an alluvial layer of different sized sand. The thickness of the productive horizon increases from North-east to South-west from 20–40 m to 70–100 m. In total, 2 ore bodies with widths varying from 50–1300 m and lengths from 8.8–26.4 km have been identified within the deposit. In cross-section, ore bodies may be roll fronts/ irregular rolls, lenses and tails of rolls. Ore intervals vary in thickness from 0.9–20.7 m. The average mineralized thickness is 7.2 m.

Geological ore reserves: C1 – 42 528 tU and C2 – 5125 tU (initial)

Total resources = 50 400 tU at an average grade of 0.032% U (2007)

Recoverable reserves: Recovery is estimated to be 90%

Mineralogy of U: uranium mineralization is represented by coffinite (34%) and pitchblende (66%)

VII–2. FACTORS AFFECTING ISL PROCESS

Lithological composition of ores: constituents of the ore bearing sands include: quartz 70–80% and feldspar 7–18%

Mineral composition of ore: trace minerals contained in the ore of the Mynkuduk deposit include: selenium 0.001 g/t, rhenium 0.09–0.1 g/t, scandium 3.8 g/t, rare earths plus yttrium 91.1–110.6 g/t, and yttrium 21.8–23.9 g/t

Permeability:	3.7–13.3 m/d
Depth of orebody:	335 m
Depth of static level head below surface:	The hydrostatic head is 100–270 m above the top of the productive horizon

Carbonate content in ore: 0.3%

Total mineralization of groundwater: 5 000–6 000 mg/L

VII–3. TECHNOLOGY OF LEACHING

Type of leaching: acid

Leaching agent: H_2SO_4

VII–3.1. Wellfields parameters

Well construction: casing diameter; 90 mm (inj), 190 mm (rec)

casing material; PVC

screening type, length; 8–12 m, material; PVC

Well patterns: shape; 7-spot

distance between wells; radius of 40–45 m

Pumping technique: type, diameters; Grundfos, Odessy submersibles, 110 mm

Production well pumping rate: 2.2 L/s

VII–3.2. Processing plant parameters

Production capability: 2 000 tU/a

Technology of solution processing: ion exchange

Ion exchange resin specification: trade mark; Amberlite 910

Elution reagent specification: NH_4NO_3

Final product precipitation NH_4NO_3

VII–3.3. Restoration

Technology of groundwater restoration: natural attenuation

Operating period of restoration process: 10–15 a (estimated)

Final groundwater quality: to near baseline conditions

Annex VIII

KAZAKHSTAN – TAUKENT (KANZUGAN, MOINKUM)

Associated company names: JSC NAC Kazatomprom, (Mining Group, Taukentskiy Mining Chemical Complex)

Location: Chu-Saryssu Basin, South Kazakhstan

Period of operation: from 1982 to present

Annual production: average 558 tU/a, maximum 1 037 tU (2009)

Total production through 2010: 15 626 tU

Current status (12/09): operating at the Kanzugan and South Moinkum deposits

VIII–1. GEOLOGY

Type of deposit: uranium occurs within the Kanzugan deposit in two formations: Kanzugan, 230 to 250 m in depth, and Uyuke, 270 to 300 m. Separating these two formations is an intervening formation of low permeability. Both formations are Palaeogene in age and both host uranium in a series of separated pods with reserves/resources ranging from 300 to 2000 tU per pod. The average thickness is 4.5 m.

TABLE VIII–1. GEOLOGICAL ORE RESERVES

Original reserves – Kanzugan deposit				
Category	Formation	Tonnes ore	Grade (% U)	tU
C_1	Kanzugan	15 549	0.039	5 993
C_2	Kanzugan	2 532	0.037	933
Sub-Total		18 081	0.038	6 926
C_1	Uyuke	34 608	0.037	12 881
C_2	Uyuke	4 106	0.033	1 342
Sub-total		38 714	0.037	14 223
Total		56 795	0.037	21 149

(1/1/2003) RAR= 15,700 tU, EAR = 3 900 tU, thickness = 5.3 m, grade = 0.045%U

(1/1/07) Total resources for the Kanzugan and Moinkum (site 1) deposits were reported to be 28 192 tU at an average grade of 0.057%U.

Original resources at the Kainor site of Kanzugan were reported to be: C_1 – 7 150 tU at 0.037% U and C_2 – 5 775 tU at 0.047% U

Recoverable reserves: Estimated recovery is 87%

Mineralogy of U: 75%–~100% coffinite, 0.7–25% uraninite

VIII–2. FACTORS AFFECTING ISL PROCESS

Lithological composition of ores: medium- and fine-grained quartz (67–76%) and feldspar (10–15%) are the main host rock constituents.

Permeability:	6–14 m/d
Depth of orebody:	230–300 m
Depth of static level head below surface:	+20–100 m
Carbonate content in ore:	0.1%
Total mineralization of groundwater:	0.2–0.4 g/L
Groundwater temperature:	18–25^{o}C

VIII–3. TECHNOLOGY OF LEACHING

Type of leaching: acid

Leaching agent: H_2SO_4

Leaching agent concentration in operational solutions (average): initially 25 g/L

Period of block start up (acidification): 5 months

VIII–3.1. Wellfields parameters

Well construction:	casing diameter; inj = 110 mm, rec = 210 mm
	casing material; PVC
	screening length; 15 m
Well patterns:	Initially rows spaced at 50 m with 25 m between production wells and 15 m between injection wells. Later 7-spot with 40–50 m spacing.
	ratio between recovery and injection wells; 0.5
Pumping technique:	150 mm submersible electric pumps for wells with deeper water levels.

Production well pumping rate: 1.4 L/s

Specific consumption of electrical power to pump one cubic meter solution from the well: ~50kWh/kgU

VIII–3.2. Processing plant parameters

Volume of processed solution:	2 000 m^3/h
Production capability:	1 200 tU/a
Technology of solution processing:	ion exchange
Elution reagent specification:	elution reagent; NH_4NO_3
Chemistry of:	resin regeneration; H_2SO_4
	final product precipitation; NH_4HCO_3

Injection and recovery stream storage type: open air settling ponds

VIII–3.3. Restoration

Technology of groundwater restoration: natural attenuation

Annex IX

KAZAKHSTAN – CHIELI (NORTH AND SOUTH KARAMURAN DEPOSITS)

Associated company names: JSC NAC Kazatomprom (Mining Group – 6 LLP)

Location: Shieli District of the Kyzylorda region

Period of operation: from 1985 to present

Annual production: average 581 tU/a, maximum 1 130 tU (2008)

Total production through 2010: 15 127 tU

Current status (2013): operating

IX.1. GEOLOGY

Type of deposit: North and South Karamurun are roll-front type deposits located within flat-lying permeable sediments

North Karamuran includes three major roll-front ore bodies spread over a length of about 5 km and positioned at depths of 450–700 m. Ore bodies are 25–450 m wide and 6–24 m thick. The average grade is 0.06% U and the average thickness is 4.7 m

The average grade and thickness for South Karamuran are 0.06% U and 3.4 m, respectively

Geological ore reserves: (1/1/03) North Karamuran – RAR = 15 650 tU, EAR = 3 925 tU, South Karamuran – RAR = 10 115 tU, EAR = 8 075 tU

Recoverable reserves: mining recoveries are estimated to be 91%

Mineralogy of U: coffinite and (sooty) pitchblende are the principal U minerals

Average operational thickness: total U ore 4.7 m (North Karamurun), 3.4 m (South Karamurun)

Cut off: cut-off criteria for mineralization to be incorporated into the reserve estimates for Mining Group-6 LLP includes the following: minimum grade 0.01% U, minimum thickness 0.2 m, minimum productivity coefficient 1.0 kgU/m^2, and minimum filtration coefficient 1.0 m/d

IX.2. FACTORS AFFECTING ISL PROCESS

Lithological composition of ores: Host rocks are Campanian and Maastrichtian fluvial feldspathic quartz sands characterized by low contents of carbonaceous debris and carbonate, high permeability

Lithologic composition of ores: 65–80% quartz, 7–15% feldspar, 10–25% chert

Mineral composition of ore: coffinite and (sooty) pitchblende are the principal uranium minerals. Associated minerals/elements include selenium in the form of native Se and ferriselite, vanadium (<4% V_2O_5) as tyuyamunite and häggite, <0.3 % Ge, <0.2 % As, and <19 ppm Re

Permeability:	10–15 m/d
Thickness of productive aquifer:	24 m (average at North Karamurun)
Depth of orebody:	North Karamuran 450–550 m
	South Karamuran 570–680 m
Depth of static level head below surface:	static water levels range from 5–15 m below ground surface due to high pressures in the mineralized horizon
Total mineralization of groundwater:	0.5–0.8 g/L
Groundwater temperature:	35–40^{o}C

IX.3. TECHNOLOGY OF LEACHING

Type of leaching: acid

Leaching agent: H_2SO_4

Leaching agent concentration in operational solutions (average): Leaching proceeds in two phases with a sulphuric acid concentration of 30 g/L in the first stage for a period of about three months. A solution concentration of 5–7 g/L of sulphuric acid is used for the remainder of the life of the well field; three to five years. Production continues until the uranium concentration declines to 40 mg/L, at which time the well is shut in.

IX.3.1. Wellfields parameters

Well construction: pilot holes for well installation are drilled to full depth at a diameter of 132 mm. These pilot holes are then logged with radiometric, resistivity, self-potential, caliper and directional tools. If the well has deviated more than five to ten meters from vertical, it is redrilled. If the well meets all criteria for acceptance, it is then enlarged to a diameter of 161 mm and cased with 110 mm plastic pipe having a thickness of 18 mm. The wells are not cemented since a zone of squeezing clay seals the annulus of the well and prevents communication between formations. Well screens are constructed of a series of plastic rings 120 mm in diameter with a 1 mm gap between rings. The minimum length of well screen installed is 5 m. On average, the productive horizon at the North Karamurun deposit is approximately 15 thick. Production wells are equipped with 25 to 40 mm plastic air lift pipes to a depth 60 to 70 m from surface to bring wellfield solutions into the collection system.

Well patterns:	all wellfields are installed on a hexagonal pattern with a spacing of 40 m
	ratio between recovery and injection wells; 0.25

IX.3.2. Processing plant parameters

Volume of processed solution:	1 700 m^3/h
Production capability:	1 250 tU/a
Technology of solution processing:	ion exchange; upflow

Elution reagent specification:	elution reagent; NH_4NO_3
Resin regeneration	H_2SO_4
Final product precipitation	NaOH

IX.3.3. Restoration

Technology of groundwater restoration: natural attenuation

Annex X

KAZAKHSTAN – INKAI

Associated company names: Cameco Corporation (60%), JSC NAC Kazatomprom (40%)

Location: Chu-Saryssu Basin, South Kazakhstan

Period of operation: from 2002 (test mining), commercial production 2009 to present

Annual production: average 525 tU/a, maximum 1637 tU (2010, Inkai 1–2)

Total production through 2010: 3 676 tU

Current status (12/11): commercial operations

X.1. GEOLOGY

Type of deposit: uranium ore occurs in Cretaceous sediments at depths of 260 to 525 m in broad (800 m to 1,900 m) roll-front-like deposits which are characterized by high permeabilities, up to 35 D (30 m/s). 65% of the ore occurs in the Inkuduk horizon and 35% in the Mynkuduk horizon. Ore reserves have an average grade of 0.04% U and an average thickness of 7 m.

TABLE X.1. GEOLOGICAL ORE RESERVES (12/31/08)

Category	Ore (kt)	Grade (%U)	Content (tU)
Proven reserves	7 415	0.07	5 269
Probable reserves	86 080	0.06	49 269
Measured resources	0	–	0
Indicated resources	10 904	0.06	6 846
Inferred resources	254 696	0.04	98 115
Totals	359 095	0.04	159 500

Mineralogy of U: sooty pitchblende 85% and coffinite 15% are the principal uranium minerals as coatings on sand grains.

Cut off: grade 0.01%U, GT 0.06 m%U

X.2. FACTORS AFFECTING ISL PROCESS

Lithological composition of ores: quartz 71%, siliceous debris 13%, feldspar, mica, clay, limonite 15%

Mineral composition of ore: 15% coffinite and 85% sooty pitchblende

Permeability: 2–21 m/d

Transmissivity of ores: 11 m/d

Depth of orebody: 260 to 525 m

Depth of static level head below surface: artesian 8 to 10 m

Carbonate content in ore: 0.1–0.2%

Sulphide content in ore: 1–2%

Total mineralization of groundwater: 900–4700 mg/L

Natural groundwater flow: velocity 1–4 m/a, direction northwest

X.3. TECHNOLOGY OF LEACHING

Type of leaching: acid

Leaching agent: H_2SO_4

Leaching agent concentration in operational solutions (average): 10–20 g/L

X.3.1. Wellfields parameters

Well construction: casing diameter; 110 mm

Well patterns: shape 7-spot

Production well pumping rate: 2.3 L/s

Number of simultaneously working wells: 278 extraction wells

X.3.2.Processing plant parameters

Volume of processed solution: 1 400 m^3/h at each block

Production capability: 2 000 tU/a

Technology of solution processing: ion exchange

Ion exchange resin specification: loading capacity; 35 kg/m^3

volume of resin in operation; 515 m^3.

Elution reagent specification: elution reagent; H_4NO_3

Chemistry of: resin regeneration; H_2SO_4

final product precipitation; $H_2O_2 + NH_3$

Annual consumption of other chemicals: NH_4NO_3 = 10 500 t/a

Volume and type of equipment (vessels, pumps, piping): 18 IX columns

Satellite sorption stations: The main processing plant is located on Block 1 and a satellite plant is located on Block 2. The main processing plant has an ion exchange capacity of 1 000 tU/a, and a product recovery drying and packaging capacity of 2 000 tU/a.

Annex XI

KAZAKHSTAN – IRKOL

Associated company names: Semizbai-U LLP (a joint venture JSC NAC Kazatomprom 51% and Beijing Sino-Kaz Uranium Resources Investment Company Limited of the People's Republic of China 49%)

Location: Shieli District of the Kyzylorda region

Period of operation: from 2007 to present

Annual production: average 157 tU/a, maximum 224 tU (2010)

Total production through 2010: 506 tU

Current status (2013): operating

XI–1. GEOLOGY

Type of deposit: the deposit is classified as the hydrogenic (groundwater infiltration or roll front) type related to regional oxidation. The host rock consists of grey coloured sediments of the Turonian, Coniacian, Santonian and Campanian formations. Sediments of the Turonskiy formation are fine-grained sands with a thickness 40–50 m. The Konyaksky horizon is represented by fine-grained sand, pebbles and gravel, where the thickness of the productive horizon is 60 m. The Santonskiy formation is primarily a grey-coloured fine- to medium-grained sand and the thickness of the productive horizon is 80 m. Sediments of the Kampanskiy formation are mostly fine and medium-grained sands with a thickness of 20 m. The total thickness of the ore-bearing horizons is 210 m.

Ore bodies within the deposit have lengths of 500–6 000 m and widths of 25–650 m. The thickness ranges from 1–20 m and the depth of occurrence from 80–640 m. The average grade is 0.042%U.

Geological ore reserves: C_1 – 16 800 tU, C_2 – 12 753, P_1 – 8 900 tU (initial)

Mineralogy of U: coffinite 70 to 90% and pitchblende up to 30%.

XI–2. FACTORS AFFECTING ISL PROCESS

Lithological composition of ores: Constituents of the ore bearing sands include: quartz (65–80%) and feldspar (5–10%)

Mineral composition of ore: Trace minerals include: selenium 0.04–0.05 g/t, rhenium 0.1–0.5 g/t, scandium 4–5 g/t, and vanadium 4%. The carbonate content is less than 2% and the clay content is 15–20%

Permeability:	2–10 m/d
Depth of static level head below surface:	The hydrostatic head ranges from 65 m in the north to 880 m in the south

Total mineralization of groundwater: 600–900 mg/L

XI–3. TECHNOLOGY OF LEACHING

Type of leaching: acid

Leaching agent: H_2SO_4

XI–3.1. Processing plant parameters

Production capability: 750 tU/a

Technology of solution processing: ion exchange

Satellite sorption stations: no

XI–3.2. Restoration

Technology of groundwater restoration: natural attenuation

Annex XII

KAZAKHSTAN – BUDENOVSKOYE (2) (KARATAU)

Associated company names: Karatau LLP (a 50/50 joint venture between Uranium One Corporation and JSC NAC Kazatomprom)

Location: Suzak region of South Kazakhstan

Period of operation: from 2007 to present.

Annual production: average 376 tU, maximum 653 tU (2008)

Total production through 2008: 1129 tU

Current status (12/09): operating

XII–1. GEOLOGY

Type of deposit: the deposit is classified as the hydrogenic (groundwater infiltration) type related to regional oxidation. The host rock consists of grey coloured sediments of the Mynkuduk, Inkuduk, and Zhalpak Formations. Ore bodies of Budenovskoye deposit are sinuous bands with widths of 3.5 km and lengths up to 25 km. In cross-section, ore bodies may be roll fronts, irregular rolls, lenses or tabular units. The average ore thickness is about 7 m.

Sediments of the Mynkuduk Formation are mainly grey coloured fine and medium-grained sands (60–90%) and coarse-grained sand, pebbles and gravel (10–40%). The thickness of the productive horizon ranges from 0 to 30 m. The depth of the Mynkuduk Formation is 680–700 m, or more.

The Inkuduk Formation is primarily a grey coloured fine- to medium-grained sand (30–95%) and coarse-grained sand, pebbles and gravel. The thickness of the productive horizon varies from 30–100 m. Inkuduk is 640–700 m deep, or more. This formation hosts most of the ore.

Sediments of the Zhalpak Formation are mostly red coloured, more rarely grey/green coloured medium-grained sands with layers of coarse-grained sand, pebbles and gravel with a thickness of 40–80 m. Zhalpak is 540–630 m deep.

TABLE XII–1. GEOLOGICAL ORE RESERVES

Category	Ore (Mt)	Grade (%U)	Content (tU)
C1	9.8	0.12	11 300
C2	0.9	0.09	800
P1	16.8	0.09	14 600

Recoverable reserves: recovery has been estimated at 85%

Area of deposit: C1 + C2 = ~100 hectares

TABLE XII–2. MINERALOGY OF U

Horizon	Coffinite	Pitchblende
Mynkuduk	12%	83%
Inkuduk	39%	55%
Zhalpak	52%	39%

Number of aquifers: above; Uvanas at 400 m Zhalpak at 600 m

below; Mynkuduk at 700 m

Underlying formation, rock type: depth from surface ~680 m, clay

Overlying formation, rock type: clay at ~650 m

Average operational thickness: total 40–50 m, U ore 15–20 m

Cut off: grade 0.01%U, GT 0.06 m%U

Below cut off U reserves: N/A

XII–2. FACTORS AFFECTING ISL PROCESS

Lithological composition of ores:

- Mynkuduk: quartz 60–70%, SiO_2 10–15%, feldspar 5–10%.
- Inkuduk: quartz 52–61%, SiO_2 11–18%, feldspar 7–12%.
- Zhalpak: quartz 55–59%, SiO_2 8–13%, feldspar 10–17%.

Mineral composition of ore:

- Mynkuduk: rhenium 0.03 g/t, scandium 3.7 g/t, rare earths plus yttrium 147 g/t.
- Inkuduk: rhenium 0.05 g/t, scandium 3.2 g/t, rare earths plus yttrium 138 g/t.
- Zhalpak: rhenium 0.03 g/t, scandium 4.6 g/t, rare earths plus yttrium 142 g/t.

Permeability: 7–12 m/d

Thickness of productive aquifer: 40–50 m

Ratio of effective thickness to ore thickness: 15/40 = 0.375

Depth of orebody: 670 m

Depth of static level head below surface: Artesian +30 m

Position of orebody in aquifer: middle and bottom

Carbonate content in ore: Mynkuduk 0.11%, Inkuduk 0.5%, Zhalpak 0.17%.

Total mineralization of groundwater: 1.5–3.5 g/L

Groundwater temperature: 27°C

Natural groundwater flow: direction; from southeast to northwest

XII–3. TECHNOLOGY OF LEACHING

Type of leaching: acid

Leaching agent: H_2SO_4

Leaching agent concentration in operational solutions (average): 7 g/L

Period of block start up (acidification, alkalization): Acidification stage; this is the conditioning stage of the process, with strong acid (20–25 g/L H_2SO_4) applied to the wellfield for around 2 months. This consumes the bulk of the carbonates in the ore, and drives the pH down from the aquifer pH of around 7 to the operational pH of <2.0.

Period of individual wellfields (blocks) operation:

Operational stage; when in the operational stage the feed acid concentration will be lowered to approximately 6–10 g/L in order to maintain the exit pH of <2.0. The wellfield is operational for 3–4 a.

Flushing stage; during the final production stage of the wellfield, no additional acid is added to the returning lixiviant. This period is between 6–12 months.

XII–3.1. Wellfields parameters

Well construction: casing diameter; 90 mm (injection wells), 195 mm for the 1st 30 m then 90 mm to bottom of ore zone (recovery wells). Note: pumps are placed at a depth of 30 m.

casing material; PVC

grouting; surface to 65 m depth

screening type 1.2 mm, length 10 to 12 m, material PVC disk type

Well patterns: shape; 50% 7-spot, 50% linear

distance between wells; 45–50 m (inj to rec)

ratio between recovery and injection wells; 1:2.7

Pumping technique: type; submersible

Production well pumping rate: ~10 m^3/h

Number of simultaneously working wells: ~500

XII–3.2. Processing plant parameters

Volume of processed solution: 1 400 m^3/h

Production capability: 2 000 tU/a

Technology of solution processing: ion exchange, upflow

Ion exchange resin specification: type; strong base anion, trade mark; Amberjet 920Cl

loading capacity 50 g/L

Elution reagent specification: NH_3NO_3

Technology of sorption/desorption: continuous transfer of loaded resin to desorption

total volume of resin 550–600 m^3

Chemistry of final product precipitation; hydrogen peroxide

Initial load of ion exchange resin 120 m^3

Volume and type of equipment (vessels, pumps, piping): 7–56 m^3 sorption columns, 3–72 m^3 U-shaped columns for desorption, material for both is stainless steel

Satellite sorption stations: none.

XII–3.3. Restoration

Technology of groundwater restoration: natural attenuation

Operating period of restoration process: annual monitoring required for 15 a, 30–40 a estimated requirement for completion.

Final groundwater quality: non potable

Annex XIII

KAZAKHSTAN – KHARASAN 1

Associated company names: Kyzlkum LLP a joint venture of Kazatomprom (30%), Energy Asia (BVI) Limited which is a consortium of Japanese utilities and a trading company (40%), and Uranium One Corporation

Location: Yanykurgan region of the Kzyl-Ordinsky Oblast adjacent to the Kharasan 2 project

Period of operation: from 2008 to present

Annual production: average 12 tU/a, maximum 12 tU (2008)

Total production through 2008: 12 tU

Current status (12/09): in production

XIII–1. GEOLOGY

Type of deposit: The deposit is classified as the hydrogenic (groundwater infiltration) type related to regional oxidation. The host rock consists of grey coloured sediments of the Maastrichtian/Santonian, and Campanian formations. The Maastrichtian comprises three sand layers each of which is 10–15 m thick. The main ore reserves are concentrated in the middle and lower subhorizons (72%). 18% of the total reserves are in the Campanian formation which has a thickness of 15–25 m. 10% occurs in the Santonian formation where the thickness is 18–25 m. The total thickness of the ore bearing zone of the deposit is 50–80 m. In total, 10 ore bodies with widths varying from 100–500 m and lengths from 3–10 km have been identified within the deposit. In cross-section, the ore bodies are mainly lenticular. Thickness of the ore interval varies from 0.6–12 m. The depth of occurrence is 600–750 m. The average grade is 0.111%U and the average thickness is 3.6 m.

TABLE XIII–1. GEOLOGICAL ORE RESERVES

Category	Ore (t)	Grade (%U)	Contained U (t)
Indicated resources	2 635 300	0.201	5 300
Inferred resources	30 531 700	0.095	29 050
P_1	44 200 000	0.082	54 150

Recoverable reserves: recovery is estimated to be 90%.

Mineralogy of U: uranium mineralization includes: coffinite (40–50%) and pitchblende (50–60%) with occasional carnotite [$K_2(UO_2)_2(VO_4)_2.H_2O$].

Cut off: grade: 0.01%U, GT; 0.06 m%U

XIII–2. FACTORS AFFECTING ISL PROCESS

Lithological composition of ores: quartz (53–74%), feldspar (5–13%), and SiO_2 (8–18%)

Mineral composition of ore: trace minerals include: selenium 0.053–0.075%, rhenium 0.09–0.15 g/t, scandium 2.5–3.0 g/t, rare earths 56–76 g/t, yttrium 13–15 g/t, and vanadium pentoxide 150–174 g/t.

Permeability:	5–6 m/d
Transmissivity of ores:	40–110 m^2/d
Depth of orebody:	650–700 m
Depth of static level head below surface:	2–5 m
Carbonate content in ore:	0.1–1.5%
Total mineralization of groundwater:	600–900 mg/L
Groundwater temperature:	35–40^{o}C

XIII–3. TECHNOLOGY OF LEACHING

Type of leaching: Acid

Leaching agent: H_2SO_4

Leaching agent concentration in operational solutions (average): Leaching proceeds in three stages: 1) an oxidation stage utilizing a sulphuric acid solution with a concentration of 20 g/L; 2) a leaching stage utilizing a sulphuric acid solution with a concentration of 6 to 10 g/L; and 3) a final stage within which no acid is added to the leaching solution.

Period of block start up (acidification, alkalization): 4 months

Period of individual wellfields (blocks) operation: 3.5 to 5 a

XIII–3.1. Wellfields parameters

Well construction: casing diameter; 90 mm (inj), 195 mm (rec)

screening type; 1 mm mesh

Well patterns: shape; 7-spot and rows

Distance between wells; 7-spot at 40–45 m diameter, rows at 50–60 m between rows, 30 m between recovery wells and 20 m between injection wells.

Pumping technique: type; submersible 7.5 kW

Production well pumping rate: 0.6 L/s

XIII–3.2. Processing plant parameters

Production capability:	3000 tU/a
Technology of solution processing:	ion exchange, continuous counter-current
Ion exchange resin specification:	type, trade mark - Amberlite IRA910 Cl (Rohm and Haas) or MP-60021 (Lewatit)
	loading capacity 18 g/L (estimated)
Elution reagent specification:	elution reagent NH_3NO_3 and H_2SO_4
Technology of sorption/desorption:	continuous counter-current

Chemistry of final product precipitation NaOH

Volume and type of equipment (vessels, pumps, piping): desorption vessels of 60 m^3

Satellite sorption stations: 1 000 tU/a satellite to be added in the future

Annex XIV

KAZAKHSTAN – KHARASAN 2

Associated company names: Baiken-U LLP (Marubeni 60%, Tepco 30%, Tohuku - 10%)

Location: Yanykurgan region of the Kzyl-Ordinsky Oblast adjacent to the Kharasan 1 project

Current status (12/09): under development with initial commercial production expected in 2010

XIV–1. GEOLOGY

Type of deposit: uranium ore bodies lie within Cretaceous sediments as a series of lenses and extensive ribbon-like bodies extending over several kilometres. Most of the mineralization occurs in the Maastricht horizon which is approximately 35–45 m thick, and consists of an upper zone of multi-coloured siltstone and clayey sandstone, and a lower zone of grey alluvial sandstone, 15 m thick.

Geological ore reserves: 24 824 tU at an average grade of 0.108% U

Recoverable reserves: recovery is expected to be 90%.

Mineralogy of U: pitchblende and coffinite occur in nearly equal amounts with minor carnotite. Pitchblende is speciated as fine nodules (<80 μm) on other mineral surfaces such as quartz, pyrite, and silicates. Coffinite is very fine grained (<10 μm) and is dispersed on the interstitial clay cement and detrital grain surfaces.

Cut off: grade 0.01% U, GT 0.06 m% U

XIV–2. FACTORS AFFECTING ISL PROCESS

Lithological composition of ores: quartz 53–74%, feldspar 5–13%, rock fragments 8–19%, micas 1–2%, carbonate phytodetritus 2.5 %, clay minerals 5–17 %, phosphorites up to 1.65%.

Permeability: 4–6 m/d

Transmissivity of ores: 40–110 m^2/d

Carbonate content in ore: 0.3–0.7%

Total mineralization of groundwater: 600–900 ppm

XIV–3. TECHNOLOGY OF LEACHING

Type of leaching: acid

Leaching agent: H_2SO_4

Leaching agent concentration in operational solutions (average):

acidulation stage: 20–23 g/L for 3–4 months

operational stage: 7–10 g/L for 3–4 a

Final stage: 0 g/L for 6–12 months

XIV–3.1. Wellfields parameters

Well construction: casing diameter; rrecovery: 0 to 130 m: 195 mm; 130 m to 650 m: 90 mm

injection: 90 mm

screening type KDF, length 10 m

Well patterns: shape; alternating rows of inj and rec wells with 50–60 m between rows, 30 m between recovery wells and 20 m between injection wells. Also, 7-spot with 45–50 m between injection and recovery wells.

ratio between recovery and injection wells 1: 2.6

Pumping technique: type; submersible, 150 mm diameter

Production well pumping rate: 2.8 L/s

XIV–3.2. Processing plant parameters

Volume of processed solution: 3 200 m^3/h

Production capability: 2 000 tU/a

Technology of solution processing: ion exchange

Ion exchange resin specification: type - Amberlit IRA-910 Cl; Lewatit MP-60021 U type or similar

Elution reagent specification: elution reagent NH_4NO_3

Chemistry of: resin regeneration H_2SO_4

final product precipitation NaOH

Initial load of: ion exchange resin 2150 m^3

Annual consumption of: ion exchange resin 0.95 L/kgU

Annual consumption of all other chemicals:

NH_4NO_3 3.5 kg/kgU, NaOH 0.4 kg/kgU, H_2SO_4 ~75 kg/kgU

Volume and type of equipment (vessels, pumps, piping): ion exchange columns 56 m^3, elution columns 33 m^3.

Process water consumption: 2 m^3/kgU

Steam consumption: 0.12 Gkal/kgU

Electric power consumption: 35 kWh/kgU

XIV–3.3. Restoration

Technology of groundwater restoration: natural attenuation

Operating period of restoration process: 12–60 a

Annex XV

KAZAKHSTAN – MUYUNKUM (MOYNKUM, MOINKUM), SOUTH MUYUNKUM AND TOTKUDUK

Associated company names: Katco JV (AREVA 51%, Kazatomprom 49%)

Location: Suzak district of South Kazakhstan

Period of operation: pilot testing commenced in 2001. Commercial production commenced in 2006

Annual production: average 418 tU/a, maximum 3 132 tU (2009)

Total production through 2009: 6 061 tU

Current status (12/09): operating

XV–1. GEOLOGY

Type of deposit: mainly roll front type, but also tabular or lenticular. Rolls may be up to 1 000 m in width and 30 km in length

Geological ore reserves: (2004) South Muyunkum: B – 3550 tU, C_1 – 21 059 tU and C_2 – 2684 tU). Muyunkum (Center): C_2 – 11 542 tU, P1 – ~20 000 tU. Muyunkum North/Tortkuduk: C_1 – 10 740 tU and C_2 – 10 189 tU. The average grade is 0.074% U

Recoverable reserves: recovery is estimated to be 85%

Mineralogy of U: Muyunkum; mainly coffinite. Tortkuduk; coffinite (65%) and sooty pitchblende (35%). U minerals fill interstices and coat sand grains.

Underlying formation, rock type: clayey sediments

Overlying formation, rock type: clay, mud, argillaceous sand

XV–2. FACTORS AFFECTING ISL PROCESS

Lithological composition of ores: medium- and fine-grained quartz sand with a low clay component

Permeability (Tortkuduk): 5–10 m/d

Thickness of productive aquifer: <50 m

Depth of orebody: Muyunkum 400–600 m, Tortkuduk 250–350 m

XV–3. TECHNOLOGY OF LEACHING

Type of leaching: acid

Leaching agent: H_2SO_4

XV–3.1. Wellfields parameters

Well patterns: shape; alternating rows of injection and recovery wells

XV–3.2. Processing plant parameters

Production capability:	4 000 tU/a (target 2012)
Technology of solution processing:	ion exchange
Elution reagent specification:	elution reagent; NH_4NO_3
Chemistry of:	final product precipitation; H_2O_2, NH_3

Annex XVI

KAZAKHSTAN – SEMIZBAI

Associated company names: Semizbai-U LLP (a joint venture JSC NAC Kazatomprom 51% and Beijing Sino-Kaz Uranium Resources Investment Company Limited of the People's Republic of China 49%)

Location: Northern Kazakhstan 60 km east of Stepnogorsk

Period of operation: from 1982 to 1990. Modern operation started 2009, full production 2011

Current status (2012): commercial production

XVI–1. GEOLOGY

Type of deposit: Semizbai is a basal-channel sandstone-type type deposit. It occurs in a complexly branched palaeochannel system which was incised into the Proterozoic-Paleozoic basement of the eastern Kokshetau Massif. Ore bodiesare 500 m–5 km in length and 20–80 m in width occur in two horizons separated by a 10–15 m thick argillaceous horizon. Depths range from 50–150 m and the average thickness is 2.1 m

Geological ore reserves: original resources were reported to be approximately 20 000 tU at an average grade of 0.10%U. More recently, resources were reported to be 30 350 000 t of ore at an average grade of 0.057%U containing 17 300 tU

Recoverable reserves: recovery by ISR methods has been estimated to be 60%

Mineralogy of U: coffinite, pitchblende and sooty pitchblende disseminated in the matrix

Cut off: grade 0.01%U, GT 0.04 m%U

XVI–2. FACTORS AFFECTING ISL PROCESS

Mineral composition of ore: gangue minerals are reported to be carbonate and chlorite

Depth of orebody: 50–150 m

XVI–3. TECHNOLOGY OF LEACHING

Type of leaching: acid (assumed)

Leaching agent: H_2SO_4 (assumed)

XVI–3.1. Processing plant parameters

Production capability: 500 tU/a

Technology of solution processing: ion exchange

Annex XVII

KAZAKHSTAN – SOUTH INKAI

Associated company names: Betpak Dala JV (Uranium One 70%, Kazatomprom 30%)

Location: The South Inkai deposit, sometimes referred to as Section 4 of the Inkai deposit, is located in the Suzak region of the South Kazakhstan Oblast, approximately 450 km northwest of Shymkent

Period of operation: from 2007 to present.

Annual production: 435 tU in 2008

Total production through 2008: 435 tU

Current status (12/09): commercial operations

XVII–1. GEOLOGY

Type of deposit: South Inkai is a roll front type deposit which covers a 17 km length of the main Inkai trend and is underlain by Cretaceous to Cenozoic sediments, predominately sands, with occasional pebble and gravel layers, clay and loamy soils up to 550 m thick. The sediments are gently dipping to the southeast. There are eight mineralized beds identified to date, of which three are in the Mynkuduk horizon and five in the overlying Inkuduk horizon.

Two resource areas hosted in the Mynkuduk horizon have been delineated to date. The main roll fronts may reach a thickness of 20 m, but more commonly they average 7–10 m at their thickest and 1–2 m on the limbs. The grade ranges from 0.02–0.07% U, averaging 0.041% U for the deposit.

Geological ore reserves: (2/10/06) 40 390 000 t of ore at an average grade of 0.041%U containing 16 720 tU classified as Inferred Mineral Resources

Area of deposit: 280 ha

Mineralogy of U: coffinite 18% and pitchblende 82%

Number of aquifers: above; Zhalpak, Uvanas

Underlying formation, rock type: clay/siltstone

Average operational thickness: total 16–20 m, U ore 6.3 m

Cut off: grade 0.01% U, GT 0.06 m%U

XVII–2. FACTORS AFFECTING ISL PROCESS

Lithological composition of ores: quartz 51–61%, fragments of siliceous rocks 11–23%, feldspar 10–17%, clay5–10% and mica 1–4%

Permeability: 8–13 m/d

Thickness of productive aquifer:	60–80 m
Depth of orebody:	550 m
Depth of static level head below surface:	+20 m (natural artesian)
Position of orebody in aquifer:	middle and lower portions of aquifer
Carbonate content in ore:	0.1 to 0.3%
Sulphide content in ore:	0.1 to 0.3%
Total mineralization of groundwater:	2.7–4.7 g/L
Groundwater temperature:	24°C
Natural groundwater flow:	direction; SE to NW

XVII–3. TECHNOLOGY OF LEACHING

Type of leaching: acid

Leaching agent: H_2SO_4

Leaching agent concentration in operational solutions (average): Leaching to proceed in three phases: 20 g/L initially, 6 to 10 g/L for operational phase and 0 g/L during final phase.

Period of block start up (acidification, alkalization): 60 d acidification

Period of individual wellfields (blocks) operation: 3–5 a

XVII–3.1. Wellfields parameters

Well construction:	casing diameter; inj 90 mm, rec 190 mm to depth of 280 m and 90 mm to final depth
	casing material; PVC
	grouting; neat cement with tremi pipe
	screening type, length, material; PVC, 8–10 m
Well patterns:	shape–alternating rows of injection and recovery wells
	distance between wells; 60 m between rows, 30 m between recovery wells and 15 m between injection wells
	wellfield area total; 4.5 ha per mining block
	ratio between recovery and injection wells; 0.4

Pumping technique: type; submersible pumps, Grundfos, Odessy, 110 mm dia

Production well pumping rate: 2.8 L/s

Area of simultaneously working wellfields (blocks): 60 ha

Number of simultaneously working wells: 450 prod and inj

XVII–3.2. Processing plant parameters

Volume of processed solution:	1 300 m^3/h
Production capability:	2 000 tU/a
Technology of solution processing:	ion exchange
Ion exchange resin specification:	type, trade mark; Amberlite 910
	loading capacity; 20 kgU/m^3
	particle size; 0.8 mm
	volume of resin in operation; 616 m^3
Elution reagent specification:	elution reagent; NH_4NO_3
Technology of sorption/desorption:	upflow sorption, U shaped desorption
	total volume of resin; 616 m^3
Chemistry of:	resin regeneration H_2SO_4
	final product precipitation H_2O_2
Initial load of:	ion exchange resin 140 m^3 in 2007
Annual consumption of:	ion exchange resin 0.03 kg/kgU

Injection and recovery stream storage type: sand ponds

Satellite sorption stations: no

XVII–3.3. Restoration

Technology of groundwater restoration: natural attenuation

Operating period of restoration process: estimate 10 a

Final groundwater quality: near baseline conditions

Annex XVIII

KAZAKHSTAN – STEPNOYE (UVANAS AND EAST MYNKUDUK DEPOSITS)

Associated company names: JSC NAC Kazatomprom (Stepnoye Mining Group LLP)

Period of operation: from 1978 to present

Annual production: average 865 tU/a, maximum 1300 tU (2008)

Total production through 2008: 26 800 tU

Current status (12/09): operating

XVIII–1. GEOLOGY

Type of deposit: Myunkuduk East is a roll-front type uranium deposit, 34 km in length, 50–300 m in width, and relatively linear in plan view. The depth ranges from 100 m in the eastern part to 120 m in the western part. Uranium mineralization occurs in Palaeogene sediments of medium to coarse quartz/muscovite sands between two clay horizons. The formation is from 10–15 m thick with 1–5 m of mineralization. It was formed in a deltaic/shallow warm sea environment and contains fossils of fish and trees replaced with pyrite. Uranium mineralization within this formation has an average grade of 0.03% U.

The Myunkuduk formation is the productive horizon in the Myunkuduk East area and is equivalent to Turonion. It is a grey sand/gravel layer, very coarse, loose and uncemented, with most of the gravel at the base of the formation. It is composed of quartz, plagioclase and biotite. The carbonate content is less than 1.0%. Within the Myunkuduk Formation, the primary productive horizon is 20–30 m thick, while the mineralized thickness varies from 5–15 m. Uranium grades range from 0.025–0.040% U.

Geological ore reserves: Original reserves at Uvanas were approximately 20 000 tU

Original "approved" reserves for the Myunkuduk East deposit amounted to: C_1 – 23 245 tU and C_2 – 4708 tU

As of 1/1/07, reserves for both deposits in total were reported to be 27 102 tU at an average grade of 0.032% U

Recoverable reserves: Mining recovery is reported to be 90%

Mineralogy of U: (both) coffinite and uraninite in approximately equal proportions

Average operational thickness: total; Uvanas 10–15 m, Myunkuduk East 20–30 m

U ore; Uvanas 1–5 m, Myunkuduk East 5–15 m

XVIII–2. FACTORS AFFECTING ISL PROCESS

Lithological composition of ores: medium to coarse quartz/muscovite sands

Mineral composition of ore: coffinite and uraninite in equal proportions

Permeability: 7 m/d

Depth of static level head below surface: 65 m

Carbonate content in ore: <1.0%

Total mineralization of groundwater: 9 000 ppm (~mg/L)

Natural groundwater flow: velocity 1–3 m/a, direction northwest

XVIII–3. TECHNOLOGY OF LEACHING

Type of leaching: acid

Leaching agent: H_2SO_4

Leaching agent concentration in operational solutions (average): Leaching proceeds in three stages: Stage I; 30 g/L H_2SO_4 for 3–5 months, Stage II; 10–15 g/L H_2SO_4 for 1 a and Stage III; 5–10 g/L H_2SO_4 for 1.5 a or until the U concentration in the wellfield solutions declines to 20 mg/L.

Specific consumption of reagents: Uvanas 41 kg H_2SO_4 per kgU, Mynkuduk 140 kg H_2SO_4 per kgU

XVIII–3.1. Wellfields parameters

Well construction:

Mynkuduk East: Production wells are 300 mm in diameter from surface to final depth and are cased with 210 mm plastic pipe from surface to a depth of 175 m. The remaining 60 m of hole are cased with 110 mm plastic. Well screens 120 mm in diameter are typically 10 m in length with a minimum length of 8 m.

Uvanas: Wells meeting the minimum criteria of 1.0 m of 0.010 percent U are enlarged to 250 mm for the full depth. Plastic casing, 160 mm for production wells and 90 mm for injection wells, is installed along with 120 mm well screens for both. The minimum well screen length is 2.0 m.

Well patterns: Wellfield patterns at the Uvanas deposit consist of parallel rows of injection and production wells. In those areas where hydrologic communication exists with an underlying unit, rows are spaced 30 m apart, production wells are 20 m apart, and injection wells are 15 m apart. Normal wellfield spacing is 40 to 60 m between rows, 20 to 25 m between production wells, and 15 m between injection wells.

Wellfield patterns at Mynkuduk East comprise a series of alternating rows of injection and production wells. The rows are spaced 60 m apart, production wells 45 m apart, and injection wells 30 m apart.

Ratio between recovery and injection wells; Uvanas 0.4

Pumping technique: electro-submersible pumps

Production well pumping rate: Uvanas 1L/s, 2 kW; Myunkuduk East 2.8 L/s, 10 kW

Specific consumption of electrical power to pump one cubic meter solution from the well: Mynkuduk; 50 kWhr/kgU, Uvanas; 48 kWhr/kgU

XVIII–3.2. Processing plant parameters

Volume of processed solution: 1 875 m^3/h

Production capability: 1 300 tU/a

Technology of solution processing: ion exchange

Ion exchange resin specification: loading capacity 39 kgU/t (Mynkuduk East)

Chemistry of resin regeneration NH_4NO_3

Volume and type of equipment (vessels, pumps, piping): uranium is recovered from solution onto ion-exchange resin in a series of two 80 m^3 and eight 50 m^3 stainless steel columns

Injection and recovery stream storage type: settling ponds for PLS

Satellite sorption stations: Mynkuduk East operates as a satellite to the Stepnoye facility

XVIII–3.3. Restoration

Technology of groundwater restoration: natural attenuation

Annex XIX

KAZAKHSTAN – WEST MYNKUDUK

Associated company names: APPAK LLP (Kazatomprom 65%, Sumitomo Corporation 20% and Kansai Electric Power 15%)

Location: Suzak area of Southern Kazakhstan

Period of operation: from 2008 to present

Annual production: average 100 tU, maximum 100 tU (2008)

Total production through 2008: 100 tU

Current status (12/09): operating

XIX–1. GEOLOGY

Type of deposit: uranium is concentrated along regional roll fronts. The project area contains three separate deposits within two separate Upper Cretaceous formations. The deposits are the Osennii, Peschanyi and Zapadnyi. The Peschanyi deposit is located in the younger Inkuduk formation, which lies unconformably on the lower Mynkuduk formation. Regionally the formation ranges from 40 to 130 m in thickness and is predominantly arkosic sand with interbeds of silts and clays.

The Osennii and Zapadnyi deposits lie in the older Mynkuduk formation, which is the main ore-hosting unit for the area. Regionally the unit is 30 to 90 m thick and is predominately clastic sediments, which were deposited through two sedimentary cycles. Each cycle is characterized by a gradual upward transition from coarse- to medium- to fine-grained sand and then to clay. Fine- to medium-grained sands predominate.

The average grade is 0.034% U and the average thickness is 6.2 m

Geological ore reserves: Initial Reserves – C_1 11 800 tU, C_2 14 400 tU

Recoverable reserves: 90% extraction is anticipated

Mineralogy of U: mineralization consists of coffinite (40%) and sooty pitchblende (60%) and has a disseminated texture. Pitchblende occurs as micron-sized globules and spherical aggregates and coffinite as tiny crystals. Coffinite prevails in ores of the Inkuduk formation whereas pitchblende is dominant in those of the Mynkuduk formation.

Cut off: grade 0.01% U, GT 0.06 m%U

XIX–2. FACTORS AFFECTING ISL PROCESS

Lithological composition of ores: quartz (70–86%), feldspar (7–18%)

Permeability: 10 m/d

Porosity, effective porosity of ores: 25–30%

Depth of orebody: 380 m

Depth of static level head below surface: 200–300 m

Carbonate content in ore: 0.73%

Sulphide content in ore: 0.25%

Total mineralization of groundwater: 5000–6000 mg/L

Groundwater temperature: 15°C

Natural groundwater flow: velocity 7.5 m/a

XIX–3. TECHNOLOGY OF LEACHING

Type of leaching: acid

Leaching agent: H_2SO_4

Leaching agent concentration in operational solutions (average): Leaching will proceed in three phases: 1) initial injection of strong acid (oxidation stage) of 20 g/L for a period of 4 months; 2) operational leaching will take place over a period of 3.5 a with an acid concentration of 7 g/L; 3) a decommissioning stage will require an additional 2 more years during which time no acid will be added.

Specific consumption of reagents: 75 kg H_2SO_4 per kgU

XIX–3.1. Wellfields parameters

Well construction: Wells are completed by drilling a 290 mm hole and cased with a 200 mm pipe for the first 50 m. The next 330 m is drilled with a 190 mm hole and cased with a 190 mm casing. The lower part of the well has a section completed and under reamed and gravel packed. This is done to keep the sand production to a minimum. The lower portion has a screen section the length of which will be determined by the thickness of the ore zone. Screen openings are 0.1 mm. The upper part of the gravel pack has a 5 m cement pack to prevent solution migration.

Well patterns: shape; alternating rows of injection and recovery wells spaced 60 m apart

distance between wells; 30 m between recovery wells and 15 m between injection wells

ratio between recovery and injection wells; 0.4

Pumping technique: 150 mm diameter 7.5 kW electosubmersible pumps

Production well pumping rate: 7 L/s

XIX–3.2. Processing plant parameters

Volume of processed solution: 850 m^3/h

Production capability: 1 000 tU/a

Technology of solution processing: ion exchange

Elution reagent specification: elution reagent NH_4NO_3

Volume and type of equipment (vessels, pumps, piping): 4 IX columns 3 m in diameter by 9 m in height with a volume of 56 m^3 each

XIX–3.3. Restoration

Technology of groundwater restoration: natural attenuation

Annex XX

KAZAKHSTAN – ZARECHNOYE

Associated company names: JV Zarechnoye JSC, a joint venture of Kazatomprom 50% and ARMZ Uranium Holding Company (Russian Federation) 50%.

Location: Southern Kazakhstan province within the Otrarski region

Period of operation: from 2007 to present

Annual production: average 150 tU/a, maximum 166 tU (2008)

Total production through 2008: 280 tU

Current status (12/09): operating

XX–1. GEOLOGY

Type of deposit: the deposit is classified as the 'hydrogenic (groundwater infiltration) type related to regional oxidation. The host rock consists of grey coloured sediments of the Maastrichtian, Santonian, and Campanian Formations. The Maastrichtian Formation is represented by fine-grained sand, while the Sanfconian consists of gravel and sand. The Campanian Formation is represented by a fine-grained sand. The total thickness of the ore bearing zone of the deposit is 180 m.

In total, 9 ore bodies with widths varying from 50–1 200 m and lengths from 500 m–15 km have been identified within the deposit. In cross-section, ore bodies may be lenticular or simple to complex roll fronts. The thickness of the ore intervals varies from 1–12 m and averages 4.1 m. The depth of occurrence is 330–590 m. The average grade is 0.057%U.

TABLE XX–1. GEOLOGICAL ORE RESERVES

Category	kt Ore	Ore Grade (%U)	Contained U (t)
B	1 304	0.060	782
C1	22 999	0.060	13 691
C2	9 385	0.049	4 575
Total	33 688	0.057	19 048

Recoverable reserves: recovery is estimated to be 94%

Mineralogy of U: uranium minerals include coffinite (80–90%) and pitchblende (up to 20%)

Cut off: grade; 0.01%U

XX–2. FACTORS AFFECTING ISL PROCESS

Lithological composition of ores: quartz 60 to 65%, feldspar 7–11%

Mineral composition of ore: trace minerals include; selenium–0.015–0.298%, rhenium 1.0 g/t, scandium 1–25 g/t, rare earths 90–120 g/t, yttrium 14–15 g/t and vanadium 0.027–0.048%.

Permeability: 11–13.5 m/d

Transmissivity of ores: 240–1 010 m^2/d

Ratio of effective thickness to ore thickness: 2.5

Depth of orebody: 530 m

Depth of static level head below surface: waters are artesian with a static level 11 m above ground surface and a hydraulic head is 290–580 m on the ore zone.

Total mineralization of groundwater: unknown

Groundwater temperature: 35^oC

XX–3. TECHNOLOGY OF LEACHING

Type of leaching: acid

Leaching agent: H_2SO_4

Leaching agent concentration in operational solutions (average): 20 g/L in the oxidation stage. 7 g/L in the mining stage and 0 g/L in the completion stage.

Period of block start up (acidification, alkalization): 2 months

Specific consumption of reagents: ~49 kg H_2SO_4 per kgU produced

XX–3.1. Wellfields parameters

Well construction: casing diameter 110 mm

screening type; frame disk KDF-120

Well patterns: shape; 7-spot and in-line grid

distance between wells; 7-spot radius 40–50 m, in-line grid 25 m by 50 m

ratio between recovery and injection wells; 0.4

Production well pumping rate: 2.8 L/s

The air-lifts consumption of pressurized air - capacity of pressurized air production: 10 m^3 per m^3 of solution

XX–3.2. Processing plant parameters

Volume of processed solution:	750 m^3/h
Production capability:	1 000 tU/a
Technology of solution processing:	ion exchange
Ion exchange resin specification:	type; strong base anionite, trade mark; AMP
	volume of resin in operation; 195 m^3
Elution reagent specification:	elution reagent; HNO_3 or NH_3NO_3 and H_2SO_4
Technology of sorption/desorption:	fixed bed; upflow
	total volume of resin; 260 m^3
Chemistry of:	final product precipitation; NaOH
Annual consumption of:	ion exchange resin; 22 t/a

Annual consumption of all other chemicals: 3 000 t NH_3NO_3, 730 t NaOH

Volume and type of equipment (vessels, pumps, piping): 4 IX columns 3 m diameter by 9.6 m high, 4 desorption columns 2 m diameter by 9 m high

Satellite sorption stations: no

Process water consumption: 100 L/kgU

Electric power consumption: 33 kWh/kgU

Annex XXI

KAZAKHSTAN – ZHALPAK

Associated company names: Semizbai-U LLP (a joint venture JSC NAC Kazatomprom 51% and Beijing Sino-Kaz Uranium Resources Investment Company Limited of the People's Republic of China 49%)

Location: Zhalpak is located in the South-East Suzak region of South Kazakhstan Oblast

Current status (12/09): proposed future development

XXI–1. GEOLOGY

Type of deposit: the deposit is classified as the hydrogenic (groundwater infiltration) type related to regional oxidation. The host rock consists of grey coloured sediments of the lower interval of the Zhalpak Formation. It is an alluvial layer of different sized, but mostly medium-grained, sand (0.5–0.25 mm) with a thickness of 15–40 m.

In total, 8 ore bodies with widths varying from 25 to 850 m have been identified within the deposit. The depth of occurrence is 130–150 m. The average uranium grade is 0.032% U, and the average mineralized thickness is 4 m

Geological ore reserves: total reserves of the deposit ($B+C_1+C_2+P_1$) are 13 880 tU, including: B – 682 tU, C_1 – 5778 tU, C_2 – 7095 tU, and P_1 – 325 tU

XXI–2. FACTORS AFFECTING ISL PROCESS

Lithological composition of ores: constituents of the ore-bearing sands include: quartz 85%, and feldspar 5-10%, and SiO_2 5-7%.

Mineral composition of ore: trace minerals contained in the ore of the Zhalpak deposit include; selenium 0.002%, rhenium 0.16 g/t, scandium 2.4 g/t, rare earths plus yttrium 106 g/t, and yttrium 13 g/t

Depth of orebody: 130–150 m

Carbonate content in ore: 0.1%

Total mineralization of groundwater: 4.3–7.3 g/L

XXI–3. TECHNOLOGY OF LEACHING

Type of leaching: acid

Leaching agent: H_2S0_4

XXI–3.1. Processing plant parameters

Production capability: 1 000 tU/a

Technology of solution processing: ion exchange

Annex XXII

PAKISTAN – QABUL KHEL

Associated company names: Pakistan Atomic Energy Commission (PAEC)

Location: Northwest Frontier Province

Period of operation: from 1996 to present.

Annual production: average 20 tU (uncertain), maximum 25 tU (2000; uncertain)

Total production through 2008: 280 tU (uncertain)

Current status (12/09): operating (semi-commercial scale)

XXII–1. GEOLOGY

Type of deposit: reworked roll fronts in sandstone dipping at 27^{o}. The average grade is 0.061% U.

Mineralogy of U: coffinite (+ pitchblende? + uraninite?)

Underlying formation, rock type: Shale

Overlying formation, rock type: Shale

XXII–2. FACTORS AFFECTING ISL PROCESS

Lithological composition of ores: gray, medium to fine grained sandstones with repeated interlayering of fine grained sandstone.

Mineral composition of ore: SiO_2 70%, Al_2O_3 12%, Fe_2O_3 1.4%, FeO 1.4%, CaO 4.9%, MgO 2.1%, Na_2O 1.2%, K_2O 2%, CO_2 3%

Permeability: 2–4 m/d

Porosity, effective porosity of ores: 30–40%

Thickness of productive aquifer: 60 m

Depth of orebody: 68–118 m

Depth of static level head below surface: 65 m

Carbonate content in ore: 4.5%

Total mineralization of groundwater: 446 mg/L

Groundwater temperature: 25^{o}C

XXII–3. TECHNOLOGY OF LEACHING

Type of leaching: alkaline

Leaching agent: $NH_3HCO_3 + H_2O_2$

Leaching agent concentration in operational solutions (average): 4 g/L NH_3HCO_3 and 0.7 g/L H_2O_2 (50%)

Period of individual wellfields (blocks) operation: ~2 a

XXII–3.1. Wellfields parameters

Well construction:	casing diameter; 150 mm
	casing material; pvc
	grouting; only at the water table
	screening type; slotted (1 mm) pvc
Well patterns:	shape; 5-spot
	distance between wells; 14 m inj to rec,
Pumping technique:	type; submersible, diameters; 4-inch

Production well pumping rate: 1.1 L/s

XXII–3.2. Processing plant parameters

Technology of solution processing: ion exchange; semi fluidized bed

Ion exchange resin specification: type; strong base anion

Elution reagent specification: elution reagent; NaCl (2 molar) and $NaHCO_3$ (0.4 g/L)

Chemistry of final product precipitation: HCl, H_2O_2 and NaOH

Volume and type of equipment (vessels, pumps, piping): 3 ion exchange columns 1.8 m in diameter and 4.8 m high.

Annex XXIII

RUSSIAN FEDERATION – DALUR (DOLMATOVSKOYE AND KHOHLOVSKOE DEPOSITS)

Associated company names: JSC Atomredmetzoloto

Location: Dalmatovsky district of the Russian Federation's Kurgan Region south of Ekaterinburg

Period of operation: from 2002 to present

Annual production: average 218 tU/a, maximum 508 tU (2010)

Total production through 2010: 2 495 tU

Current status (12/09): operating

XXIII–1. GEOLOGY

Type of deposit: sandstone basal channel deposits of Late Jurassic – Early Cretaceous age filled with fluvial sediments incised into a basement of Devonian volcanics and continental and marine sediments.

A number of ore bodies occur at a depth of 360 to 500 m in an 11 km long main, and an 8 km long tributary, palaeovalley. The valleys are up to 1.5 km wide. Channel facies are Middle-Upper Jurassic alluvial sediments composed of pink oxidized and grey reduced sandy gravel, sandstone and conglomerate interbedded with silty mudstone. The channels are incised about 100 m into schists and, towards the headwaters to the SW, into Devonian rhyolite and rhyolite-porphyry.

In plan view, most ore bodies are lenticular in shape and markedly elongated along the valley axis. In cross-section, they show a lenticular or roll-shape. Ore bodies occur individually or stacked at several levels separated by argillaceous aquicludes. Individually, ore bodies are from 400 to 4,500 m long, 50 to 700 m wide, and 2 to 12 m thick. Rolls can be as much as 20 m thick

Geological ore reserves: (1/1/2007) 15 732 tU at an average grade of 0.04%U, 18 496 tU.

Recoverable reserves: anticipated mining recovery is 75%

Mineralogy of U: uranium is present as coffinite and pitchblende.

XXIII–2. FACTORS AFFECTING ISL PROCESS

Depth of orebody: 360–500 m

XXIII–3. TECHNOLOGY OF LEACHING

Type of leaching: acid

Leaching agent: H_2SO_4

XXIII–3.1. Wellfields parameters

Well patterns: ratio between recovery and injection wells; 0.35

XXIII–3.2. Processing plant parameters

Production capability: 1 000 tU/a

Technology of solution processing: ion exchange

Satellite sorption stations: yes, Zapadna was commissioned in 2008.

XXIII–3.3. Restoration

Annex XXIV

RUSSIAN FEDERATION – KHIAGDA

Associated company names: JSC Atomredmetzoloto

Location: Vitimsky District, Transbaykal Region, Republic of Buryatia, Siberia, 140 km north of Chita

Period of operation: from 2002 to 2008, pilot plant operations, ramping up to commercial production

Annual production: average 40 tU/a, maximum 135 tU (2010)

Total production through 2010: 514 tU

Current status (12/09): commercial facility under construction

XXIV–1. GEOLOGY

Type of deposit: Sandstone basal channel. Deposits occur in Tertiary palaeochannels filled with carbonaceous sandy, silty and clayey sediments of alluvial-fluvial origin. The channels are incised into a Proterozoic metamorphic and granite basement and covered by a 10–30 m (locally up to 200 m) thick basalt sheet.

Eight basal channel-type U deposits occur in close association within a 250 km^2 area: Khiagda (or Khiagdinskoye), Tetrakhskoye, Vershinnoye, Dybryn, Istochnoye, Kolichikan, Koretkondinskoye, and Namaru. The distance between deposits varies from 1.5–6 km. Khiagda with 15 500 tU is the largest deposit. Its average ore grade is 0.05%U. Resources at Tetrakhskoye are in excess of 5 000 tU, while resources of the other deposits lie between 1 500 and 5 000 tU each.

Khiagda includes seven ore zones. Host rocks are slightly consolidated, from a few meters to 120 m thick, Neogene fluvial sediments. These sediments fill relatively narrow palaeochannels which are incised into Paleozoic granite and covered by Neogene to Quaternary basalt. Ore bodies are in the form of elongated lenses which extend ribbon like along a palaeochannel. Individual ore lenses are 850–4100 m long, 15– 400 m wide and 1–20 m thick. They occur at depths of 60–240 m.

The production situation is made more complicated by a permafrost zone 90 m deep

Geological ore reserves: 30 932 tU at an average grade of 0.05% U (1/1/2007), 41 492 tU (1/1/2011)

Recoverable reserves: mining recovery of 75% is anticipated

Mineralogy of U: uranium mineralization consists of dispersed pitchblende, coffinite and sooty pitchblende

XXIV–2. FACTORS AFFECTING ISL PROCESS

Depth of orebody: 60–240 m

XXIV–3. TECHNOLOGY OF LEACHING

Type of leaching: acid

Leaching agent: H_2SO_4

XXIV–3.1. Processing plant parameters

Production capability: 1 000 tU/a

Technology of solution processing: ion exchange

Satellite sorption stations: It is anticipated that as many as 4 to 6 satellites may be in operation at any one time.

Annex XXV

USA – ALTA MESA

Associated company name: Mestena (or Mesteña) Uranium LLC

Location: Brooks County, Texas

Period of operation: from 2006 to present (2012)

Annual production: average 390 tU, maximum 500 tU (estimated)

Total production (through 2012): 2000 tU (estimated)

Current status: operating

XXV–1. GEOLOGY

General Description: uranium mineralization at Alta Mesa occurs as roll fronts some 15–45 m in width within loosely-consolidated sandstones of the Pliocene age Goliad Formation at depths of 120–150 m. The average grade is 0.15% U_3O_8 and the average thickness is ~4 m. Disequilibrium is reported to be slightly positive at about 1.1:1.

Resources/reserves: historical reports of total initial resources range from 1 800 to 3 400 tU depending upon the cut-off grade used (0.03/0.01% U_3O_8).

(Note: Alta Mesa is operated by a private company which does not publish information relative to resources and reserves)

Mineralogy of U: U minerals tend to be primarily pitchblende, coffinite and brannerite (?). They are present in two modes: The first two occur as small globules coated on, and intermixed with clay minerals and other authigenic and detrital minerals, and the latter as large grains composed of U-Ti oxides.

Stratigraphic setting: the ore-bearing Goliad Formation is underlain by the Fleming Formation, a calcareous clay, and overlain by claystone

XXV–2. FACTORS AFFECTING ISL PROCESS

Lithological/mineral composition of ores: quartz (60–75%), calcite (20–35%), lithic fragments (3–5%)

Hydraulic conductivity:	2–12 m/d
Porosity, effective porosity of ores	28–40%
Depth of mineralized layer:	120 m
Carbonate content in ore:	15% (CO_2)
Sulphide content in ore:	0–3%

Total mineralization of groundwater: 1.0 g/L TDS

Natural groundwater flow: velocity 10 m/a, direction southeast

XXV–3. TECHNOLOGY OF LEACHING

Type of leaching: alkaline

Leaching agent: natural groundwater with O_2 as an oxidant

Operational Conditions: leaching agent concentration; O_2 at 500ppm

XXV–3.1. Wellfield parameters

Well construction: casing diameter; 152 mm

casing material; pvc

Well patterns: shape; single line drive

distance between wells; 20 m injector to extractor

Pumping technique: submersible pumps, average extraction well pumping rate; 3.8 L/s

Water balance management: above ground tanks with filtration and byproduct material management. Reverse osmosis (9 L/s, 75% recovery) with deep well disposal of excess (6 L/s).

XXV–3.2. Processing plant parameters

Flow rate of leaching solution: 1150 m^3/h

Production capability: 680 tU/a

Technology of solution processing: ion exchange

Ion exchange resin specification: dow 21K

volume of resin in operation: 112 m^3

Technology of desorption: elution reagent; NaCl

Chemistry of desorption: resin regeneration; HCl

Technology of downstream processing: final product precipitation; NaOH and H_2O_2

drying; vacuum

Volume and type of equipment: 8 IX columns with 14 m^3 each of resin

XXV–3.3. Restoration

Technology of groundwater restoration: groundwater sweep with reverse osmosis

Operating period of restoration process: yet to be determined

Final groundwater quality: anticipated to be class of use

Annex XXVI

USA – BENAVIDES

Country: USA

Project name: Benavides

Associated company name: Uranium Resources, Inc.

Location: Duval County, Texas

Period of operation: from 1980 to 1983

Annual production: average 46 tU, maximum 75 tU (1980)

Total production (through 2009): 185 tU

Current status: secommissioned, released for unrestricted use

XXVI–1. GEOLOGY

General description: roll front(s) in the lower half of the Soledad Member of the Catahoula Formation. Average ore grade was 0.06%U

Reserves/resources: 930 tU, expected recovery was ~60%

XXVI–2. FACTORS AFFECTING ISL PROCESS

Hydraulic conductivity: 1–2 m/d

Depth of mineralized layer: 80 m

XXVI–3. TECHNOLOGY OF LEACHING

Type of leaching: alkaline

Leaching agent: $NaHCO_3$, O_2 and H_2O_2

XXVI–3.1. Wellfield parameters

Well patterns: shape - staggered line drive

distance between wells 15–30 m

ratio between recovery and injection wells 1:1

Pumping technique: submersible pumps, average extraction well pumping rate 1.6 L/s

XXVI–3.2. Processing plant parameters

Flow rate of leaching solution:	275 m^3/h
Production capability:	200 tU/a
Technology of solution processing:	ion exchange
Technology of desorption:	elution reagent; NaCl + Na_2Co_3 + $NaHCO_3$
Technology of downstream processing:	precipitation; HCl, NaOH and H_2O_2

Annex XXVII

USA – BISON BASIN

Associated company names: Ogle Petroleum, Duke Power, OPI-Western Joint Venture

Location: Fremont County, Wyoming

Period of operation: from 1981 to 1982

Annual production: average 10 tU, maximum 10 tU (1982)

Total production (through 2009): 20 tU

Current status (2012): closed, restored and decommissioned

XXVII–1. GEOLOGY

General description: roll front(s) in the Laney member of the Green River Formation (Eocene). Average grade was 0.05%U.

Resources/reserves: 1600 tU

Cut-off criteria: grade 0.02 %U, GT 0.013 m%U

Area of deposit: 16 ha

Stratigraphic setting: Overlying and underlying mudstones and siltstones

XXVII–2. FACTORS AFFECTING ISL PROCESS

Lithological/mineral composition of ores:	quartz: 30–40%, feldspar; 15–20%, calcareous fragments: 5%.
Hydraulic conductivity:	0.1–0.6 m/d
Porosity, effective porosity of ores	30%
Depth of mineralized layer:	120 m (average or range)
Static water table in mining aquifer (+/-):	30 m (average or range)
Total mineralization of groundwater:	1.5 g/L TDS
Groundwater temperature:	12 °C

XXVII–3. TECHNOLOGY OF LEACHING

Type of leaching: alkaline

Leaching agent: $Na_2CO_3/NaHCO_3$ plus O_2

Operational Conditions: leaching agent concentration; 1–3 g/L

XXVII–3.1. Wellfields parameters

Well construction: casing diameter; 114 mm

casing material; yellowmine

screening length; 15 m

Well patterns: shape; 7-spot

distance between wells; 15 m inj to ext

well density; 44 (inj and ext) per hectare

ratio between recovery and injection wells; 0.53

Pumping technique: submersible pumps

average recovery well pumping rate; 0.6 L/s

Number of simultaneously working wells: 100 extraction wells

Water balance management: evaporation ponds (3) for disposal of about 0.4 L/s

XXVII–3.2. Processing plant parameters

Flow rate of leaching solution: 135 m^3/h

Production capability: 175 tU/a

Average uranium concentration in pregnant leach solution: 35 mg/L

Technology of solution processing: ion exchange

Technology of downstream processing: precipitation; HCl, H_2O_2, NaOH

XXVII–3.3. Restoration

Technology of groundwater restoration: uranium removal by ion exchange, groundwater sweep with reverse osmosis treatment and reinjection. Six pore volumes were circulated through the aquifer

Operating period of restoration process: 13 months

TABLE XXVII–1. FINAL GROUNDWATER QUALITY

Groundwater quality, Bison Basin Project (mg/L) – Typical			
Constituent	Pre-mining	Post-mining	Post-reclamation
TDS	1 390	5 548	826
Sodium	433	1 563	263
Sulphate	840	1 860	205
Bicarbonate	109	1 420	235
Chloride	40	643	188
Uranium	<0.001	19	0.4
Radium 226 (pCi/L)	165	812	124

Annex XXVIII

USA – BRUNI

Country: USA

Project Name: Bruni

Associated company name: Westinghouse Electric Co.

Location: Webb County, Texas

Period of operation: from 1975 to 1980

Annual production: average 61 tU, maximum 90 tU (1979)

Total production (through 2009): 305 tU

Current status: closed, decommissioned, released for unrestricted use

XXVIII–1. GEOLOGY

General description: roll front(s) in the Soledad Member of the Miocene Catahoula Formation. Disequilibrium ratio 1.1 in favor of chemical analyses

Average grade = 0.06% U.

Resources/reserves: 460 tU

Recoverable reserves: estimated at 70%

Area of deposit: 67 000 m^2

Mineralogy of U: uraninite and coffinite concentrated between oxidized, altered sediment and sulphide-rich reduced materials

Stratigraphic setting: underlain by the Frio Clay and overlain by dense clay at the top of the Catahoula Formation

XXVIII–2. FACTORS AFFECTING ISL PROCESS

Lithological/mineral composition of ores: Volcanic, plagioclase-rich, medium- to fine-grained sandstones containing numerous mudstone lenses

Hydraulic conductivity: 0.08–0.52 m/d

Porosity, effective porosity of ores 28%

Depth of mineralized layer: 55 m

Total mineralization in Groundwater:

Baseline groundwater quality: PA 1,2 1979

TABLE XXVIII–1. BASELINE GROUNDWATER QUALITY

Parameter	Value
Bicarbonate	175 mg/L
Chloride	1 090 mg/L
Sodium	413 mg/L
Sulphate	142 mg/L
TDS	2 312 mg/L
Radium	129 pCi/L
Uranium	0.30 mg/L
Arsenic	0.020 mg/L
Selenium	0.050 mg/L

Natural groundwater flow direction east/southeast

XXVIII–3. TECHNOLOGY OF LEACHING

Type of leaching: alkaline

Leaching Agent: NH_4HCO_3+ $(NH_4)_2CO_3$ + H_2O_2

Operational Conditions: leaching agent concentration; NH_4 as N 2 300 ppm

Bicarbonate; 2 000 ppm, H_2O_2; 0–1 500 ppm

XXVIII–3.1. Wellfield parameters

Well construction: casing diameter; 114 mm

casing material; pvc

screening type; open hole

Well patterns: shape; 5-spot

ratio between recovery and injection wells; 0.8

Pumping technique: submersible pumps

average recovery well flow rate; 0.4 L/s

XXVIII–3.2. Processing plant parameters

Flow rate of leaching solution: 160 m^3/h

Production capability: 200 tU/a

Technology of solution processing: ion exchange

XXVIII–3.3. Restoration

Surface reclamation: A soil-washing process was used to reduce surface contamination in area of pipeline spills.

Annex XXIX

USA – BURNS RANCH

Note: Burns Ranch includes Boots/Brown, Burns/Moser and Pawlik

Associated company name: Cities Service, Dalco, United States Steel Corporation, USX

Location: Live Oak County, Texas

Period of operation: from 1977 to 1986

Annual production: average 206 tU/a, maximum 400 tU (1981)

Total production (through 2009): 2055 tU

Current status: closed, decommissioned and released for unrestricted use

XXIX–1. GEOLOGY

General description: roll front deposits at the base of the Oakville Formation

Resources/reserves: 3500 tU

XXIX–2. FACTORS AFFECTING ISL PROCESS

Depth of mineralized layer: ~100 m

XXIX–3. TECHNOLOGY OF LEACHING

Type of leaching: alkaline

Leaching agent: initially NH_4HCO_3, later O_2

XXIX–3.1. Wellfield parameters

Well construction: casing diameter; inj 100 mm, ext 150 mm

casing material; pvc

screening; pvc with a 1.4-2.4 mm

Well patterns: shape; 5-spot

distance between wells; 30 m inj to inj

Pumping technique: submersible pumps

XXIX–3.2. Processing plant parameters

Satellite sorption stations: yes, up to 8 satellites total for Burns Ranch and Clay West

XXIX–3.3. Restoration

Technology of groundwater restoration: groundwater sweep and reverse osmosis
Operating period of restoration process: uranium mining took place at Boots/Brown Mine Production Area Number 1 from May 1978 to July 1987, after which groundwater restoration of the ore-bearing aquifer began. Since restoration efforts were initiated, approximately 1.70 billion gallons (6.435 Mm^3) of aquifer water were removed during the restoration process.

Burns/Moser restoration was from 1981 to 1997.

Final groundwater quality: USX Corporation: Texas Uranium Operations (USX) applied for modification to Production Area Authorization (PAA) UR01890-011, Burns/Moser mine. The permit and PAA 1 were issued and mining began in 1980. Mining continued until 1986. USX requested amendment of the restoration table under 30 TAC §331.107(f)(2).The proposed amendment would change restoration table values specifying groundwater constituent concentrations for calcium, magnesium, potassium, bicarbonate, sulphate, arsenic, iron, manganese, selenium, ammonia, molybdenum, radium-226, uranium. These values were to be met by the permittee (USX) to achieve successful restoration of the mined aquifer in PAA 1. The proposed values were not to change the use category of the water. The average water quality present before mining exceeded the TNRCC and EPA primary drinking water standard for radium-226. Before mining commenced, the water in the production area was used for rural domestic, livestock and industrial purposes.

Texas Uranium Operations (USX) applied for a production area authorization (PAA) restoration table amendment (RTA) to Burns/Moser Mine Production Area Number 2, Authorization Number UR01890-021, which would change groundwater constituent concentrations that are to be met by the permittee (USX) to achieve successful restoration of the site's mined aquifer in PAA 2. The proposed amendment would change restoration table concentration values for calcium, magnesium, potassium, bicarbonate, sulphate, nitrate, alkalinity, manganese, molybdenum, selenium, uranium, and ammonia. Furthermore, a restoration table concentration value for radium has been added to complete the restoration table in the original PAA issued for Production Area Number 2 on October 12, 1982.

Texas Uranium Operations (USX) applied for a production area authorization (PAA) restoration table amendment (RTA) to Burns/Moser Mine Production Area Number 3, Authorization Number UR01890-031, which would change groundwater constituent concentrations that are to be met by the permittee (USX) to achieve successful restoration of the site's mined aquifer in PAA 3. The proposed amendment would change restoration table concentration values for calcium, magnesium, potassium, bicarbonate, sulphate, total dissolved solids, alkalinity, arsenic, iron, manganese, and uranium. Uranium mining took place at Burns/Moser Mine Production Area Number 3 from March 1980 to June 1986, after which groundwater restoration of the ore-bearing aquifer began. Since restoration efforts were initiated, approximately 409.85 million gallons (1.551 Mm^3) of aquifer water were removed during the restoration process.

Texas Uranium Operations (USX) applied for modification to Production Area Authorization (PAA) UR01890-041, Burns/Moser mine. The permit and PAA 4 were issued and mining began in 1986. Mining continued until 1987. Restoration, using groundwater sweep and reverse osmosis, was from 1987 to 1997. USX requested amendment of the restoration table under 30 TAC §331.107(f)(2). The proposed amendment would change restoration table values specifying groundwater constituent concentrations for arsenic, calcium, iron, manganese, magnesium, molybdenum, potassium, alkalinity,

ammonia, chloride, conductivity, sulphate, TDS, radium-226, uranium. These values were to be met by the permittee (USX) to achieve successful restoration of the mined aquifer in PAA 4. The proposed values were not to change the use category of the water. The average water quality present before mining exceeded the TNRCC and EPA primary drinking water standard for radium-226.

The Boots/Brown and Moser wellfield patterns areas were released for unrestricted use (Texas Register 13 July 2001).

Annex XXX

USA – IRIGARY – CHRISTENSEN RANCH

Associated company names: Homestake Mining, World Nuclear, American Nuclear, Wyoming Minerals, Western Nuclear, Inc., Malapai Resources, Total Minerals, Cogema Mining, Inc., Uranium One

Location: Johnson and Campbell Counties, Wyoming

Period of operation: from 1989 to present 2012 (intermittently)

Annual production: average 85 tU/a, maximum 280 tU (1996)

Total production (through 2009): 1425 tU

Current status: operating, former operating wellfields have been restored. Operations restarted in 2011. Christensen Ranch is operated as a satellite to the Irigaray central processing facility. Willow Creek is the current project name

XXX–1. GEOLOGY

General description: uranium mineralization at Christensen Ranch occurs as sinuous roll front deposits in permeable, fluvial sandstones of the Eocene age Wasatch Formation at depths averaging 130 m. Grades and thicknesses average 0.09% U and 2.5 m, respectively.

Resources/reserves: 11 000 tU (initial), ~3500 tU (current)

Recoverable reserves: 7700 tU (initial projected), ~2500 tU (current)

Area of deposit: 700 000 m^2 (current)

Mineralogy of U: uraninite is the principal uranium mineral, but coffinite is also present

XXX–2. FACTORS AFFECTING ISL PROCESS

Hydraulic conductivity: 1.2 m/d

Depth of mineralized layer: 130 m

XXX–3. TECHNOLOGY OF LEACHING

Type of leaching: alkaline

Leaching agent: $NaHCO_3$ and CO_2 plus O_2

XXX–3.1. Wellfield parameters

Well patterns: shape; 5-spot

distance between wells; 18 to 28 m (inj to ext)

ratio between recovery and injection wells; 0.6

Pumping technique: submersible

Water balance management: Deep well disposal with 2 wells (1 200 m and 2 000 m) each with a capacity of 5 L/s

XXX–3.2. Processing plant parameters

Christensen Ranch operates as a satellite to the Irigaray central processing facility. Loaded resin is trucked approximately 24 km from Christensen Ranch to Irigaray

Flow rate of leaching solution: 900 m^3/h

Production capability: 275 tU/a

Technology of solution processing: ion exchange

Annex XXXI

USA – CLAY WEST

Associated company names: United States Steel Corporation, USX, Atlantic Richfield Corporation, Dalco, Niagara Mohawk

Location: Live Oak County, Texas

Period of operation: from 1975 to 1987

Annual production: average 237 tU, maximum 450 tU (1981)

Total production (through 2009): 3080 tU

Current status: closed, decommissioned and released for unrestricted use

XXXI–1. GEOLOGY

General description: roll front(s) in the basal unit of the Miocene Oakville Formation. Ore grade 0.04%U. Includes the Lyne deposit.

Resources/reserves: ~5000 tU

XXXI–2. FACTORS AFFECTING ISL PROCESS

Depth of mineralized layer: <170 m (average or range)

Natural groundwater flow: velocity 3.7 m/a

XXXI–3. TECHNOLOGY OF LEACHING

Type of leaching: alkaline

Leaching agent: initially NH_4HCO_3 + $(NH_4)_2CO_3$, later O_2

XXXI–3.1. Wellfield parameters

Well construction: casing diameter; 100 mm (inj) and 150 mm (rec)

casing material; pvc

grouting; all wells cemented to surface

screening type; pvc, 1.4-2.4 mm slots

Well patterns: shape; 5-spot

distance between wells; 21 m (inj to rec)

well density; 25 inj wells per hectare

Pumping technique: submersible pumps

Water balance management: deep disposal wells (2) into the Cockfield Sandstone at a depth of 1380m

XXXI–3.2. Processing plant parameters

Flow rate of leaching solution: 450 m^3/h

Production capability: 400 tU/a

Technology of solution processing: ion exchange

Technology of desorption: elution reagent; NaCl

Technology of downstream processing: precipitation; NH_3

Volume of storage tanks: pregnant wellfield solution tank 150 m^3

Satellite sorption stations: yes, up to 8 satellites total for Burns Ranch and Clay West

XXXI–3.3. Restoration

Technology of groundwater restoration: Groundwater sweep and reverse osmosis

Operating period of restoration process: Restoration was from March 1981 to May 1997

Final groundwater quality: USX requested amendment of the restoration table under 30 TAC §331.107(f)(2). The amendment changed restoration table values specifying groundwater constituent concentrations for calcium, magnesium, potassium, bicarbonate, sulphate, arsenic, iron, manganese, selenium, ammonia, molybdenum, radium-226, and uranium, which were to be met by the permittee (USX) to achieve successful restoration of this site's mined aquifer in PAA 1. The proposed values were not to change the use category of the water. The average water quality present before mining exceeded the TNRCC and EPA primary drinking water standard for radium-226. Before mining commenced, the water in the production area was used for rural domestic, livestock, and industrial purposes.

Annex XXXII

USA – CROW BUTTE

Associated company names: Ferret Exploration Company, Western Fuel Company, Uranerz, Power Resources Inc., Cameco Inc.

Location: Dawes County, Nebraska

Period of operation: from 1981 to present

Annual production: average 275 tU, maximum 320 tU (1999)

Total production (through 2011): 5820 tU

Current status (2013): operating

XXXII–1. GEOLOGY

General description: uranium occurs in roll fronts within permeable Oligocene fluvial sandstones of the lower portion of the Chadron Formation at depths of about 200 m. The ore trend is eleven miles in length and up to 460 m in width

Resources/reserves: 9150 tU (initial resource)

TABLE XXXII–1. 2009 RESOURCES

Category	Ore (kt)	Grade (%U)	Content (tU)
Proven reserves	782.1	0.13	998
Probable reserves	704.4	0.18	1 286
Measured resources	64.4	0.23	146
Indicated resources	1 318.2	0.23	2 973
Inferred resources	2 534.7	0.12	2 879
Totals	5 403.8	0.16	8 282

Recoverable reserves: projected recovery is 85% of current resources

Area of deposit: 225 ha (initial resource)

Mineralogy of U: uranium minerals include coffinite and uraninite both in the matrix and as a coating on grains

Stratigraphic setting: the mineralized horizon is underlain by the Pierre Shale at a depth of about 220 m and overlain by a bentonitic clay

Cut off criteria: grade 0.04%U, GT 0.065 m%U

XXXII–2. FACTORS AFFECTING ISL PROCESS

Lithological/mineral composition of ores:	weakly cemented quartzose with microcline detritus and sparse pyrite
Hydraulic conductivity:	3–5 m/d
Porosity, effective porosity of ores	28%
Depth of mineralized layer:	200 m
Static water table in mining aquifer (+/-):	50 m
Total mineralization of groundwater:	1.25 g/L TDS
Natural groundwater flow:	velocity; 6 m/a, direction; east

XXXII–3. TECHNOLOGY OF LEACHING

Type of leaching: alkaline

Leaching agent: $NaHCO_3$, O_2

Operational conditions: leaching agent concentration; 1 900 mg/L HCO_3, leaching period; ~5 a

XXXII–3.1. Wellfield parameters

Well construction: casing diameter; 125 mm

casing material; pvc

grouting; ore zone to surface

screening material; stainless steel

Well patterns: shapes 7-spot, 5-spot and alternating single line drive

distance between wells 14–20 m (inj to rec)

Pumping technique: submersible pumps (5 hp); diameter 102 mm, average recovery well pumping rate 2.4 L/s

Area of simultaneously working wellfields: permitted for: 3 mine units in construction, 5 mine units in production and 5 mine units in restoration

Number of simultaneously working wells: 2 560 active wells; with a ratio of 4 to 1 injection to extraction wells

Water balance management: evaporation ponds and deep disposal well

XXXII–3.2. Processing plant parameters

Flow rate of leaching solution: 725 m^3/h

Production capability: 450 tU/a

Technology of solution processing: ion exchange

Ion exchange resin specification: type; Dow 21K

total loading capacity; 60 g/L

particle size; 20 μm

volume of resin in operation; 266 m^3

Technology of sorption: fixed bed, upflow, and downflow

Technology of desorption: elution reagent; NaCl

Technology of downstream processing: precipitation; HCl, H_2O_2, NaOH

drying; vacuum

Volume and type of equipment: 6 IX columns 3.51 m diameter × 4.55 m high

Volume of storage tanks: 18.93 m^3

Injection and recovery stream storage type: 2 injection surge tanks on upflow system of 166.5 m^3.

Satellite sorption stations: no

Process water consumption: 27 m^3/h

Electric power consumption: 1.9 MW

XXXII–3.3. Restoration

Technology of groundwater restoration: reverse osmosis and IX treatment

Operating period of restoration process: the NRC timeliness rule for restoration of a mine unit is 2 a per mine unit.

TABLE XXXII–2. FINAL GROUNDWATER QUALITY: BASELINE OR CLASS OF USE

Water quality data – Crow Butte – Mine Unit No. 1				
Parameter (mg/L)	Baseline water quality	Post mining average water quality	Post-restoration average water quality	Stabilization period average water quality
Alkalinity	293	875	321	347
Arsenic	0.002	0.021	0.024	0.017
Bicarbonate	344	1 068	392	421
Manganese	0.11	0.075	0.01	0.02
Molybdenum	0.069	0.487	<0.10	0.10
pH	8.5	7.35	7.95	8.18
Radium-226 (pCi/L)	230	786	247	303
Selenium	0.003	0.124	0.001	<0.002
TDS	1 170	3 728	967	1 094
Uranium	0.092	12.2	0.963	1.73
Vanadium	0.066	0.96	0.26	0.11

Annex XXXIII

USA – EL MESQUITE

Note: El Mesquite includes Holiday and O'Hern deposits

Associated company name: Mobil Oil Corp., Malapai Resources, Total Minerals, Cogema Mining Inc.

Location: Duval and Webb Counties, Texas

Period of operation: from 1976 to 1989 and from 1991 to 1996

Annual production: average 112 tU, maximum 285 tU (1980)

Total production (through 2009): 2125tU

Current status: the O'Hern site has been decommissioned and the licensee plans to submit a report to the NRC requesting confirmatory surveys in order to release the site for unrestricted use. The Holiday/Mesquite plant site is currently undergoing decommissioning, and final surface reclamation activities in the well fields are on-going.

XXXIII–1. GEOLOGY

General description: El Mesquite is located in the south Texas uranium district where uranium occurs as roll fronts in loosely-consolidated sandstones of the Soledad and Fant Members of the Oligocene/Miocene Catahoula Formation. The average depth at El Mesquite is 140 m, the average grade is 0.07% U and the average thickness is 3.7 m.

Resources/reserves: 9600 tU (initial)

Stratigraphic setting: argillaceous tuff and tuffaceous clay of the Chusa Member of the Upper Catahoula Formation overlies the mineralized zone.

XXXIII–2. FACTORS AFFECTING ISL PROCESS

Depth of mineralized layer: 140 m

XXXIII–3. TECHNOLOGY OF LEACHING

Type of leaching: alkaline

Leaching agent: $NaHCO_3$ and O_2

Operational conditions: leaching agent concentration; O_2 = 200 to 500 ppm in leaching solution

XXXIII–3.1. Wellfield parameters

Well construction: casing material - fiberglass or pvc

Well patterns: shape; 5-spot

distance between wells; 20 m (inj to rec)

ratio between recovery and injection wells; 0.54

Pumping technique: submersible pumps

Area of simultaneously working wellfields: 1 ha

Water balance management: deep disposal wells (2) to 1200 m depth each with a capacity of 10 L/s.

XXXIII–3.2. Processing plant parameters

Flow rate of leaching solution:	725 m^3/h
Production capability:	250 tU/a
Technology of solution processing:	ion exchange
Ion exchange resin specification:	type; strong base anion exchange
	trade mark; Dow 21K
	operational loading capacity; 20 to 100 g/L
	volume of resin in operation; 160 m^3
Technology of desorption:	elution reagent; NaCl and NaOH
Technology of downstream processing:	precipitation; HCl, H_2O_2 and NaOH
Volume and type of equipment:	5 sets of 3 each 9.2 m^3 ion exchange columns
Volume of storage tanks:	pregnant lixiviant tank; 636 m^3, barren lixiviant tank; 636 m^3

XXXIII–3.3. Restoration

Technology of groundwater restoration:

Operating period of restoration process: Holiday 1983 to 2002, El Mesquite 1986 to 2002, O'Hern 1983 to 1997.

Final groundwater quality: COGEMA Mining, Inc. applied for a restoration table amendment of a Production Area Authorization (PAA) for Holiday Mine Production Area 6 (also known as Grid 6), Permit Number UR02156-061 which would change groundwater constituent concentrations that are to be met by the permittee to achieve successful restoration of the site's mined aquifer in PAA 6. The proposed amendment would change restoration table concentration values for calcium, carbonate, bicarbonate, sulphate, alkalinity, manganese, molybdenum, selenium, uranium, and radium-226

[Texas Natural Resource Conservation Commission: Items Signed by Executive Director October 30, 1998].

ANNEX XXXIV

USA – HIGHLAND

Note: in 2002, the Highland ISL operation was merged with the Smith Ranch project and became a satellite to that project. Prior to 1988, Highland was operated as an open pit mine and conventional acid-leach mill.

Associated company names: Everest Minerals Corporation, Central Electricity Generating Board Exploration, Interuran, Power Resources, Inc., Cameco, Inc.

Location: Converse County, Wyoming

Period of operation: from 1988 to 2005

Annual production: average 300 tU, maximum 600 tU (1997)

Total production (through 2009): 5330 tU

Current status: closed, groundwater restoration and surface reclamation are in progress

XXXIV–1. GEOLOGY

General description: operations are located in the Powder River Basin of east-central Wyoming where uranium occurs in oxidation/reduction roll front deposits 8–15 m in width within permeable Palaeocene fluvial sandstones (lower Fort Union) at depths of up to 250 m. The average ore thickness is 6 m and the average grade is 0.11% U.

Resources/reserves: >7 700 tU (initial)

Recoverable reserves: recovery is estimated to be 80%

Mineralogy of U: coffinite is the principal U mineral; pitchblende/sooty pitchblende is present in lesser amounts. These minerals coat sand grains in thin, sooty or earthy layers or form minute spherulitic or botryoidal concretions with diameters of less than 10 μm. Some ore is cemented by calcite

Stratigraphic setting: the mineralized horizon is underlain by Cretaceous sandstones and shales, and is overlain by Eocene sandstones and shales

Cut off criteria: grade 0.017%U, GT 0.13 m%U

XXXIV–2. FACTORS AFFECTING ISL PROCESS

Hydraulic conductivity:	1–3 m/d
Porosity, effective porosity of ores	27%
Depth of mineralized layer:	150 m

Total mineralization of groundwater: 0.37 g/L TDS

Natural groundwater flow: direction; northeast

XXXIV–3. TECHNOLOGY OF LEACHING

Type of leaching: alkaline

Leaching agent: CO_2, O_2

Operational conditions: duration of leaching phase - 12–24 months

XXXIV–3.1. Wellfields parameters

Well construction: casing diameter; 127 mm (inj), 152 mm (rec)

casing material; schedule 40 pvc

grouting; from top of ore zone to surface

screening material; pvc

Well patterns: shape; 5-spot

distance between wells; 15–30 m (inj to rec)

Pumping technique: submersible pumps (5–10 hp); 102 mm diameter

production well pumping rate; 2 L/s

Water balance management: disposal of excess wellfield solution is by means of irrigation (1.25 L/s)

XXXIV–3.2. Processing plant parameters

Flow rate of leaching solution: 750 m^3/h,

Production capability: 770 tU/a

Technology of solution processing: ion exchange

Ion exchange resin specification: operational loading capacity 64 kgU/m^3

Technology of desorption: elution reagent; NaCl, Na_2CO_3

Technology of downstream processing: precipitation; HCl, NH_4

Satellite sorption stations: yes (2 each at 570 m^3/h)

XXXIV–3.3. Restoration

Technology of groundwater restoration: groundwater sweep, pump and treat with reverse osmosis (RO) and reduction of the formation through the use of chemical or biological processes.

Operating period of restoration process: groundwater restoration began in 1993 with Mine Unit-A (MUA) and continues to 2012 with Mine Unit-C. MUA and MUB ground water restoration is complete and has been approved by the WDEQ. MUA has been approved by the NRC. 5 to 10 pore volumes of ground water circulation are generally required.

Final groundwater quality: meets Wyoming Department of Environmental Quality (WDEQ) class of use standard; Class IV suitable for industrial use after Best Practicable Technology has been applied.

Annex XXXV

USA – HOBSON – GOLIAD

Associated company name: Uranium Energy Corporation

Location: Goliad County, Texas

Annual production: projected; 380 tU/a

Current status (2012): Goliad was licensied and permitted by Q1 2013, intended as a satellite to the recently refurbished Hobson processing facility

XXXV–1. GEOLOGY

General description: roll front/tabular deposits within fluvial sands and silts

Resources/reserves: 2100 tU

Area of deposit: 435 000 m^2

Mineralogy of U: unidentified, but most likely uraninite

Cut off criteria: grade 0.017%U, GT 0.078 m%U

XXXV–2. FACTORS AFFECTING ISL PROCESS

Lithological/mineral composition of ores:

Hydraulic conductivity:	2.5–18 m/d
Depth of mineralized layer:	27–140 m
Static water table in mining aquifer (+/-):	20–30 m
Groundwater temperature:	24°C
Natural groundwater flow:	direction; southeast

XXXV–3. TECHNOLOGY OF LEACHING

Type of leaching: alkaline

Leaching agent: $NaH(CO_3)$

Operational conditions: leaching agent concentration; 400 ppm

XXXV–3.1. Wellfield parameters

Well construction: casing diameter; 127–152 mm

casing material; pvc

grouting; neat cement

screening type; pvc coated wire wrapped around perforated casing with a gap between wraps of 0.25 mm

screen length; 2.5 m (average)

screen material; perforated pvc

Well patterns: shapes; 5-spot, 7-spot and line drive

distance between wells; 15 to 30 m

Pumping technique: submersible pumps, 102 mm diameter

average production well pumping rate; 1.9 L/s

Water balance management: reverse osmosis and deep disposal well

XXXV–3.2. Processing plant parameters

Flow rate of leaching solution: 800 m^3/h,

Production capability: 450 tU/a

Average uranium concentration in pregnant leach solution: 55 mg/L

Technology of solution processing: ion exchange

Ion exchange resin specification: type; strong anion exchange

trade mark; Dow 21K

operational loading capacity; 156 kgU/m^3

particle size; 575 μm

volume of resin in operation; 85 m^3

Technology of desorption: elution reagent; NaCl

Technology of downstream processing: precipitation, washing, dewatering, drying/calcination,

Consumptions: ion exchange resin; 1%/a

Volume of storage tanks: 38–175 m^3

XXXV−3.3. Restoration

Technology of groundwater restoration: groundwater sweep with reverse osmosis

Operating period of restoration process: timeline varies; 6 pore volumes of circulation are planned

Final groundwater quality: target quality is at or below baseline

Annex XXXVI

USA – HOBSON – LAS PALMAS

Associated company name: Everest Minerals Corporation (operator), Everest Exploration, Inc. (owner)

Location: Duval County, Texas
Period of operation: from 1981 to 1983

Total production (through 2009): >231 tU

Current status: closed and fully restored. All necessary approvals have been obtained from the State of Texas and land has been released to land owner

XXXVI–1. GEOLOGY

General description: roll front(s) in the lower Oakville Formation. Ore grade; 0.06%U

Resources/reserves: 280 tU

Recoverable reserves: recovery estimated at 70 to 80%

Mineralogy of U: primarily uraninite

Area of deposit: 8.9 ha

Stratigraphic setting: the Lower Oakville at Las Palmas is both underlain and overlain by shale

Cut off criteria: grade 0.04%U, GT 0.13 m%U

XXXVI–2. FACTORS AFFECTING ISL PROCESS

Depth of mineralized layer:	170–195 m
Total mineralization of groundwater:	1.3 g/L TDS
Natural groundwater flow:	velocity; 10 m/a

XXXVI–3. TECHNOLOGY OF LEACHING

Type of leaching: alkaline

Leaching agent: HCO_3 and dissolved oxygen

Operational conditions: leaching agent concentration; 250–300 mg/L as O_2; duration of leaching phase; 8–14 months

XXXVI–3.1. Wellfield parameters

Well construction: casing diameter; 102 mm injection wells; 152 mm recovery wells

casing material; pvc Schedule 40

grouting; cement

screening material; 64 and 76 mm pvc wellscreen

Well patterns: shape; 5-spot

distance between wells; 15–23 m (inj to inj)

well density; 20/ha (inj and rec)

ratio between recovery and injection wells; 0.44

Pumping technique: submersible pumps; 64 mm diameter

Production well pumping rate: 3.2 L/s

Number of simultaneously working wells: 30–50

Water balance management: disposal in a Class I non-hazardous waste disposal well.

XXXVI–3.2. Processing plant parameters

Note: Las Palmas was a satellite ion exchange plant tributary to the Hobson facility. Loaded resin was trucked from Hobson 240 km to the Hobson facility.

Flow rate of leaching solution: 680 m^3/h,

Production capability: 80 tU/a

Technology of solution processing: three stage gravity feed upflow ion exchange

Ion exchange resin specification: trade mark; Dowex 21K + Rohm and Haas

total loading capacity; 1.2 mol eq/L

particle size; 0.8–1.0 mm

Technology of desorption: elution reagent; 9 % sodium chloride + 2 % sodium carbonate

Technology of downstream processing: precipitation; H_2O_2

Injection and recovery stream storage type: no surge tanks utilized

XXXVI–3.3. Restoration

Technology of groundwater restoration: groundwater sweep

Operating period of restoration process: 3 a

Final groundwater quality: Groundwater in the wellfields has been restored to the levels authorized in the UIC permits. The site has been decommissioned to meet release to unrestricted use criteria. Land returned to landowner.

Annex XXXVII

USA – HOBSON – MOUNT LUCAS

Associated company name: Everest Minerals Corporation (operator), Everest Exploration, Inc. (owner)

Location: Live Oak County, Texas

Period of operation: from 1983 to 1987

Annual production: average 192 tU/a

Total production (through 2009): 796 tU

Current status: closed, wellfield groundwater restored and approved by State of Texas, surface reclamation continuing

XXXVII–1. GEOLOGY

General description: roll front(s) in the Goliad Formation

Resources/reserves: 954 tU

Stratigraphic setting: the mineralized formation is both underlain and overlain by shale

Cut off criteria: grade 0.04%U, GT 0.13 m%U

XXXVII–2. FACTORS AFFECTING ISL PROCESS

Lithological/mineral composition of ores: clean, well sorted fine to very fine sands with iron minerals, primarily marquisate, which were very reactive

Porosity, effective porosity of ores	28%
Depth of mineralized layer:	100–135 m
Static water table in mining aquifer (+/-):	30 m
Carbonate content in ore:	8–10% (as CO_2)
Sulphide content in ore:	trace, but very reactive
Total mineralization of groundwater:	1.0–1.1 g/L TDS
Natural groundwater flow direction:	southeast

XXXVII–3. TECHNOLOGY OF LEACHING

Type of leaching: alkaline

Leaching agent: HCO_3 plus O_2

Operational conditions: leaching agent concentration - variable 200–500 mg/L O_2

duration of leaching phase - 5 months to 1 a

XXXVII–3.1. Wellfield parameters

Well construction: casing diameter; injection wells 102 mm, recovery wells 152 mm

casing material; schedule 40 pvc

grouting; cement

screening type; pvc wire wrap slotted screen 63 mm on injectors and 102 mm on producers

Well patterns: shape; 5 spots and line drives

distance between wells; variable, 15–23 m injector to injector in 5-spot patterns and 15–23 m injector to producer in line drives

Pumping technique: submersible pumps

Recovery well pumping rate: 3.2 - 11 L/s

Number of simultaneously working wellfields: 3

Number of simultaneously working wells: 60 recovery wells, maximum

Water balance management: pretreatment of bleed to remove uranium and radium and then used in an irrigation land application facility

XXXVII–3.2. Processing plant parameters

Note: Mt. Lucas functioned as a satellite to Hobson. Loaded ion exchange resin was trucked from Mt. Lucas to the Hobson facility for elution, precipitation and drying.

Flow rate of leaching solution: 640 m^3/h,

Production capability: 200 tU/a

Technology of solution processing: ion exchange; pressurized two stage down flow

Ion exchange resin specification: trade mark; Dowex 21K

total loading capacity 1.2 mol eq/L

particle size; 0.55-1.0 mm

volume of resin in operation; 30 m^3

Technology of desorption: elution reagent; 9 % NaCl 2% sodium carbonate

Technology of downstream processing:	precipitation; H_2O_2
Consumptions:	ion exchange resin; 1.4 m^3/a
Volume and type of equipment:	4 IX columns with 7.5 m^3 resin each
Volume of storage tanks:	no surge capacity
Injection and recovery stream storage type:	basins/tanks
Satellite sorption stations	yes, 2

XXXVII–3.3. Restoration

Technology of groundwater restoration: groundwater sweep with addition of hydrogen sulphide and injection of water from overlying aquifer

Operating period of restoration process: 5 a

Final groundwater quality: groundwater within the wellfields has been restored to the levels authorized in the UIC permits. Surface reclamation activities are continuing.

Annex XXXVIII

USA – HOBSON – PALANGANA

Note; also known as La Palangana

Associated company names: Union Carbide Corporation, Chevron Resources Company, Rio Grande Resources, Everest Minerals Corporation, South Texas Mining Venture (STMV) 99 % Uranium One, Inc. and 1 % Everest Exploration, Inc. and Uranium Energy Corporation

Location: Duval County, Texas

Period of operation: from 1977 to 1980 and from 1985 to 1986

Annual production: maximum 70 tU (1979 – estimated)

Total production (through 2009): 90 tU

Current status: areas previously mined are now closed, reclaimed and decommissioned. New uranium discoveries post-2005 is in development. Commercial permits have been issued for resumption of commercial ISR activities. Planned production will be as a satellite operation with uranium-bearing ion exchange resin transported by truck to the Hobson plant for elution, resin regeneration, precipitation and drying

XXXVIII–1. GEOLOGY

General description: uranium mineralization at Palangana occurs as roll fronts in Pliocene sandstones (Goliad Formation) of continental origin. These sandstones overlie a collapsed salt dome and contain uranium mineralization at an average grade of 0.13% U and an average thickness of 2.5 m. The average depth is about 100 m. Ore on top of the collapsed dome is highly faulted and fragmented into small, discontinuous blocks.

Resources/reserves:	2 200 tU (remaining resource)
Recoverable reserves:	400 tU
Area of deposit:	~30 ha
Mineralogy of U:	disseminated sooty pitchblende in a highly calcareous, clay-gall conglomerate interbedded with friable sand and locally impregnated with a little oil.
Stratigraphic setting:	the ore-bearing Goliad Formation is underlain by the Oakville Sandstone.
Number of aquifers:	above: one
	below: base of fresh water is at 200 m subsurface

Underlying formation, rock type: Oakville Formation, sandstone

Overlying formation, rock type: sandstone

Average operational thickness: total; <7 m, U ore; 1–3 m

cut off: grade 0.03 % U_3O_8, GT 0.5 ft% (0.15 m%)

XXXVIII–2. FACTORS AFFECTING ISL PROCESS

Lithological composition of ores: ore on top of collapsed dome is highly faulted and fragmented into small, discontinuous blocks.

Mineral composition of ore:	uraninite and pitchblende
Permeability:	~3 m/d
Transmissivity of ores:	3.0×10^{-4} m^2/s
Porosity, effective porosity of ores	25%
Depth of mineralized layer:	100 - 200 m
Static water table in mining aquifer (+/-):	30 m
Total mineralization of groundwater:	1.0 g/L TDS

XXXVIII–3. TECHNOLOGY OF LEACHING

Note: the following information applies to proposed future operations

Type of leaching: alkaline

Leaching agent: HCO_3 and oxygen

Operational conditions: leaching agent concentration; 200–400 mg/L O_2

XXXVIII–3.1. Wellfield parameters

Well construction: casing diameter; 127 mm

casing material; pvc

grouting; cement

screening; 76 mm wire wrapped pvc

Well patterns: shape; line drive

distance between wells; 15–23 m

well density: 100/ha (inj and rec)

ratio between recovery and injection wells; 0.25

Pumping technique: submersible pumps

Recovery well pumping rate: 2.2 L/s

XXXVIII–3.2. Processing plant parameters

Note: Palangana will be operated as a satellite to the Hobson processing facility.

Flow rate of leaching solution:	680 m^3/h,
Production capability:	450 tU/a
Technology of solution processing:	ion exchange pressurized down flow
Ion exchange resin specification:	trade mark; Dowex 21K XLT
	total loading capacity; 1.2 mol eq/L
	particle size; 0.6 μm
	volume of resin in operation; 130 m^3

Technology of desorption: elution reagent; 9% NaCl and 2% Na_2CO_3

Technology of downstream processing: precipitation; H_2O_2

Consumptions: ion exchange resin; 38 L/a

Injection and recovery stream storage type: no surge capacity in leaching circuit

XXXVIII–3.3. Restoration

Technology of groundwater restoration: ground water sweep, reverse osmosis, and addition of chemical reductant.

Annex XXXIX

USA – HOBSON – TEX-1

Associated company name: Texaco, Everest Minerals Corporation

Location: Karnes County, Texas

Period of operation: from 1986 to 1990

Total production (through 2009): 192 tU

Current status (12/09): closed; wellfields restored and approved by State of Texas; surface reclamation complete, awaiting final approval from Texas Commission on Environmental Quality

XXXIX–1. GEOLOGY

General description: roll front(s) in the Deweesville Sandstone of the Whitsitt Member of the Jackson Formation

Resources/reserves: 270 tU

Mineralogy of U: primarily coffinite with traces of uraninite

Stratigraphic setting: the mineralized formation at Tex-1 is overlain by shale/mudstone

Cut off criteria: grade 0.018%U, GT 0.13m% U

XXXIX–2. FACTORS AFFECTING ISL PROCESS

Lithological/mineral composition of ores: marine clays, deposit is on the laguna side of a Gulf Coast barrier bar. High silicate content, volcanic glass shards, very low inorganic carbon content

Porosity, effective porosity of ores	28%
Depth of mineralized layer:	110–135 m
Static water table in mining aquifer (+/-):	95 m
Total mineralization of groundwater:	1.45 g/L TDS
Groundwater temperature:	26°C
Natural groundwater flow:	velocity; 2–3 m/a, direction; southeast

XXXIX–3. TECHNOLOGY OF LEACHING

Type of leaching: alkaline

Leaching agent: $NaHCO_3$ and O_2

XXXIX–3.1. Wellfield parameters

Well construction: casing diameter; 127 mm

casing material; pvc

grouting; cement

screening type; 102 mm slotted pvc wrapped with pvc wire

Pumping technique: submersible pumps

Water balance management: disposal in a Class I non- Hazardous waste disposal well

XXXIX–3.2. Processing plant parameters

Note: Tex-1 was operated as a satellite to the Hobson processing facility

Technology of solution processing: ion exchange

Ion exchange resin specification: trade mark; Dowex 21K

total loading capacity; 1.2 mol eq/L

particle size; 0.55-1.0 mm

Technology of desorption: elution reagent; NaCl and $NaCO_3$

Technology of downstream processing: precipitation; H_2O_2

Type of equipment: fiberglass tanks and pvc piping

XXXIX–3.3. Restoration

Technology of groundwater restoration: groundwater sweep and injection of water from overlying aquifer

Operating period of restoration process: 5 a

Final groundwater quality: groundwater in Tex-1 wellfields has been restored to levels authorized in underground injection control (UIC) permits. Surface reclamation is continuing.

Annex XL

USA – IRIGARAY

Associated company names: Wyoming Minerals Corporation, Malapai Resources, Total Minerals, Cogema Mining, Inc. and Uranium One

Location: Johnson County, Wyoming

Period of operation: from 1977 to 1981, 1987 to 1990 and 1993 to 1994

Annual production: average ~30 tU, maximum 75 tU (1988)

Total production (through 2009): 272 tU

Current status: standby (non-operational), groundwater restoration complete for former operation

XL–1. GEOLOGY

General description: uranium mineralization at Irigaray occurs as roll fronts in fluvial sands of the Upper Irigaray Sandstone of the Wasatch Formation (Eocene) at depths of 80–160 m with an average thickness of 2.2 m. The average grade was 0.11%U

Resources/reserves: 4 600 tU (initial)

Recoverable reserves: 2 600 tU (current)

Mineralogy of U: uraninite is the predominant uranium mineral, but coffinite is also present. Uranium mineralization commonly coats quartz grains, may cut through calcite masses where permeable and fills voids

Stratigraphic setting: The uranium-bearing formation at Irigaray is underlain by medium dark gray shale and claystone at a depth from surface of 215 m. It is overlain by shale-claystone with thin lignitic coal seams

Cut off criteria: grade 0.03%U, GT 0.03 m%

XL–2. FACTORS AFFECTING ISL PROCESS

Lithological/mineral composition of ores: Arkosic coarse to fine grained poorly-sorted sands. Vanadium occurs in association with the uranium. Accessory minerals include: pyrite, calcite, hematite and limonite. Selenium, arsenic and molybdenum occur in trace amounts.

Hydraulic conductivity: 1.0 m/d

Porosity, effective porosity of ores 25–30%

Depth of mineralized layer: 90 m

Carbonate content in ore: 1–3% (CO_2)

Total mineralization of groundwater: 0.375 g/L TDS

Groundwater temperature: 11°C

Natural groundwater flow: direction; northwest

XL–3. TECHNOLOGY OF LEACHING

Type of leaching: alkaline

Leaching agent: phase I NH_4HCO_3 + $(NH_4)_2CO_3$, H_2O_2; Phase II $NaH(CO_3)$, O_2

Operational phases: leaching agent concentration; 1.5 g/L CO_3, 0.5 g/L H_2O_2

XL–3.1. Wellfield parameters

Well construction: casing diameter; 102 mm

casing material; pvc

Well patterns: shape; 7-spot

distance between wells; 15 m

ratio between recovery and injection wells; 0.4

Pumping technique: submersible pumps, production well pumping rate; 0.5 L/s

XL–3.2. Processing plant parameters

Flow rate of leaching solution: 275 m^3/h

Production capability: 150 tU/a

Technology of solution processing: ion exchange

Ion exchange resin specification: operational loading capacity; 100 kgU/m^3

Technology of desorption: elution reagent; NaCl, NaOH

Technology of downstream processing: precipitation; HCl, H_2O_2, NaOH

Satellite sorption stations: yes, Christensen Ranch is a satellite operation to the Irigaray facility

XL–3.3. Restoration

Technology of groundwater restoration: Restoration of the well fields involves the withdrawal of residual fluids from well fields by pumping. Contaminated residual fluids are treated by reverse osmosis and the purified stream is reinjected into the formation via injection wells. Uncontaminated water from outside the well field is allowed to migrate into the field thus restoring the ore zone to premining conditions. Contaminated fluids concentrated by the reverse osmosis process together with other contaminated fluids are disposed of by injection into deep disposal wells.

Operating period of restoration process: 1997–2003

Final groundwater quality: All constituents with Groundwater Standards met Target Restoration Values except Mn. Mn, Se, U and Ra-226 exceeded WDEQ Standards. Groundwater modeling demonstrated that residual levels are no threat to Class of Use Standards outside of the permit area. Unconditional restoration approval was received from WDEQ in November 2005.

Annex XLI

IRIGARY – CHRISTENSEN RANCH (WILLOW CREEK)

Associated company names: Homestake Mining, World Nuclear, American Nuclear, Wyoming Minerals, Western Nuclear, Inc., Malapai Resources, Total Minerals, Cogema, Mining, Inc., Uranium One

Location: Johnson and Campbell Counties, Wyoming

Period of operation: from 1989 to 2005 (intermittently), from 2011

Annual production: average 85 tU/a, maximum 280 tU (1996)

Total production (through 2009): 1425 tU

Current status: operating, former operating wellfields have been restored. Operations restarted in 2011. Christensen Ranch is operated as a satellite to the Irigaray central processing facility. Willow Creek is the current project name.

XL–1. GEOLOGY

General description: uranium mineralization at Christensen Ranch occurs as sinuous roll front deposits in permeable, fluvial sandstones of the Eocene age Wasatch Formation at depths averaging 130 m. Grades and thicknesses average 0.09% U and 2.5 m, respectively.

Resources/reserves: 11 000 tU (initial), ~3 500 tU (current)

Recoverable reserves: 7 700 tU (initial projected), ~2 500 tU (current)

Area of deposit: 70 ha (current)

Mineralogy of U: uraninite is the principal uranium mineral, but coffinite is also present

XL–2. FACTORS AFFECTING ISL PROCESS

Hydraulic conductivity: 1.2 m/d

Depth of mineralized layer: 130 m

XL–3. TECHNOLOGY OF LEACHING

Type of leaching: alkaline

Leaching agent: $NaHCO_3$ and CO_2

XL–3.1. Wellfield parameters

Well patterns: shape; 5-spot

distance between wells; 18–28 m (inj to rec)

ratio between recovery and injection wells; 0.6

Pumping technique: submersible

Water balance management: deep well disposal; 2 wells (1 200 m and 2 000 m) each with a capacity of 5 L/s.

XL–3.2. Processing plant parameters

Christensen Ranch operates as a satellite to the Irigaray central processing facility. Loaded resin is trucked approximately 24 km from Christensen Ranch to Irigaray.

Flow rate of leaching solution: 900 m^3/h

Production capability: 590 tU/a

Technology of solution processing: ion exchange

Annex XLII

USA – KINGSVILLE DOME

Associated company names: Western Nuclear, Uranium Resources, Inc.

Location: Kleberg County, Texas

Period of operation: from 1988 to 1990, 1996 to 1999 and 2006 to 2009

Annual production: average 52 tU/a, maximum 330 tU (1996)

Total production (through 2009): 1 635 tU

Current status (12/09): groundwater restoration underway; (Q1 2013) standby

XLII–1. GEOLOGY

General description: uranium mineralization at Kingsville Dome occurs in narrow roll fronts (~30m) within four units of loosely-consolidated sandstones of the Pliocene Goliad formation. Depths, grades and thicknesses average 200 m, 0.13% U and 3 m, respectively. Severe disequilibrium at the site requires the use of neutron activation logging equipment in order to provide an accurate determination of in-place grade and location.

Resources/reserves: Initial in-place Measured Resources were stated to be approximately 1800 tU and Inferred Resources were stated to be 5 900 tU. As of 12/07, Proven Reserves at Kingsville Dome were reported to be 38 tU at an average grade of 0.064% U.

Area of deposit: 25.5 ha (initial measured resources)

Mineralogy of U: coffinite and pitchblende tend to be the principal U minerals. They coat and occur interstitial to sand grains

Stratigraphic setting: the mineralized formation at Kingsville Dome is underlain by the Lagarto Clay and overlain by the Beaumont Clay

XLII–2. FACTORS AFFECTING ISL PROCESS

Hydraulic conductivity:	~5 m/d
Porosity, effective porosity of ores	30%
Depth of mineralized layer:	200 m
Total mineralization of groundwater:	0.9–1.3 g/L TDS

XLII–3. TECHNOLOGY OF LEACHING

Type of leaching: alkaline

Leaching agent: $NaHCO_3$ plus O_2

Operational conditions: leaching agent concentration - O_2 at 400 ppm; duration of leaching phase ~24 months

XLII–3.1. Wellfield parameters

Well construction: casing diameter; 150 m of 155 mm pvc with 35 m of 110 mm FRP at the bottom

casing material; pvc

grouting; Class A cement with 4% bentonite gel

Well patterns: shapes; staggered or alternating line drives or 5-spot

distance between wells; 15 m from inj to ext

ratio between recovery and injection wells; 1.0

Pumping technique: submersible pumps

Production well pumping rate: 3.8 L/s

Water balance management: lined evaporation ponds and deep well disposal.

XLII–3.2. Processing plant parameters

Flow rate of leaching solution: 1200 m^3/h,

Production capability: 450 tU/a

Technology of solution processing: ion exchange

Ion exchange resin specification: type; strong base

trade mark; Dow 21K

total loading capacity; 1.4 mol eq/L

operational loading capacity; 600 kgU/m^3

particle size; 0.8-1.0 mm

Technology of desorption: elution reagent; NaCl + $NaHCO_3$

Technology of downstream processing: precipitation; HCl, NaOH and H_2O_2

drying; vacuum

Satellite sorption stations: yes, Kingsville Dome has served as a central processing facility for loaded resin from the Vasquez satellite.

XLII–3.3. Restoration

Technology of groundwater restoration: Kingsville Dome employs a combination of groundwater sweep and recirculation of treated water to achieve restoration. Residual fluids are pumped from the production wells allowing the inward migration of uncontaminated groundwater from outside the field in response to pumping, thus displacing the residual fluids. The extracted residual fluids, after ion exchange, are treated by reverse osmosis. The treated water (two-thirds of the feed) along additional purchased fresh water is re-injected into the restoration zone thus reducing the withdrawal of groundwater.

One-third of the reverse osmosis feed reports as a concentrated contaminant stream. This stream is commingled with the process bleed (previously stored in ponds) and other liquid waste products and discharged into a deep disposal well with a depth of approximately 1 500 m. The volume of waste fluids injected averages 6 L/s with a surface pressure not exceeding 1 000 psig.

Baseline groundwater quality: PAA 2 2/13/1990

TABLE 1. BASELINE GROUNDWATER QUALITY

Parameter	Value
Bicarbonate	297 mg/L
Chloride	224 mg/L
Conductivity	1 662 umhos/cm
Sodium	323 mg/L
Sulphate	224 mg/L
TDS	1035 mg/L
Radium	92 pCi/L
Uranium	1.89 mg/L
Arsenic	0.006 mg/L
Selenium	0.008 mg/L

Annex XLIII

USA – KINGSVILLE DOME – VASQUEZ

Associated company name: Coastal States Uranium, Uranium Resources Inc.

Location: Duval County, Texas

Period of operation: from 2004 to 2008

Annual production: average 52 tU, maximum 125 tU

Total production (through 2009): 260 tU

Current status: groundwater restoration underway

XLIII–1. GEOLOGY

General description: uranium mineralization at Vasquez occurs as narrow (20–30 m) roll fronts in loosely-consolidated sandstones of the basal member of the Oakville Formation at a depth of 70 m. The average grade is 0.17% and the average thickness is 2.5 m.

Resources/reserves: As of 12/04, initial in-place Proven Reserves were stated to be approximately 895 tU and probable in-place reserves were stated to be 543 tU. As of 12/07, proven reserves at Vasquez were reported to be 28 tU at an average grade of 0.071% U.

Area of deposit: 20 ha

XLIII–2. FACTORS AFFECTING ISL PROCESS

Depth of mineralized layer: 70 m static water table in mining aquifer

XLIII–3. TECHNOLOGY OF LEACHING

Type of leaching: alkaline

Leaching agent: CO_2 with O_2 as an oxidant, but the O_2 was replaced with H_2O_2 in the latter stages of operation.

Operational conditions: leaching agent concentration; CO_2 300 ppm, O_2 400 ppm

XLIII–3.1. Wellfield parameters

Well construction: casing diameter; 152 mm

casing material; pvc

Well patterns: ratio between recovery and injection wells; 0.85

Pumping technique:	submersible pumps
Recovery well pumping rate:	1.4 L/s
Water balance management:	lined evaporation ponds and deep well disposal.

XLIII–3.2. Processing plant parameters

Note: the Vasquez processing plant was essentially a satellite plant to the Kingsville Dome operation since loaded resin at Vasquez was transferred by truck to Kingsville Dome for elution, precipitation, dewatering, drying and packaging.

Flow rate of leaching solution:	600 m^3/h,
Production capability:	350 tU/a
Technology of solution processing:	ion exchange
Ion exchange resin specification:	type; strong base
	trade mark; Dow 21-K
	particle size; 0.8-1.0 mm
	volume of resin in operation; 60 m^3
Technology of sorption:	fixed bed, up-flow
Technology of desorption:	elution reagent; NaCl + $NaHCO_3$
Technology of downstream processing:	precipitation; HCl, NaOH and H_2O_2
Volume and type of equipment:	4 IX columns; 3.7 m diameter
Satellite sorption stations	satellite to Kingsville Dome

XLIII–3.4. Restoration

Technology of groundwater restoration: groundwater restoration was estimated to require four pore volumes with reverse osmosis treatment. It was planned that restoration of depleted wellfields would be enhanced by displacing formation water from new wellfields into old wellfields undergoing restoration.

Annex XLIV

USA – LAMPRECHT

Associated company name: Wyoming Minerals Corporation, Intercontinental Energy Corporation

Location: Live Oak County, Texas

Period of operation: from 1977 to 1981(estimated) and from 1984 to 1988

Annual production: average; 57 tU/a, maximum 115 tU (1979)

Total production (through 2009): 570 tU

Current status: closed, ground water restoration completed, surface reclamation not yet completed, litigation re: surface reclamation was ongoing

XLIV−1. GEOLOGY

General description: roll front(s) in the Oakville Formation

Ore grade: 0.04–0.08%U

Resources/reserves: 480 tU

Area of deposit: 23 ha

Stratigraphic setting: the underlying formation at Lamprecht is the Catahoula Clay and the overlying formation is the Oakville Formation which is composed of clay, sand, cemented sandstone and sandy clay.

XLIV−2. FACTORS AFFECTING ISL PROCESS

Lithological/mineral composition of ores: medium-grained calcareous sandstone

Porosity, effective porosity of ores 30%

Depth of mineralized layer: 70 m

Total mineralization of groundwater: 1–2 g/L TDS

Natural groundwater flow: velocity; 13 to 20 m/a

XLIV−3. TECHNOLOGY OF LEACHING

Type of leaching: alkaline

Leaching agent: NH_3, CO_3, H_2O_2

XLIV–3.1. Wellfield parameters

Well patterns: well density; 114/ha (ext and rec)

ratio between recovery and injection wells; 2.0

Pumping technique: submersible

Water balance management: deep well disposal with a capacity of up to 22 L/s at a depth of 2 000 m in the Wilcox Formation. Evaporation ponds (2 at 700 m^2 each)

XLIV–3.2. Processing plant parameters

Flow rate of leaching solution:	350 m^3/h,
Production capability:	125 tU/a
Technology of solution processing:	ion exchange
Technology of desorption:	elution reagent; $NH_4Cl + NH_4HCO_3$
Technology of downstream processing:	precipitation; HCL, H_2O_2 and NH_3
Satellite sorption stations	no

XLIV–3.3. Restoration

Technology of groundwater restoration: groundwater sweep plus reverse osmosis with deep well disposal of excess fluids.

Final groundwater quality: groundwater has been restored to meet UIC permit limits. Surface contamination issues remained.

Annex XLV

USA – LONGORIA

Associated company name: Uranium Resources, Inc.

Location: Duval County, Texas

Period of operation: from 1979 to 1981

Annual production: average 6 tU/a, maximum - 10 tU (1980)

Total production (through 2009): 18 tU

Current status: closed, decommissioned and released for unrestricted use

XLV–1. GEOLOGY

General description: roll front(s) in the Soledad Member of the Catahoula Formation. Average ore grade was 0.06%U

Resources/reserves: 240 tU

Area of deposit: 15 000 m^2

XLV–2. FACTORS AFFECTING ISL PROCESS

Hydraulic conductivity: ~5 m/d

Depth of mineralized layer: 200 m

XLV–3. TECHNOLOGY OF LEACHING

Type of leaching: alkaline

Leaching agent: HCO_3

XLV–3.1. Wellfield parameters

Well patterns: shape; staggered line drive

well density; 8 recovery wells per hectare

ratio between recovery and injection wells; 1:1

Pumping technique: submersible pumps

Recovery well pumping rate: 1.7 L/s

Water balance management: evaporation ponds (3 at 0.1 ha each). Waste fluids to be used for secondary recovery of oil

XLV–3.2. Processing plant parameters

Flow rate of leaching solution:	180 m^3/h,
Production capability:	75 tU/a
Technology of solution processing:	ion exchange
Technology of desorption:	elution reagent; NaCl + Na_2CO_3 + $NaHCO_3$
Technology of downstream processing:	precipitation; HCl, NaOH and H_2O_2
Volume and type of equipment:	3 IX columns, 2 elution columns

Annex XLVI

USA – LOST CREEK

Associated company name:	Ur-Energy, Inc., Lost Creek ISR
Location:	Sweetwater County, Wyoming
Period of operation:	proposed initiation of production in 2013
Current status (q1 2013):	construction

XLVI–1. GEOLOGY

General description: uranium mineralization occurs as roll fronts in fluvial arkosic sandstones of the Eocene age Battle Spring Formation.

Stratigraphic setting: Alluvial fan deposits of thick-bedded arkosic sandstones interlayered with mudstones and siltstones. The Battle Spring Formation is greater than 1150 feet (350 m) thick in the project area and dips from 3 degrees northwest to 3 degrees southwest.

TABLE 1. RESOURCES/RESERVES

Lost Creek resources (June 2006)				
Category	Ore (t)	Thickness (m)	Grade (%U)	Contained U (tU)
Indicated	7 711 000	6.0	0.049	3 770
Inferred	635 000	2.9	0.064	423

Recoverable reserves:	postulated recovery is 80%
Area of deposit:	77 ha
Cut off criteria:	grade 0.03%U, GT 0.08 m% U

Additional inferred material was published in 2012 for a series of adjacent deposits acquired by the company

XLVI–2. FACTORS AFFECTING ISL PROCESS

Lithological/mineral composition of ores:	medium to coarse-grained sandstones interbedded with siltstone, shale and claystone.
Depth of mineralized layer:	130–190 m

XLVI–3. TECHNOLOGY OF LEACHING

Type of leaching: alkaline

XLVI–3.1. Processing plant parameters

Flow rate of leaching solution: 1 350 m^3/h,

Production capability: 900 tU/a

Annex XLVII

USA – MCBRYDE

Associated company name: Caithness Mining Corporation

Location: Duval County, Texas

Period of operation: from 1980 (?) to 1984 (?)

Total production (through 2009): 115 tU

Current status: closed, decommissioned and released for unrestricted use

XLVII–1. GEOLOGY

General description: roll fronts in sandstone of the basal unit of the Lower Oakville Formation. The average grade was 0.06% U

Resources/reserves:	400 tU
Recoverable reserves:	115 tU
Stratigraphic setting:	the mineralized formation was underlain by clay and overlain by clay and shale

XLVII–2. FACTORS AFFECTING ISL PROCESS

Lithological/mineral composition of ores:	fine- to medium-grained, subrounded to rounded, fluvial quartz arenites
Depth of mineralized layer:	100 m
Static water table in mining aquifer (+/-):	25 m
Total mineralization of groundwater:	1.3–1.5 g/L TDS

XLVII–3. TECHNOLOGY OF LEACHING

Type of leaching: alkaline

Leaching agent: NaCl + Oxidant

XLVII–3.1. Wellfield parameters

Well construction:	casing diameter; 120 mm
	casing material; FRP

	grouting; from ore zone to surface
Well patterns:	shape; 5-spot
	ratio between recovery and injection wells; 0.5
Pumping technique:	submersible pumps
Water balance management:	deep disposal well

XLVII–3.2. Processing plant parameters

Flow rate of leaching solution:	225 m^3/h,
Production capability:	80 tU/a
Technology of downstream processing:	precipitation; HCl + H_2O_2 + NaOH

Annex XLVIII

USA – NICHOLS RANCH

Associated company name: Cleveland-Cliffs Iron Company, Uranerz Energy Corporation

Location: Campbell and Johnson Counties, Wyoming

Current status: construction, initial production expected in 2013

XLVIII–1. GEOLOGY

General description: roll fronts within fluvial sandstones the Eocene age Wasatch Formation. The average thickness is 2 m and the average grade is 0.097% U

TABLE 1. RESOURCES/RESERVES

Mineral resource estimate – Nichols Ranch property (June, 2009)					
Sand	GxT minimum (m-%U)	Category	Tonnes	% U	tU
A	0.05	Indicated	1 173 600	0.097	1,134
A	0.13	Indicated	824 400	0.111	916

Area of deposit: 40 ha

Mineralogy of U: amorphous uranium oxide, sooty pitchblende and coffinite

XLVIII–2. FACTORS AFFECTING ISL PROCESS

Lithological/mineral composition of ores: the host sands are primarily arkosic in composition, friable, and contain traces of carbonaceous material and organic debris.

Hydraulic conductivity: 0.28 m/d

Depth of mineralized layer: 150 m

Static water table in mining aquifer (+/-): 18–60 m

Total mineralization of groundwater: 0.33 g/L TDS

Natural groundwater flow: velocity; 0.018 m/d, direction; northeast

XLVIII–3. TECHNOLOGY OF LEACHING

Type of leaching: alkaline

Leaching agent: carbonate/bicarbonate solution fortified with oxygen or peroxide as an oxidant.

XLVIII–3.1. Wellfield parameters

Water balance management: deep disposal well (2.2 L/s)

XLVIII–3.2. Processing plant parameters

Flow rate of leaching solution: 800 m^3/h,

Production capability: 900 tU/a

Technology of solution processing: ion exchange

Satellite sorption stations: yes, a satellite plant will be located at the Hank deposit and will be tributary to the primary recovery facility at Nichols Ranch. See Hank profile for details.

XLVIII–3.3. Restoration

Technology of groundwater restoration: groundwater sweep with re-injection of groundwater treated by reverse osmosis and possible use of a reductant.

Annex XLIX

USA – NICHOLS RANCH – HANK

Associated company name: Uranerz Energy Corporation

Location: Campbell County, Wyoming

Current status: proposed satellite to Nichols Ranch; currently (2010) in the licensing permitting process

XLIX–1. GEOLOGY

General description: rolls fronts in the Eocene age Wasatch Formation.

TABLE 1. RESOURCES/RESERVES

Total measured and indicated resources (F sand)			
GT minimum	tU	t Ore	Average grade (% U)
0.10	958	2 231 800	0.043
0.20	860	823 100	0.104
0.50	283	167 500	0.169
Summary of inferred mineral resources (F sand)			
0.20	95	129 000	0.074

Mineralogy of U: amorphous uranium oxide, sooty pitchblende and coffinite

XLIX–2. FACTORS AFFECTING ISL PROCESS

Lithological/mineral composition of ores: fine- to coarse-grained sand consisting of quartz, feldspar, accessory biotite and muscovite mica, and locally occurring carbon fragments.

Hydraulic conductivity: 0.18 m/d

Depth of mineralized layer: 70 m

Total mineralization of groundwater: 1.0 g/L TDS

Natural groundwater flow: velocity; 0.01 m/d, direction; west

XLIX–3. TECHNOLOGY OF LEACHING

Type of leaching: alkaline

Leaching Agent: Carbonate/bicarbonate solution with oxygen or peroxide as an oxidant.

XLIX–3.1. Processing plant parameters

Flow rate of leaching solution: 600 m^3/h,

Production capability: 115 tU/a

XLIX–3.2. Restoration

Technology of groundwater restoration: groundwater sweep with re-injection of groundwater treated by reverse osmosis and possible use of a reductant.

Annex L

USA – PAWNEE

Associated company name: Intercontinental Energy Corporation

Location: Bee County, Texas

Period of operation: from 1977 to 1979

Annual production: average; 10 tU, maximum 20 tU (1977)

Total production (through 2009): 30 tU

Current status (12/09): closed and restored.

L–1. GEOLOGY

General description: roll front(s) in the Oakville Formation

L–2. FACTORS AFFECTING ISL PROCESS

Depth of mineralized layer: 75 m (average or range)

L–3. TECHNOLOGY OF LEACHING

Type of leaching: alkaline

Leaching agent: NH_3HCO_3 +H_2O_2 or O_2

L–3.1. Wellfield parameters

Well patterns: well density – 114 (inj and rec) per hectare

Pumping technique: submersible pumps

L–3.2. Processing plant parameters

Technology of solution processing: ion exchange

L–3.3. Restoration

Technology of groundwater restoration: groundwater sweep at 16 L/s with disposal by irrigation on an area of 41 hectares

Annex LI

USA – ROSITA

Associated company name: Uranium Resources, Inc.

Location: Duval County, Texas

Period of operation: from 1990 to 1992, 1995 to 1999 and 2008

Annual production: average 110 tU, maximum 290 tU (1991)

Total production (through 2009): 1 015 tU

Current status: restoration and reclamation, (Q1 2013) standby

LI–1. GEOLOGY

General description: uranium mineralization at Rosita occurs in a series of narrow (25–40 m), overlapping roll fronts within the Pliocene Goliad Formation, a loosely consolidated sandstone. The average depth is 65 m. The average grade is 0.17% U_3O_8 and the average thickness is 2.4 m. Uranium minerals may be either coffinite or uraninite and occur interstitial to, or as a coating on, sand grains.

Resources/reserves: initial in-place resources were stated to be approximately 2300 tU. As of 12/2008, In place proven reserves for the Rosita project were reported to be 86 tU at an average grade of 0.069% U.

Area of deposit: 18.7 ha

Mineralogy of U: uraninite/coffinite

Stratigraphic setting: the mineralized formation at Rosita is underlain by the "B" clay and overlain by the "A" clay.

LI–2. FACTORS AFFECTING ISL PROCESS

Lithological/mineral composition of ores: medium grained, arkosic to quartz sandstones

Hydraulic conductivity: > 4 m/d

Porosity, effective porosity of ores 30%

Depth of mineralized layer: 60 m

Total mineralization of groundwater: 1.8 g/L TDS

Groundwater temperature: 25°C

LI–3. TECHNOLOGY OF LEACHING

Type of leaching: alkaline

Leaching agent: $NaHCO_3$ with O_2 as an oxidant

Operational conditions: leaching agent concentration; 275–1000 mg/L HCO_3

LI–3.1. Wellfield parameters

Well construction:	casing diameter; 127 and 152 mm
	casing material; pvc
	grouting; Class A cement with 4% bentonite gel from screen to surface
	screening material; pvc
Well patterns:	shape; single line drive
	distance between wells; 20–30 m (inj to rec)
	well density; 17 recovery wells per hectare
	ratio between recovery and injection wells; 0.8
Pumping technique:	submersible pumps

Recovery well pumping rate: 1 to 2 L/s

Water balance management: liquid waste from the precipitation process and wellfield bleed via the waste stream from the reverse osmosis unit are injected into a non-hazardous Class I disposal well at depths of 1 350 to 1 650 m. Licensed flow to the disposal well is 12.5 L/s at pressures up to 860 psi.

LI–3.2. Processing plant parameters

Flow rate of leaching solution:	800 m^3/h,
Production capability:	450 tU/a
Technology of solution processing:	ion exchange
Ion exchange resin specification:	type; strong base
	trade mark; Dow 21-K
	particle size; 0.8-1.0 mm
	volume of resin in operation; 96 m^3
Technology of sorption:	up-flow

Technology of desorption:	elution reagent; NaCl + $NaHCO_3$
Technology of downstream processing:	precipitation; HCl, NaOH and H_2O_2
	filtration; EIMCO Shriver recessed plate filter press
	drying and packaging at Kingsville Dome facility
Volume and type of equipment:	8 IX columns; 3 m dia x 8 m high with 12 m^3 each of resin
Volume of storage tanks:	eluent; 3 tanks: 4.3 m dia x 4.9 m high
Injection and recovery stream storage type:	injection; 3 tanks: 4.8 m dia x 5.5 m high
Satellite sorption stations	no

LI–3.3. Restoration

Technology of groundwater restoration: Groundwater restoration was estimated to require two pore volumes of natural ground water sweep and two pore volumes with reverse osmosis permeate.

Baseline groundwater quality: PAA3 6/6/96

TABLE 1. BASELINE GROUNDWATER QUALITY

Parameter	Value
Bicarbonate	161 mg/L
Chloride	952 mg/L
Conductivity	4 276 umhos/cm
Sodium	751 mg/L
Sulphate	496 mg/L
TDS	2 524 mg/L
Radium	87.3 pCi/L
Uranium	0.586 mg/L
Arsenic	0.068 mg/L
Selenium	0.12 mg/L

Annex LII

USA – SMITH RANCH/HIGHLAND

Note: Cameco acquired Smith Ranch in 2002 at which time Cameco's Highland project was merged with the Smith Ranch project.

Associated company names: Kerr-McGee Corporation, Rio Algom Mining, Power Resources, Inc., Cameco Inc.

Location: Converse County, Wyoming

Period of operation: from 1997 to present (2012)

Annual production: average; 170 tU, maximum 765 tU (2006)

Total production (through 2009): 2 722 tU

Current status: operating

LII–1. GEOLOGY

General description: uranium mineralization at Smith Ranch occurs as oxidation/reduction roll fronts in a series of permeable Palaeocene sandstones within the Fort Union Formation at depths of up to 350 m. The average ore grade is 0.11% U_3O_8 and the average thickness is 3 m.

Resources/reserves: 16 700 tU (initial reserves)

TABLE 1. CURRENT (12/31/09) RESERVES AND RESOURCES – SMITH RANCH

	Ore	Grade	Content
Smith Ranch	(kt)	(% U)	(tU)
Reserves - proven	772	0.10	769
Reserves - probable	1 931	0.08	1 474
Resources - measured	2 835	0.08	2 308
Resources - indicated	13 171	0.05	6 538
Resources - inferred	6 370	0.04	2 538
Total	25 079	0.05	13 628

TABLE 2. CURRENT (12/31/09) RESERVES AND RESOURCES – HIGHLAND

		Ore	Grade	Content
Highland		(kt)	(% U)	(tU)
Reserves - proven		247	0.12	269
Reserves - probable		410	0.09	385
Resources - measured		866	0.08	692
Resources - indicated		47	0.08	38
Resources - inferred		108	0.17	192
	Total	1 679	0.09	1 577

Additional reserves and resources occur at the nearby Reynolds Ranch and Northwest Unit, which are likely to be developed as satellite deposits to Smith Ranch.

TABLE 3. CURRENT (12/31/09) RESERVES AND RESOURCES – REYNOLDS RANCH

		Ore	Grade	Content
Reynolds Ranch		(kt)	(% U)	(tU)
Reserves - proven		-	-	-
Reserves - probable		758	0.07	500
Resources - measured		46	0.11	38
Resources - indicated		6 395	0.05	3 192
Resources - inferred		5 036	0.03	1 808
	Total	12 235	0.05	5 538

TABLE 4. CURRENT (12/31/09) RESERVES AND RESOURCES – NORTHWEST UNIT

		Ore	Grade	Content
Northwest Unit		(kt)	(% U)	(tU)
Reserves - proven		-	-	-
Reserves - probable		-	-	-
Resources - measured		-	-	-
Resources - indicated		3 953	0.022	885
Resources - inferred		627	0.031	192
	Total	4,580	0.024	1,077

Mineralogy of U: uranium mineralization consists of sooty black uraninite- and coffinite-coated sand grains.

Stratigraphic setting: the mineralized formation at Smith Ranch is underlain by Cretaceous sandstones and shales and is overlain by Eocene, fluvial sandstones and shales.

Cut off criteria: grade 0.02%U; GT 0.13 m%U

LII–2. FACTORS AFFECTING ISL PROCESS

Lithological/mineral composition of ores: generally a fine- to coarse-grained, poorly to moderately sorted, sub-angular, feldspathic quartz arenite grading to an arkose

Hydraulic conductivity:	8 m/d
Porosity, effective porosity of ores	27%
Depth of mineralized layer:	up to 350 m
Total mineralization of groundwater:	up to 0.2 g/L TDS
Natural groundwater flow:	velocity; 0.5 m/d, direction; north/northeast

LII–3. TECHNOLOGY OF LEACHING

Type of leaching: alkaline

Leaching agent: CO_2, O_2

Operational conditions: duration of leaching phase; 1.5 to 2.5 a.

LII–3.1. Wellfield parameters

Well construction:	casing diameter; 127mm
	casing material; schedule 40 pvc
	grouting; top of ore zone to surface
	screening length; ~6 m, material; pvc
Well patterns:	shape; 5-spot
	distance between wells; 23 to 31 m (inj to inj)
	ratio between recovery and injection wells; avg. 1:1.4

Pumping technique: submersible pumps

Recovery well pumping rate: 1.5 L/s

Water balance management: 1% bleed disposed of by deep well injection.

LII–3.2. Processing plant parameters

Flow rate of leaching solution:	2 IX facilities at 700 m^3/h each
Production capability:	2500 tU/a
Technology of solution processing:	ion exchange
Ion exchange resin specification:	type; anionic
	trade mark; Dow 21K XLT
	operational loading capacity; 120 g/L
	volume of resin in operation; 2 facilities at 85 m^3 each
Technology of sorption:	down-flow
Technology of desorption:	elution reagent; 90 g/L NaCl, 20 g/L Na_2CO_3
Technology of downstream processing:	precipitation; NH_3, H_2O_2, $H2SO_4$
	thickening; cone bottom thickener
	filtering; recessed plate filter press
	drying; rotary vacuum dryers at 50 cm Hg for 17 h
Volume and type of equipment:	2 IX facilities each with six IX columns. Each column is 3.5 m in diameter and contains about 15 m^3 of resin.

LII–3.3. Restoration

Technology of groundwater restoration: **g**roundwater sweep, pump and treat with reverse osmosis (RO) and reduction of the formation through the use of chemical or biological processes.

Operating period of restoration process: generally requires 5 to 10 pore volumes of groundwater circulation. Time requirement is variable due to differing site conditions.

Final groundwater quality: must meet Wyoming Department of Environmental Quality (WDEQ) class of use standard; Class IV suitable for industrial use after Best Practicable Technology has been applied.

Annex LIII

USA – TREVINO

Associated company name: Conoco, Inc.

Location: Duval County, Texas

Period of operation: from 1981 to 1985

Annual production: average 40 tU/a

Total production (through 2009): ~200 tU

Current status: closed, decommissioned and released for unrestricted use.

LIII–1. GEOLOGY

General description: roll front(s) in fluvial sandstones of the Miocene age Oakville Formation

Recoverable reserves: 1 200 to 1 700 tU

Area of deposit: 500 000 m^2

Stratigraphic setting: the mineralized horizon at Trevino was underlain by clay and overlain by clay and shale.

LIII–2. FACTORS AFFECTING ISL PROCESS

Lithological/mineral composition of ores: fine- to medium-grained, subrounded to rounded, quartz arenite

Hydraulic conductivity: 1–4 m/d

Depth of mineralized layer: 90 m

Total mineralization of groundwater: 1.3–1.6 g/L TDS

Groundwater temperature: 25°C

LIII–3. TECHNOLOGY OF LEACHING

Type of leaching: alkaline

Leaching agent: $NaHCO_3$, O_2

LIII–3.1. Wellfield parameters

Well construction: casing diameter; 110 mm

	casing material; fiberglass
	screening type; 100 mm dia with 0.35 mm slots
Well patterns:	shape; 5-spot rectangular (30 x 25 m to 18 x 12 m)
	distance between wells; 11 m to 20 m inj to rec
	ratio between recovery and injection wells; 0.6

Pumping technique: submersible pumps (2.2–3.7 kW)

Injection well pumping rate: 2.8 L/s with a pressure of 3–6 kPa

Water balance management: deep disposal well into the Yegua Formation at a depth of 1 300 m

LIII–3.2. Processing plant parameters

Flow rate of leaching solution:	570 m^3/h
Production capability:	209 tU/a
Technology of solution processing:	ion exchange
Ion exchange resin specification:	trade mark; Dowex 21K
	volume of resin in operation; 150 m^3
Technology of sorption:	fixed bed up-flow
Technology of desorption:	elution reagent; 50 g/L Cl^-, 15 g/L $NaHCO_3/Na_2CO_3$, pH= 9.2–9.8
Technology of downstream processing:	precipitation; HCl, NaOH, H_2O_2
Volume and type of equipment:	8 ion exchange columns each 4.3 m dia x 10.7 m high
Injection and recovery stream storage type:	5 lixiviant surge tanks each 76 m^3 each
Satellite sorption stations:	no

LIII–3.3. Restoration

Technology of groundwater restoration:	groundwater and freshwater sweeps

Annex LIV

USA – WEST COLE

Associated company name: Tenneco Uranium Co., Total Minerals Corporation, Cogema Mining, Inc.

Location: Webb County, Texas

Period of operation: from 1982–1984 and from 1987–1989

Annual production: average 58 tU, maximum 75 tU (1980)

Total production (through 2009): 345 tU

Current status (12/09): closed, decommissioned, released for unrestricted use

LIV–1. GEOLOGY

General description: uranium mineralization occurs in roll fronts within the Soledad Volcanics Member of the Catahoula Formation. Roll front width ranges from 12–180 m over a total length of 2 500 m. The average grade was 0.04%U.

Resources/reserves:	initial ~750 tU
Area of deposit:	27 ha
Mineralogy of U:	uraninite and coffinite
Stratigraphic setting:	the overlying formation consists of tuffaceous montmorillonite clay.
Cut off criteria:	GT 0.05m%

LIV–2. FACTORS AFFECTING ISL PROCESS

Hydraulic conductivity:	1 m/d
Depth of mineralized layer:	80 m
Static water table in mining aquifer (+/-):	13 to 20 m
Total mineralization of groundwater:	1.3 g/L TDS
Natural groundwater flow:	velocity; 4 m/a, direction; southeast

LIV–3. TECHNOLOGY OF LEACHING

Type of leaching: alkaline

Leaching agent: $NaHCO_3$, O_2

LIV–3.1. Wellfield parameters

Well construction: casing diameter; 115 mm

casing material; pvc or frp

screening type; pcv with 0.25 mm slots

Well patterns: shape; line drive and 5-spot

well density; 1 recovery well per 2100 m^2

ratio between recovery and injection wells; 0.75

Pumping technique: submersible pumps; 2 hp 14 stage or 3 hp 26 stage

Recovery well pumping rate: 0.7 L/s

Water balance management: waste effluent was collected in a 1 100 m^3 lined pond before injection into a deep disposal well at a depth of 1 900 m. The deep well disposal rate was 20 L/s

LIV–3.2. Processing plant parameters

Flow rate of leaching solution:	400 m^3/h,
Production capability:	100 tU/a
Technology of solution processing:	ion exchange
Ion exchange resin specification:	type; strong base anion exchange
	operational loading capacity; 80 kg U/m^3
	volume of resin in operation; 100 m^3
Technology of sorption:	fixed bed
Technology of desorption:	elution reagent; NaCl, $NaHCO_3$, Na_2CO_3
Technology of downstream processing:	precipitation; HCL, NaOH, H_2O_2
Volume and type of equipment:	ion exchange columns (3, each 3.1 m dia. x 8.6 m high), 45 m^3 mechanically-agitated precipitation tank
Satellite sorption stations	no

LIV–3.3. Restoration

Technology of groundwater restoration: groundwater sweep, fluids treated with reverse osmosis

Operating period of restoration process: 1989–1999

Final groundwater quality: Cogema Mining, Inc. applied for an amendment to the production area authorization for Production Area No. 1 under existing Permit No. UR02463-011 (West Cole Mine Site). The proposed amendment would revise restoration values for calcium, magnesium, sodium, potassium, bicarbonate, TDS, conductivity, alkalinity, selenium, uranium, molybdenum and radium-226. The proposed values would not change the use category of the water. Prior to mining, the water in the production area was used for livestock (June 1997).

Cogema Mining, Inc. applied for a restoration table amendment to a production area authorization UR02463-021. Mining started in West Cole Production Area No. 2 in January 1982. Restoration began in December 1989 using groundwater sweep, reverse osmosis, and injection of water from an underlying aquifer. Since restoration started, 19.01 pore volumes or approximately 181 million gallons (0.685 Mm^3) of aquifer water was removed. One pore volume equals 9.6 million gallons (0.036 Mm^3). The proposed amendment would change the restoration table in accordance with 30 TAC 331.107 (Texas Register 4 June 1999).

Annex LV

USA – ZAMZOW

Associated company name: Intercontinental Energy Corporation

Location: Live Oak County, Texas

Period of operation: from 1977 to 1985

Annual production: average 53 tU, maximum 75 tU (1980)

Total production (through 2009): 480 tU

Current status (12/09): closed, ground water restoration completed, surface reclamation not yet completed, litigation re surface reclamation is ongoing

LV–1. GEOLOGY

General description: roll front(s), 3.2 km in length, in the Oakville Formation. The average grade was 0.15% U and the average thickness was about 1.5 m

Resources/reserves: 1230 tU

Area of deposit: 18 ha

Stratigraphic setting: the mineralized horizon is underlain by the Catahoula Clay and overlain by clay, sandy clay of the Oakville Formation.

Cut off criteria: grade 0.04%U; GT 0.04m%U

LV–2. FACTORS AFFECTING ISL PROCESS

Lithological/mineral composition of ores:	medium-grained, calcareous sandstone. light yellow-gray, some fossilized wood, quartz, chert/gravel
Hydraulic conductivity:	6–10 m/d
Porosity, effective porosity of ores	28%
Depth of mineralized layer:	50 m
Static water table in mining aquifer (+/-):	38 m
Total mineralization of groundwater:	1.0–3.2 g/L TDS

LV–3. TECHNOLOGY OF LEACHING

Type of leaching: alkaline

Leaching agent: NH_3CO_3, O_2

Operational conditions: leaching agent concentration; O_2 = 235 ppm, NH_3CO_3 = 5–10 g/L

LV–3.1. Wellfield parameters

Well construction: casing diameter; 104 mm

casing material; schedule 40 pvc

screening type; opening of 0.3 mm

Well patterns: shape; staggered 5-spot, 7-spot, line drive, orebody fit

distance between wells; 7 m or 12.5 m

well density 143/ha (ext and rec)

Pumping technique: submersible pumps

Recovery well pumping rate: 0.8 L/s

Water balance management: deep well disposal

LV–3.2. Processing plant parameters

Flow rate of leaching solution: 365 m^3/h,

Production capability: 75 tU/a

Technology of solution processing: ion exchange

Ion exchange resin specification: operational loading capacity; 60–90 kgU/m^3

Satellite sorption stations no

LV–3.3. Restoration

Technology of groundwater restoration: groundwater sweep with deep well disposal at 1090 m into the Yegua formation.

Operating period of restoration process: restoration commenced in early 1986 with groundwater sweep.

Final groundwater quality: groundwater in the wellfields has been restored to meet UIC permit limits. Surface contamination issues remain.

Annex LVI

UZBEKISTAN – NORTHERN MINING DIVISION (UCHKUDUK)

Associated company names: Navoi Mining and Metallurgical Integrated Works (Combinat)

Location: 100 km northwest of Zarafshan

Period of operation: from 1964 to present

Annual production: average 550 tU, maximum 833 (2000): Note: data only available from 1990 onwards.

Total production through 2008: 10 500 tU (1990–2008)

Current status (12/09): operating

LVI–1. GEOLOGY

Type of deposit: roll front type associated with redox interfaces in sandstone

Geological ore reserves: Bukantausky District: RAR + Inferred 17 884 tU (1/1/05)

Ore grade is reported to be 0.03% U. Ore thickness is 2–3 m.

Recoverable reserves: estimated recovery is 70%

Mineralogy of U: U minerals are mainly pitchblende, and coffinite with minor uranitite and uraniferous phosphatic fish detritus

Cut off: grade - 0.01% U

LVI–2. FACTORS AFFECTING ISL PROCESS

Lithological composition of ores: a) marine green-grey sand and muddy sand and b) alternating fine-grained sandstone and clay

Mineral composition of ore: associated elements include Se and Mo in concentrations of about 0.01%

Depth of orebody: 80–100 m

Depth of static level head below surface: 40 m

LVI–3. TECHNOLOGY OF LEACHING

Type of leaching: neutral

Leaching agent: natural groundwater

Specific consumption of reagents: H_2SO_4; 135 kg/kgU

LVI–3.1. Wellfields parameters

Well patterns: shape; 5-spot rectangular

distance between wells; inj wells: 10–20 m by 80–100 m

ratio between recovery and injection wells; 0.4

Pumping technique: type submersible

Production well pumping rate: 1.5 L/s

Number of simultaneously working wells: 460 extraction

LVI–3.2. Processing plant parameters

The Uchkuduk facility produces uranium slurry containing about 60 g/L U which is pumped into railroad tank cars which are hauled to Navoi for final recovery, drying and packaging. At Navoi, the slurry is redissolved in sulphuric acid, concentrated by solvent extraction and precipitated with ammonium carbonate. It is calcined at 800–900 degrees C.

Volume of processed solution: 3 000 m^3 /h

Production capability: 750 tU/a

Technology of solution processing: ion exchange

Ion exchange resin specification: trade mark; AMP

loading capacity; 100 kgU/t

Elution reagent specification: elution reagent; H_2SO_4 (5–10 g/L) and NH_3NO_3 (70–80 g/L)

Chemistry of: final product precipitation; NaOH

Volume and type of equipment (vessels, pumps, piping): elution columns: 15 m × 2 m

Satellite sorption stations: several are in operation, each with a capacity of about 225 m^3/h. Resin is hauled by truck to the central processing facility

LVI–3.3. Restoration

Technology of groundwater restoration: natural attenuation

Annex LVII

UZBEKISTAN – SOUTHERN MINING DIVISION (NURADAD)

Associated company names: Navoi Mining and Metallurgical Integrated Works (Combinat)

Location: 70 km southeast of Navoi and 20 km west of Samarkand

Period of operation: from 1966 to present

Annual production: average 660 tU/a, maximum 850 tU (1991) Note: Production information is not available before 1990

Total production through 2008: 12 540 tU (1990–2008)

Current status (12/09): operating

LVII–1. GEOLOGY

Type of deposit: sinuous roll fronts associated with redox interfaces in multiple horizons of Cretaceous age. Thicknesses range from 1–20 m.

Geological ore reserves: deposits include: Maizak North, Ketmenchi, Argon, Sabyrsai, Shark, Tutly and Nagornoye. RAR + inferred resources = 12 595 tU (1/1/05)

Recoverable reserves: recovery is estimated to be 70%

Mineralogy of U: mainly pitchblende and sooty pitchblende

LVII–2. FACTORS AFFECTING ISL PROCESS

Lithological composition of ores: mainly sand with some gravel and gritstone

Mineral composition of ore: associated minerals include: molybdenum, rhenium and scandium-bearing minerals

LVII–3. TECHNOLOGY OF LEACHING

Type of leaching: acid

Leaching agent: H_2SO_4

Leaching agent concentration in operational solutions (average): for those deposits with more than 2% carbonate present in the formation, 5–10 g/L of sulphuric acid per litre of solution is injected into the ore-bearing horizon. For those deposits with less than 2% carbonate, no acid is used for leaching except for a small amount to reduce the initial pH slightly.

LVII–3.1. Wellfields parameters

Well patterns: shape; alternating rows of inj and rec wells

distance between wells; 30–60 m between rows and 20–30 m between wells

LVII–3.2. Processing plant parameters

The Nurabad facility produces uranium slurry containing about 60 g/L U which is pumped into railroad tank cars which are hauled to Navoi for final recovery, drying and packaging. At Navoi, the slurry is redissolved in sulphuric acid, concentrated by solvent extraction and precipitated with ammonium carbonate. It is calcined at 800 to 900 °C.

Production capability: 650 tU/a

Technology of solution processing: ion exchange

LVII–3.3. Restoration

Technology of groundwater restoration: natural attenuation

Annex LVIII

UZBEKISTAN - MINING DIVISION NUMBER 5 (ZAFARABAD)

Associated company names: Navoi Mining and Metallurgical Integrated Works (Combinant)

Location: 40 km north of Dzhizak

Period of operation: from 1968 to present

Annual production: average 775 tU, maximum 962 tU (2000). Note: data only available from 1990 onwards.

Total production through 2008: 14 740 tU (1990–2008)

Current status (2012): operating

LVIII–1. GEOLOGY

Type of deposit: roll front type associated with redox interfaces in sandstone

Geological ore reserves: West-Nurantinsky District: RAR + inferred 51 552 tU (1/1/05)

Ore thickness is 1–3 m. Ore grades range from 0.042–0.117%U. Deposits include Kenimekh, Bukinai South, Bukinai North, Alendy, Terekuduk, Varadzhan, Tokumbet, Beshkak, Lyavlyakan, and Aulbek.

Recoverable reserves: estimated recovery is 70%

Cut off: grade 0.01% U

LVIII–2. FACTORS AFFECTING ISL PROCESS

Lithological composition of ores: sand-conglomerate or weakly cemented sandstone which alternate with argillaceous horizons of Lower and Upper Turonian, Coniacian-Santonian, Campanian-Maastrichtian and Palaeogene age.

Mineral composition of ore: associated elements include Se, Re, Mo and rare earths

Permeability:	2–7 m/d
Depth of orebody:	100–500 m
Carbonate content in ore:	<2.5%
Total mineralization of groundwater:	3 000 ppm (~mg/L)

LVIII–3. TECHNOLOGY OF LEACHING

Type of leaching: acid

Leaching agent: H_2SO_4

Specific consumption of reagents: H_2SO_4; 135 kg/kgU

LVIII–3.1. Wellfields parameters

Well construction: screening type, length, material; slotted polyethylene

Well patterns: shape; alternating rows of inj and rec wells

distance between wells; 30–60 m between rows and 20–30 m between wells

Pumping technique: type; submersible

Production well pumping rate: 1.7 L/s

LVIII–3.2. Processing plant parameters

The Zafarabad facility produces uranium slurry containing about 60 g/L U which is pumped into railroad tank cars which are hauled to Navoi for final recovery, drying and packaging. At Navoi, the slurry is redissolved in sulphuric acid, concentrated by solvent extraction and precipitated with ammonium carbonate. It is calcined at 800–900°C.

Production capability: 900 tU/a

Technology of solution processing: ion exchange

Ion exchange resin specification: trade mark; AMP

loading capacity; 20–40 kgU/t

Elution reagent specification: elution reagent; H_2SO_4 (5–10 g/L) and NH_3NO_3 (70–80 g/L)

Chemistry of final product precipitation; NaOH

Initial load of: ion exchange resin; 41,000 kg

Annual consumption of all other chemicals: H_2SO_4/HNO_3; 1 800 t, NH_3NO_3; 1400 t, NH_4; 900 t

Volume and type of equipment (vessels, pumps, piping): Elution columns 15 m × 2 m

Process water consumption: 0.3 m^3/kgU

Steam consumption: 0.008 Hcal/kgU

Electric power consumption: 32 kWh/kgU

LVIII–3.3. Restoration

Technology of groundwater restoration: natural attenuation