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Pyongsan Uranium Concentrate Plant (Nam-chon Chemical Complex)

Infrastructure Development and Status

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Joseph S. Bermudez Jr.
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A Report of the CSIS KOREA CHAIR

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About Beyond Parallel

Beyond Parallel: Bringing transparency and understanding to current security developments and long-term planning on the Korean peninsula with data-driven research and satellite imagery analysis. Established in 2016, Beyond Parallel is a project of the CSIS Korea Chair available online at csis.beyondparallel.org.

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Acknowledgments

This report would have not been possible without the generous input of numerous experts within the United States and internationally. These include Eric Brewer, Emma Colbran, Karl Dewey, Marie DuMond, Dana Kim, Anti Bunga Rizkiah, Dr. Mark Jensen, and CSIS's iDeas Lab and Korea Chair. Any errors of omission or commission, however, rest solely with the author. This report is made possible by funding from the CSIS Korea Chair, Korea Foundation, and UniKorea Foundation.

This is the second report in a series analyzing North Korea's uranium concentrate plants. For additional Beyond Parallel satellite imagery reports by the CSIS Korea Chair, please see below:

- ***Yongbyon Declassified*** (https://beyondparallel.csis.org/tag/yongbyon-declassified/)
  The history of North Korea's first nuclear complex.
- ***Undeclared North Korea*** (https://beyondparallel.csis.org/tag/undeclared-north-korea/)
  North Korea's undisclosed missile operating bases.
- ***Making Solid Tracks*** (https://beyondparallel.csis.org/tag/making-solid-tracks/)
  Railway infrastructure on the Korean peninsula.
- ***Mining North Korea*** (https://beyondparallel.csis.org/tag/mining-north-korea/)
  North Korea's rare earth mining operations.

Contents

Executive Summary[1]

- The Pyongsan Uranium Concentrate Plant represents a critical component of North Korea's nuclear research and weapons development programs. Since the closure of the Pakchon Pilot Uranium Concentrate Facility in the mid-1990s, it is the only verified producer of uranium concentrate (yellowcake) in the country.
- The plant's importance can be seen by its consistent receipt of scarce resources to maintain, refurbish, or modernize it since at least 2003.
- Although the International Atomic Energy Agency (IAEA) has not been able to visit the Pyongsan Uranium Concentrate Plant since 1992, satellite imagery and open source material indicate that the plant is operational. They also indicate it has worked to a relatively steady production tempo suggesting that, barring unforeseen developments, the plant is highly likely to remain active for the foreseeable future.
- Indeed, expansion to the site's waste processing infrastructure suggests the site is being readied for increased yellowcake production.
- Given known North Korean industrial practices, observed waste storage practices, and health and safety concerns raised by defectors and outside observers, there are likely to be numerous health, safety, and environmental issues surrounding the operations (and any decommissioning efforts) at the Pyongsan Uranium Concentrate Plant and its related facilities.
- The dismantlement of the Pyongsan Uranium Concentrate Plant should be an essential component to any meaningful future "complete, verifiable, irreversible dismantlement" nuclear agreement between the United States and North Korea.

The Pyongsan Uranium Concentrate Plant (38.318369 N, 126.432360 E) is located in Pyongsan-gun (평산군, Pyongsan County), Hwangbuk (황북, North Hwanghae Province), approximately 100 kilometers southeast of the North Korean capital city of Pyongyang and 96 kilometers northwest of Seoul—the capital of South Korea. The plant is co-located with the uranium ore producing January Industrial Mine, which supplies the plant. Since the closure of the Pakchon Pilot Uranium Concentrate Facility (39.710361 125.568141) in the mid-1990s,[2] Pyongsan is the only verified producer of uranium oxide (yellowcake) in the country.[3] Although the information remains to be verified, various experts, defectors, and early South Korean sources estimate that the yellowcake produced by the plant contains 80 percent triuranium octoxide (U_3O_8) by weight—the normally accepted range for yellowcake purity is 70-90 percent.[4] According to Hans Blix, then-director general of the IAEA, North Korean personnel told him during his May 1992 familiarization visit that the plant also produces other products including vanadium, nickel, molybdenum and radium—all likely in small quantities—in addition to uranium.[5]

After converting uranium ore to yellowcake on-site, the yellowcake is shipped to the Yongbyon Nuclear Research Facility. Here, the yellowcake is further processed. According to early-1990s testimony, including that by Chon Chi-pu (described in a 1992 KCTV interview as the chief engineer of Yongbyon Fuel Rod Fabrication Plant) and Kim Tae-ho (a defector who worked on a "wastewater disposal team" at Pyongsan), Pyongsan's yellowcake is used to produce fuel assemblies for the 5MWe and IRT reactors.[6] Today, it appears that Pyongsan also provides the feedstock for the uranium hexafluoride (UF_6) that feeds the Yongbyon's Centrifuge Enrichment Plant.

As the country's sole confirmed operational producer of yellowcake, Pyongsan occupies a critical role in North Korea's nuclear research and weapons programs.[7] Although it is unclear if the subject was raised during the abortive Hanoi Summit of February 27-28, 2019, the dismantlement of the Pyongsan Uranium Concentrate Plant—and the detailed accounting and safeguarding of its produced material—should be considered an essential component to any meaningful future "complete, verifiable, irreversible dismantlement" nuclear agreement between the United States and North Korea.

Slide 03: Overview Image of the Pyongsan Uranium Concentrate Plant, Tailings Pond, and January Industrial Mine (mining complex) - June 13, 2020 (Copyright © 2020 by Airbus)

For this report, during the past year, CSIS analyzed 100+ medium- and high-resolution declassified and commercial satellite images of the Pyongsan Uranium Concentrate Plant, its associated activities and local environs focusing upon changes in existing infrastructure and new developments. The analysis of these images was combined with interview data from regional, national and international experts, defectors, and open source information. It is believed that this resulting report provides a new and unique look into the subject and is one of the most comprehensive collections of unclassified information and satellite imagery presently available. Readers are cautioned, however, that due to the extremely closed nature of society within North Korea and their active programs of camouflage, concealment, and deception, accuracy in any work dealing with the country's nuclear program is a matter of relatives. Regardless, it is the authors' hope that this paper provides a firm foundation upon which further study of the subject may be developed. CSIS intends to periodically update this report as new information and satellite imagery becomes available.

1 | Facility Description

Satellite imagery locates the Pyongsan Uranium Concentrate Plant approximately 3.9 kilometers southeast of the center of the small city of Pyongsan on the north side of a bend in the Nam-chon (i.e., Nam Stream). Taken as a whole, the Pyongsan site can be divided into two essential areas: operations of the Pyongsan Uranium Concentrate Plant itself and mining operations at the January Industrial Mine, located 600-meters to the northeast on the southern slopes of Majang-san (마장산, Majang Mountain).

The Pyongsan Uranium Concentrate Plant

According to the World Nuclear Association, the process to make yellowcake is as follows:

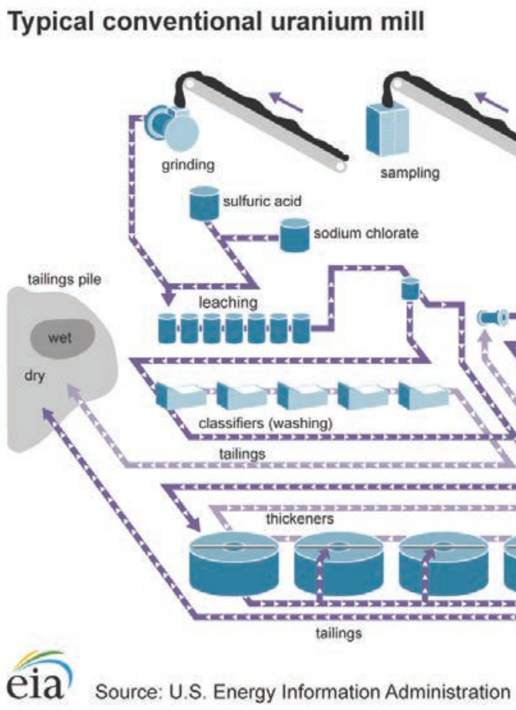
> After mining, [uranium] ore is crushed in a mill, where water is added to produce a slurry of fine ore particles and other materials. The slurry is leached with sulfuric acid or an alkaline solution to dissolve the uranium, leaving the remaining rock and other minerals undissolved . . . The uranium solution from the mines is then separated, filtered and dried to produce uranium oxide concentrate, often referred to as "yellowcake."[8]

In satellite imagery, many of these processes will provide a unique signature that allows their ready identification (for example, the tailings pond). For others, identification is more challenging, but initial functions identified here have been assessed on factors such as required production processes, building formats, and site flow, as well as other inferences.

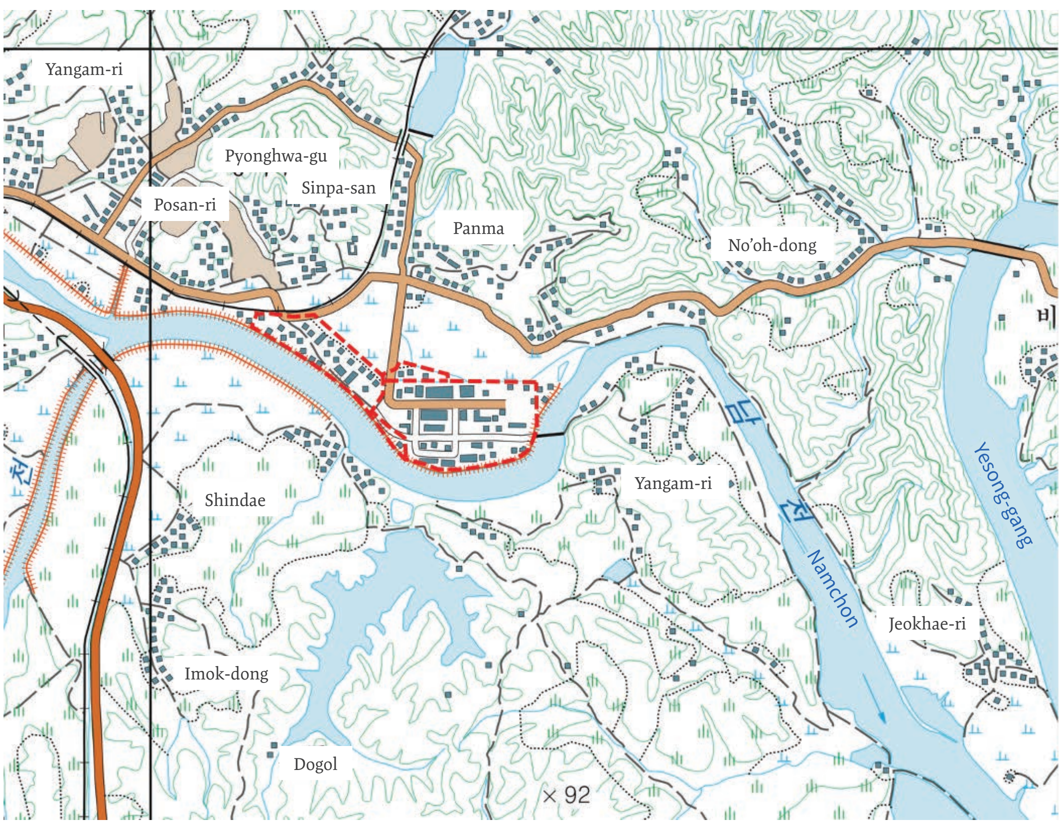
Geographically, the Pyongsan Uranium Concentrate Plant can be broken down into three major functional components: the main plant, support areas, and tailings pond. The adjacent mining complex is described separately (below).

MAIN FACILITY

Excluding the nearby mining complex, the Pyongsan Uranium Concentrate Plant encompasses a total of approximately 37.6 hectares: the main plant currently encompasses approximately 24.2 hectares, the north support area approximately 1.1 hectares, and the west support area 12.3 hectares. If the plant's tailing pond—approximately 33.7 hectares—is included, the entire Pyongsan Uranium Concentrate Plant operation encompasses approximately 71.3 hectares.[9] This compares to 38.6 hectares for the Pakchon Pilot Uranium Concentrate Plant.



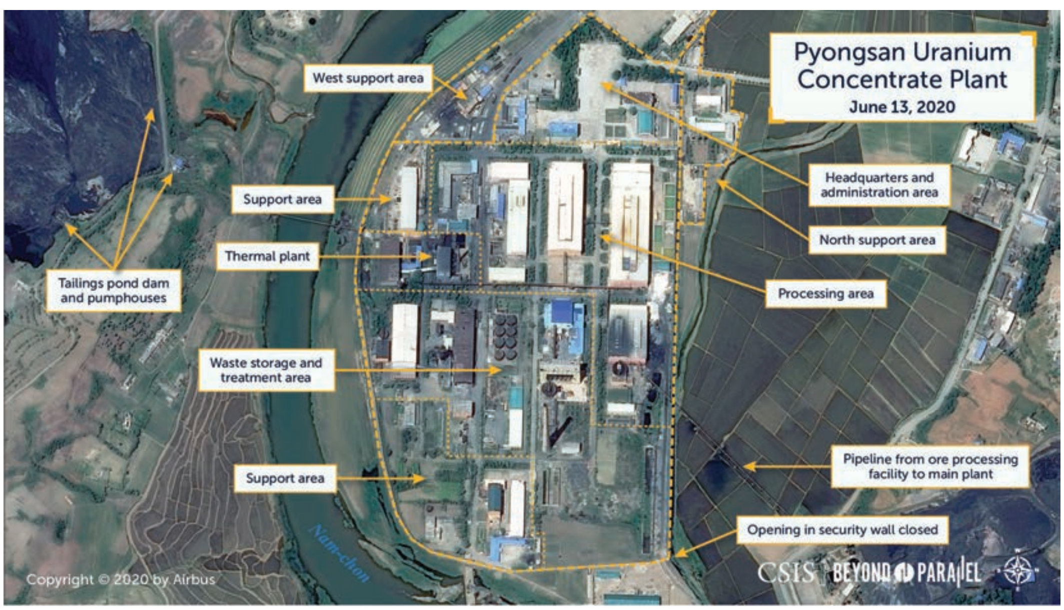
A conventional uranium concentrate plant (courtesy of U.S. Energy Information Agency)[10]



Topographic map of the Pyongsan Uranium Concentrate Plant area.

Slide 04: Overview Image of the main facility and support areas - June 13, 2020 (Copyright © 2020 by Airbus)

Most of the main plant's 24.2 hectares are enclosed within a security wall and contain approximately 100 structures. Until more detailed information becomes available, CSIS has provisionally separated the main plant into six functional areas: headquarters and administration, processing, waste storage and treatment, thermal plant, support, and railyard.[11]



Slide 05: The main plant and north support area - June 13, 2020 (Copyright © 2020 by Airbus)

The headquarters and administration area is located on the northwest side of the main plant. It controls access to the main plant and consists of approximately 24 structures (including four greenhouses), a parking/parade area, and several monuments. Aside from typical headquarters and administration functions, this area likely houses security and engineering offices. With the exception of some minor construction, this area has remained relatively unchanged since 2011. As is typical of large industrial facilities in North Korea, grain is sometimes laid out to dry in the parking/parade area.

The processing area occupies the western section of the main plant and consists of approximately 16 structures. Until more detailed information becomes available, CSIS provisionally identifies the four largest as sampling and grinding, leaching and classifying, solvent extraction and precipitation, and yellowcake production and packaging buildings. Additionally, there are a number of smaller support buildings and ten large above-ground, open-air settling tanks adjacent to the leaching and classifying building (often only six are typically visible in satellite imagery since the building blocks the view of the remaining four, two of which are very small). The general layout of this area has remained relatively unchanged since the first commercial satellite image became available in 2003. There have, however, been numerous minor changes to the existing infrastructure due to the long-term maintenance and modernization project that began in 2007-2009, including a few minor infrastructure additions (e.g., the construction of a second rail-served loading/unloading building).

The waste storage and treatment area occupies the center and northeast sections of the plant. It consists of approximately 37 structures including a rotary kiln facility (with a 4-meter-diameter by 54-meter-long rotary kiln, incinerator buildings, and a 126-meter-tall stack for waste incineration), wastewater treatment building (Plant No. 404), rail-served waste storage building, small incinerator/boiler building with a cooling/condensation stack, two greenhouses, eight 12-meter-diameter fixed-top reagent/chemical storage tanks, three smaller tanks, a motor vehicle maintenance and storage facility, and a number of smaller buildings and two small silos/stacks.[12] Here, liquid and solid waste is separated into different streams for disposal, including incineration. The plant's railyard (see below) terminates in this area. Overall, the central rotary kiln facility and wastewater treatment area have undergone numerous and significant changes since 2003. The most notable during the past ten years have been:

- The modification of the large northeast open-air waste storage facility to again accept liquid and solid waste from the sampling and grinding building. Most recently, however, the northern half of the facility was either removed or covered and a road built on top of it. This road leads from the sampling and grinding building to an opening made in the east security wall. Concurrent with this, what appears to be road base was laid leading east from this opening in the security wall to an existing road. Subsequently, the opening in the east security wall was closed.
- The reroofing of numerous buildings and the completion of the roof on the rail-served waste storage building.
- The construction and subsequent removal of a facility with 10 open-air settling tanks and a support building.
- Ongoing work that may be centered upon reactivation of the rotary kiln—a proven technology for the incineration of various industrial wastes.[13]
- Construction of two additional 12-meter fixed-top reagent/chemical storage tanks (for a current total of eight).

- The removal of one of two cooling/condensing stacks on the small incinerator/boiler building on the south side of the waste storage building, and the subsequent addition of two smaller double-wall silos/stacks south of the building.

Taken as a whole, these changes indicate a restructuring of the waste disposal processes within the plant—a potential precursor of increased yellowcake production output going forward.

In his 2006 book, the North Korean defector Kim Tae-ho describes the organization of the plant:

> The chemical factory, the nucleus of the Namch'on Chemical Complex, was built on the bank of Namch'on River in P'yonghwa-ri, with a 400,000-ton processing capability. It was made up of 12 sections, such as uranium ore crushing workshop, precipitation workshop, extraction workshop, vanadium workshop, wastewater treatment workshop, heat control workshop, exclusive line workshop, official business workshop, life's essential goods workshop, and so on.[14]

Located on the south side of the plant, the coal-fired thermal plant provides steam—and potentially emergency electricity—to many of the main plant's buildings. It has undergone significant changes (e.g., the removal of three of four conveyor belt lines, construction of new support buildings, etc.) over the years. The thermal plant now consists of a rail-served coal storage shed with adjacent coal storage pens (likely idle), a boiler building (connected to the coal storage shed by a single conveyor belt), a 56-meter-high stack, and several small buildings and storage tanks.

The remaining areas within the main plant are being used for miscellaneous support and consists of approximately 16 structures (including three greenhouses) and small storage tanks. These areas have seen minor changes since 2003.

SUPPORT AREAS

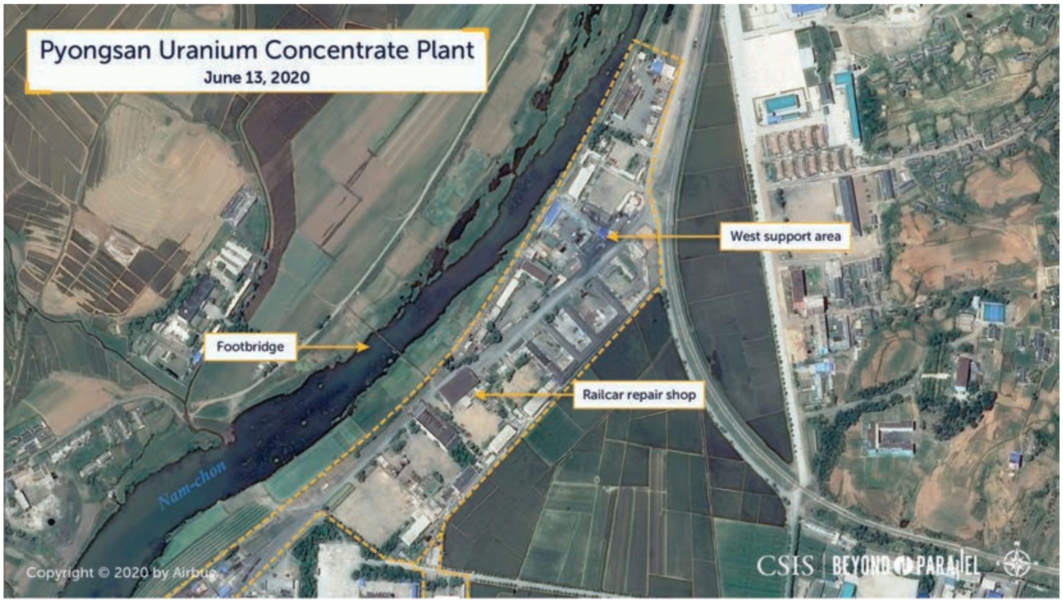
There are two dedicated support areas immediately adjacent to the Pyongsan Uranium Concentrate Plant—one on the north side and the other on the west side. Both of these were constructed during the mid- to late 1980s along with the main plant.

The north support area consists of approximately 12 buildings (including two greenhouses), an electrical substation that feeds the main plant, and the main entrance and checkpoint for the plant. Little has changed within this area since the 2010-2011 construction of two small buildings on either side of the entrance road and one on the north side of the area.

The west support area consists of approximately 75 buildings (including 12 greenhouses), vehicle maintenance and repair facilities, parts yards, open and covered storage buildings, a small foundry, and a single-track industrial spur line with small locomotive and railcar maintenance and repair facilities. Since 2003, this area has undergone minor changes that are typical of such industrial support areas elsewhere in North Korea.

RAILYARD

The Pyongsan Uranium Concentrate Plant is connected to the national rail system by a dedicated single-track industrial spur line that connects to the Pyongsan rail station and clarification yard (approximately 3.5 kilometers to the northwest). The plant and west support area share a small railyard that has dedicated but small locomotive and railcar servicing facilities and terminates within the plant in a three-track stub yard and a single spur line feeding the plant's coal storage shed.



Slide 06: Overview of the west support area - June 13, 2020 (Copyright © 2020 by Airbus)

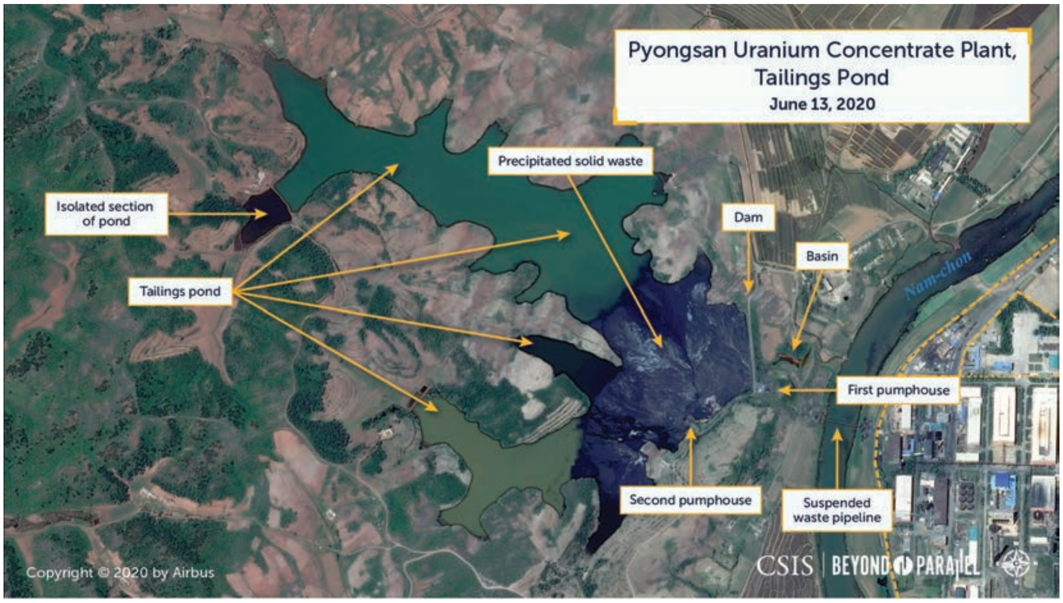
Rail cars—primarily tank cars and gondolas, but sometimes box cars—have been present at the rail facilities serving the Pyongsan Uranium Concentrate Plant in all imagery analyzed for this report since 2003. The number of railcars present typically vary from 12 to 20 but range from 2 to 27. One or two diesel locomotives (switchers) are generally present to position the railcars around the plant and western support area.

The internal layout of the Pyongsan Uranium Concentrate Plant, observed rail movements, and known North Korea railroad operating procedures indicate that the rail operations for the plant are almost exclusively inbound for coal, chemicals, and supplies and outbound for coal ash, waste chemicals, and other waste products. The outbound shipment of yellowcake is also likely undertaken by rail due to the distance to the Yongbyon nuclear facilities. The outbound shipment of the small quantities of vanadium, nickel, and other products may be undertaken by either rail or truck.

At present, there is neither evidence of the inbound rail shipment of uranium-bearing ore nor the means to efficiently handle any such rail shipments within the plant. However, as the country's only confirmed uranium concentrate plant, ore from other mines would logically be processed here.

TAILINGS POND

Located to the south of the main plant and across the Nam-chon is a large tailings pond (more accurately a lake) impounded by an approximately 200-meter-long dam. A slurry of tailings and waste is pumped from the wastewater treatment building in the main plant to the tailings pond via an approximately 380-meter-long pipeline. The pipeline is partially suspended from two towers over the Nam-chon. At the northeast corner of the dam, a pumphouse then distributes the slurry into the tailings pond via moveable pipes laid on the surface of the sediment or to a second pumphouse—also via pipes laid on the surface of the sediment. This second pumphouse then distributes the slurry further south into the eastern bays of the tailings pond.



Slide 07: Overview of the tailings pond - June 13, 2020 (Copyright © 2020 by Airbus)

Slide 08: The suspended waste pipe connecting the main plant to the tailings pond - June 13, 2020 (Copyright © 2020 by Airbus)

Although satellite imagery since 2003 clearly shows that the solid waste in the pond has increased steadily over the years, an accurate volumetric measurement of the amount of solid waste sediment is not currently practical as detailed and reliable information of the valley's topography prior to construction of the pond is not available. What is possible, however, is the measurement of the visible footprints of both the pond itself and the accumulated solid waste sediment over the years.

When taking into consideration the deposited sediment, seasonality, rainfall, and snowmelt, the footprint of the tailings pond has increased from approximately 23.8 hectares in January 2003 to approximately 33.9 hectares in June 2020. During the same period, the visible footprint of the deposited solid waste increased from approximately 1.1 hectares in January 2003 to approximately 11.68 hectares in June 2020.[15] These measurements do not include a small section of the southwest bay near Dogol (도골). This section of the pond has been separated from the main pond by earthen dams and over the years has varied significantly in size and shape from approximately 0.6 to 1.4 hectares. The exact purpose of this small section of the pond is unclear.

Although these initial gross order-of-magnitude measurements require further research, they indicate that, despite occasional fluctuations due to the demands of the nuclear program and maintenance and modernization projects, production has continued at a relatively steady tempo from 2003 until the present.

Mining Complex (January Industrial Mine)

Adjacent to the Pyongsan Uranium Concentrate Plant is a mining complex known variously as the January Industrial Mine,[16] or the Pyongsan uranium mine. The complex itself is located on the southern slopes of Majang-san (마장산, Majang Mountain), beginning approximately 600 meters to the northeast of the plant.

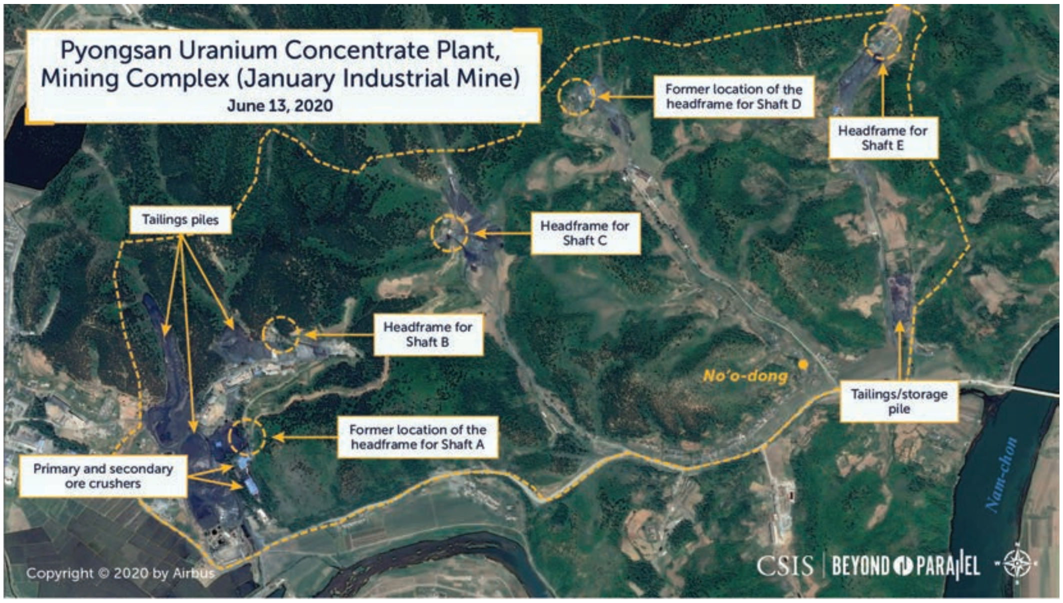
The mining complex is distributed within an area of approximately 235 hectares. The complex consists of five vertical shaft mines (of which three appear to be currently operational), tailings piles, an ore processing facility, and a variety of smaller support activities. The ore processing facility consists of primary and secondary crushers, filtering and grinding buildings, an ore preparation building, and an approximately 515-meter-long pipeline to transport a slurry of crushed uranium-bearing ore to the Pyongsan Uranium Concentrate Plant.

Kim Tae-ho describes three classes of uranium bearing ores within North Korea. Of which, Ore No. 3 appears to be primarily used at the Pyongsan Uranium Concentrate Plant:

> Uranium ores developed in North Korea are divided between Ore No. 2 and Ore No. 3. Ore No. 2 is limestone. It had been mined in the Sunchon region in South Pyongan Province but, by 1987, it had been exhausted. As for Ore No. 3, it is ore mined in the Kumchon region in Pyongsan, [North] Hwanghae Province. The scope and volume of the deposit is said to be substantial. In Ore No. 3, mainly composed of low-heat coal [lignite?], rare metals such as uranium, 0.8 percent; vanadium, 1.4 percent; and nickel, molybdenum, and radium are contained.[17]

A summary of the more significant changes observed within the mining complex in satellite imagery from 2003 until 2020 includes the following:

- Shaft A began operations during the early-1980s and continued until early-2015 when the headframe (i.e., the frame structure above the mine shaft used to raise and lower workers, equipment, and ore) was removed. Although Shaft A is no longer operational, the tailings piles below the shaft—which also serve the ore processing facility—have steadily increased in size.



Slide 09: Overview of the mining complex (January Industrial Mine) - June 13, 2020 (Copyright © 2020 by Airbus)

- 2003-2014: Slow growth spreading out below the shaft and ore processing facility.
- 2014-2017: Rapid growth extending the tailings pile up the small valley to the north. After the closure of Shaft A, this growth has come from the processing of ore from the other mine shafts.
- 2017-present: Steady growth increasing the size of the tailings piles below the shaft and ore processing facility and, most recently, extending a second level of tailings up the valley to the north.
- Shovels and trucks are often observed working on the tailings piles across most satellite images.

▪ Shaft B also began operations during the early-1980s and remained in operation until about late-2013 when it appears to have suspended operations. During 2003-2006, grading activity on the west side of the tailings pile suggested that there may have been a new mine shaft located here. Close examination of multiple satellite images, however, shows no evidence of either a vertical or horizontal mine shaft at this location. The activity observed was likely the result of grading or dragline operations to more completely fill the lower end of the small valley in which the tailings pile was located. As of April 2020, the Shaft B headframe remains in place, although the operations are either suspended or at low levels.

▪ Shaft C appears to have begun operations during the late-1980s or early-1990s and continued until sometime between 2009-2011. At that time, operations appear to have dramatically decreased to minimal levels. The headframe, however, remained in place. During 2015-2016, a new road was built connecting Shaft C more directly to the ore processing facility. Since that time, minor but continued activity has been observed on the tailings pile southeast of the headframe as it has gradually expanded. As of April 2020, Shaft C appears to be operational.

- Shaft D began operations during the late-1980s or early-1990s and continued until sometime between 2007-2011. The headframe was then removed between early- to mid-September 2015.

- During 2006, some very minor tailings were noted approximately 175 meters northeast of Shaft D. These tailings have not changed since that time and are now partially covered with vegetation. While the exact source and purpose of these tailings are unknown, they may have been related to some minor exploratory or artisanal mining.

- Shaft E began operations during the late-1980s or early-1990s and continued until sometime between August 2010 and March 2011. The headframe was partially removed sometime between 2011 and 2013 and completely removed by July 2017. During July 2018, a new headframe was observed over the shaft. Subsequent imagery shows changes to the tailings pile and indications of road traffic.

- Sometime after the establishment of Shaft E, a large tailings/storage pile was established approximately 625 meters to the south. Satellite imagery from 2003 until 2010 shows that this tailings pile remained relatively untouched. In 2011, however, small sections of it were excavated. The pile then remained unchanged until late 2019 when major portions were excavated. The reasons for this excavation are unknown; however, activity observed here may be related to efforts to recover small quantities of uranium or other minerals.[18]

Aside from minor changes typical of mining operations throughout North Korea (e.g., construction and razing of small support buildings, greenhouses, propaganda placards, etc.), no significant changes have been observed among the primary and secondary crushers, filtering and grinding buildings, ore preparation, and support buildings.

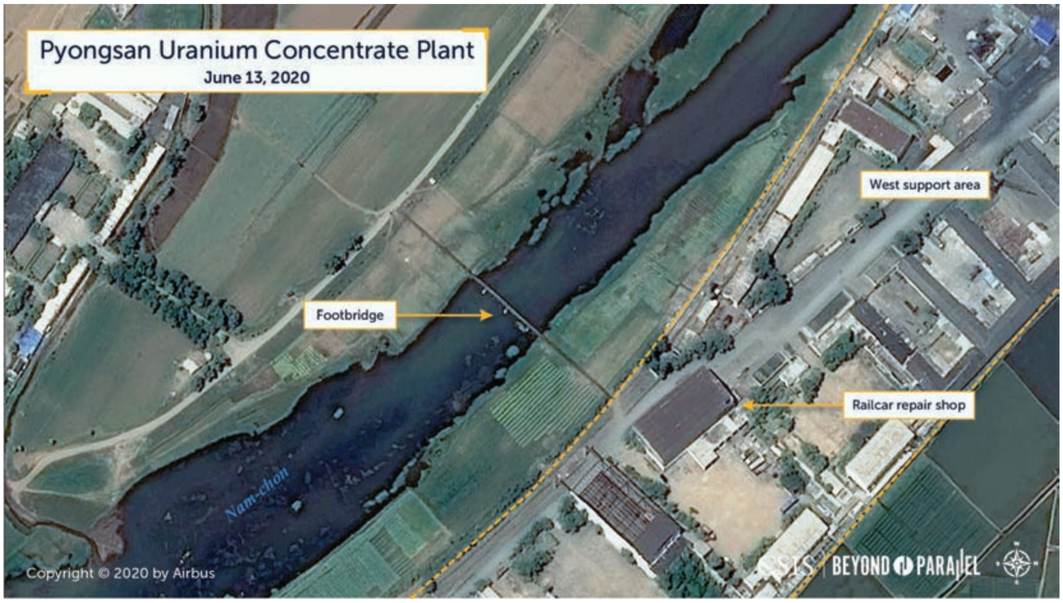
Miscellaneous Infrastructure

A 150-meter-long footbridge for workers over the Nam-chon connects the west support area to the village of Pyonghwa-ri (평화리) and has been present in all satellite images since January 23, 2003.

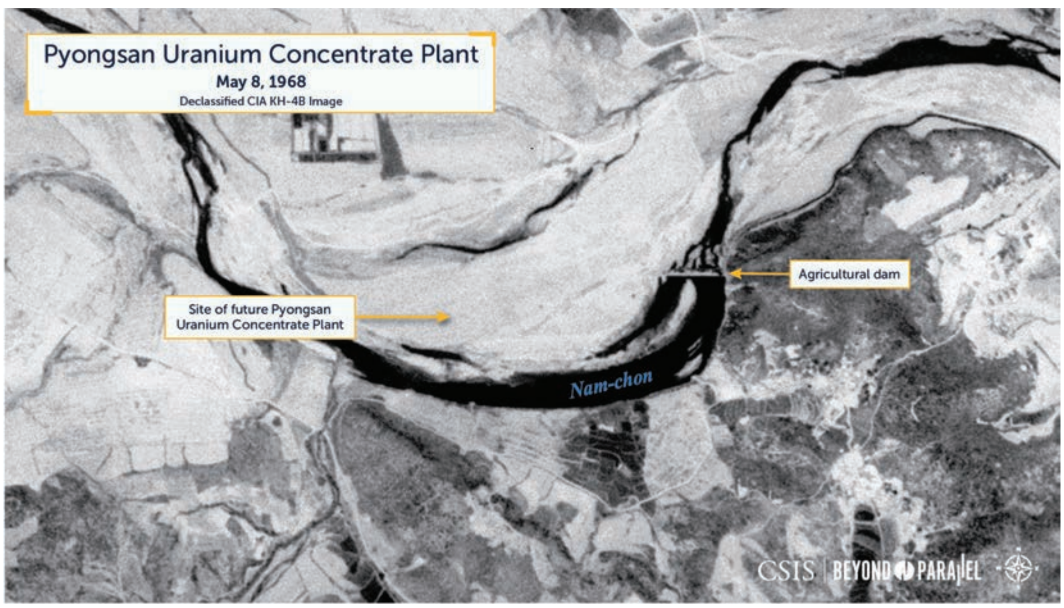
Located immediately east of the Pyongsan Uranium Concentrate Plant is a 150-meter-long dam across the Nam-chon. This dam has been in place since at least the mid-1960s and has undergone occasional repairs from 2003 to 2020. The dam provides irrigation water to local farms and appears to have a small hydroelectric power plant for local usage. It does not appear to directly support the Pyongsan Uranium Concentrate Plant.

Approximately 300-meters downstream of the dam, another footbridge over the Nam-chon connected the mining complex to the area around the village of Yangam-ni (양암리). The footbridge is present in imagery from 2003 until 2016, when it was demolished and replaced by a footbridge only 140-meters downstream of the dam. This later footbridge was subsequently replaced in 2018 by a road bridge 170-meters downstream of the dam.

A winter ford across the Nam-chon was sometimes seen in use 500-meters downstream of the dam from 2003 until 2018, when the road bridge was built. It also connected the area around the village of Yangam-ni to the mining complex.



Slide 10: The footbridge connecting the village of Pyonghwa-ri to the west support area - June 13, 2020 (Copyright © 2020 by Airbus)



Slide 11: A view of the Nam-chon dam as it existed on May 8, 1968. Declassified KH-4B image (CIA)

Slide 12: The Nam-chon dam and road bridge east of the main plant - June 13, 2020 (Copyright © 2020 by Airbus)

At a macro level, the Pyongsan Uranium Concentrate Plant is connected to the national power grid through the substation in the north support area on the northwest corner of the plant. It is served by both paved roads and the national railroad system through a dedicated industrial spur line that connects to the Pyongsan rail station and classification yard. The nearest operational air facility is the Nunchon-ni Air Base, which is 29 kilometers to the southwest.[19] There are five air defense artillery bases and a number of small military and paramilitary barracks within a 5-kilometer radius of the plant. Additionally, the plant is covered by eight S-75 (SA-2 Guideline) and two S-200 (SA-5 Gammon) surface-to-air missile bases.

Organization and Security Measures

The control and subordination of the Pyongsan Uranium Concentrate Plant is challenging to percisely delineate. In May 1994, Kim Tae-ho, a defector who worked at the plant, stated in several press conferences that although the plant was managed by the Ministry of Atomic Energy Industry, it was under the direct control of the Second Economic Committee of the Korean Workers' Party's Machine Industry Department. Specifically, it was controlled by the Second Economic Committee's Fifth Machine Industry Bureau.[20] It is likely that the Academy of National Defense Sciences' Nuclear Bureau and the State Academy of Sciences and its Hamhung Branch support the research and operations at the plant. The Ministry of Mining Industry (formerly Ministry of Extractive Industries) is believed to operate the associated January Industrial Mine complex. However, it is likely that the mining complex itself is also managed and under the direct control of the Fifth Machine Industry Bureau.[21]

Due to its vital position within the nation's nuclear program, security for the facility (and the associated mining complex) is provided by some combination of the Ministry of People's Security, Ministry of State Security, and the Guard Command—all directly subordinate to Kim Jong-un.[22]

Workers and Staff

The number of workers, staff, and scientists employed at the Pyongsan Uranium Concentrate Plant and the associated uranium mining complex is unknown. Unfortunately, defector reports and outside estimates concerning these numbers have varied considerably since the mid-1990s. For example, Kim Tae-ho, a defector who worked at the plant, stated in 1994 that the plant employed approximately 8,000 workers in the early 1990s.[23] Ten years later, in November 2004, TV Asahi reported that the Pyongsan Uranium Concentrate Plant had "some 3,000 employees, of which 75 percent are military personnel."[24] This was again contradicted by a 2009 report in which South Korean lawmaker Lee Mi-kyung, citing a Ministry of National Unification report, stated that North Korea reportedly employs "3,000 workers throughout the country's nuclear facilities, including some 200 scientists and key research personnel."[25] During 2013, a purported defector allegedly familiar with mining operations at Pyongsan stated that "the large uranium mine has approximately 3,000 workers."[26]

Housing, education, and social facilities for workers, staff, and scientists employed at the plant are located among the small towns (e.g., Chwi-gol [취골], No-o-dong [노오동], Panma [판마], Posal-li [보산리], Pyonghwa-ri [평화리], Yangam-ni [양암리], etc.) in the immediate vicinity and, of course, in the small city of Pyongsan (평산). Typical of these is the town of Posal-li, 900 meters northwest of the plant, that has the obligatory memorials to the Kim's, several apartment complexes, at least one primary/secondary school, several colleges or research institutes, and more.

Health and Environmental Issues

For at least 25 years there have been occasional open source reports concerning health, safety, and environmental issues at the Pyongsan Uranium Concentrate Plant specifically, and more generally within North Korea's nuclear program.

One of the earlier reports concerning these issues at the Pyongsan Uranium Concentrate Plant dates to 1994 when a South Korean report indicated that "many of the workers there are exposed to radioactivity, complaining of vocational diseases such as liver ailment, depilation and leucosis."[27] Similar reports have appeared since then.[28] In February 2013, a purported defector stated that "the workers from the uranium mine in Pyongsan don't live as long as most people. It's not only the miners' children who have birth defects, but also the children born to Party secretaries in the region."[29] The same defector stated that the "miners there are apparently exposed to radiation with minimal protection."[30]

The following year, Shin Chang-hoon, a research fellow at the Asan Institute in Seoul, claimed that workers at both the Pyongsan Uranium Concentrate Plant and the nearby uranium mines were exposed to heavy levels of radon, worked seven hours a day wearing just basic dust masks, and that 60 percent of female workers were suffering from infertility.[31] These allegations mirror similar ones made concerning workers and researchers at Yongbyon and civilians in the Punggye-ri area. In July 2018, the Database Center for North Korean Human Rights (NKDB) reported: "We have obtained testimony from those who have suffered health problems at the . . . uranium mine in Pyongsan County, North Hwanghae Province . . . The problems range from muscle wastage and chronic headaches to pediatric lymphoma, birth deformities, and even death."[32]

However, due to the lack of access to Pyongsan, Yongbyon, and Punggye-ri, the accuracy of all these reports remains to be verified.

Typical safety equipment used by North Korean miners (Rodong Sinmun)

In 2019, reports emerged concerning potential contamination of the Nam-chon from an alleged broken pipe at the plant leaking a “black sludge” and leakage from the tailings pond seeping into the groundwater and the Nam-chon during 2017-2019.[33] Any contamination of the Nam-chon is of concern to South Korea as the river flows south into the Yesong-gang (Yesong River) across the Demilitarized Zone into the Han-gang (Han River) estuary and the Yellow Sea—a vital fishing area for both Koreas.

South Korean intelligence officials stated that the black substance seen “leaking” into the Nam-chon from the plant “could be simple sewage.”[34] However, as a result of public anxiety over these reports, the South Korean government undertook testing of the Han-gang, its estuary, and the west coast of South Korea.[35] No abnormal radiation was detected and all results were within acceptable parameters.[36]

Aside from these reports, there are three more likely, and potentially more serious, sources of concern regarding the leakage of waste byproducts from the Pyongsan Uranium Concentrate Plant:

- The presence of a cofferdam at the tailings pond dam from May 2009 through October 2013 suggests that the dam may have experienced some type of structural issue that could have resulted in waste leakage. While water is often seen pooled in the basin at the base of the dam, this may simply be rainwater settling in a low point rather than seepage from the dam.

- Presently, there are no declassified high-resolution satellite images available showing the construction of the tailings pond. Therefore, it is not possible to determine if measures such as the construction of a subsurface core trench under the dam, or if the pond was lined with a layer of clay or nonpermeable membrane covered with dirt, were undertaken during construction to prevent seepage into the local groundwater or the nearby Nam-chon. If the pond was not lined, which is not an unreasonable assumption, then the risk of local groundwater contamination could be significant.
- As the water level in the tailings pond has risen over the years due to the increased volume of waste, the exposed sides and beaches of the pond, which show no evidence of being lined, have also been gradually covered by wastewater. This represents a significant risk for the contamination of the local groundwater.

Known North Korean industrial practices, observed waste storage operations, and raised health and safety issues present serious concerns regarding industrial health, safety, and environmental issues at Pyongsan. Although these issues may present only a minor concern to the North Korean government, they should be considered of significant concern for any future nuclear diplomacy or a future unified Korea.

Of considerable concern is the health and well-being of the individuals who were exposed to radioactive or hazardous chemicals while excavating ditches or moving pipes on the precipitated waste in the tailings pond. The hazards of working with and around the waste from uranium mining and milling are well known and are attested to by numerous nuclear and health-related organizations around the world. For example, the U.S. Environmental Protection Agency has stated that "If not managed properly, mining waste and mill tailings can contaminate the environment . . . The tailings remain radioactive and contain hazardous chemicals from the recovery process."[37]

Wider Uranium Resources

Although not generally discussed with regards to the Pyongsan Uranium Concentrate Plant, some regional experts have speculated that the areas around Puram-ni (불암리) and Yongdok-san (영덕산) may have been sites for early uranium ore exploration or served as minor early sources of uranium ore.[38] These assertions remain to be verified.

The area around the village of Puram-ni lies 6.5 kilometers west-northwest of the Pyongsan Uranium Concentrate Plant. Located around the village are a number of open-pit mines and quarries that were connected up until the early 2000s by rail to the Pyongsan city rail facilities.

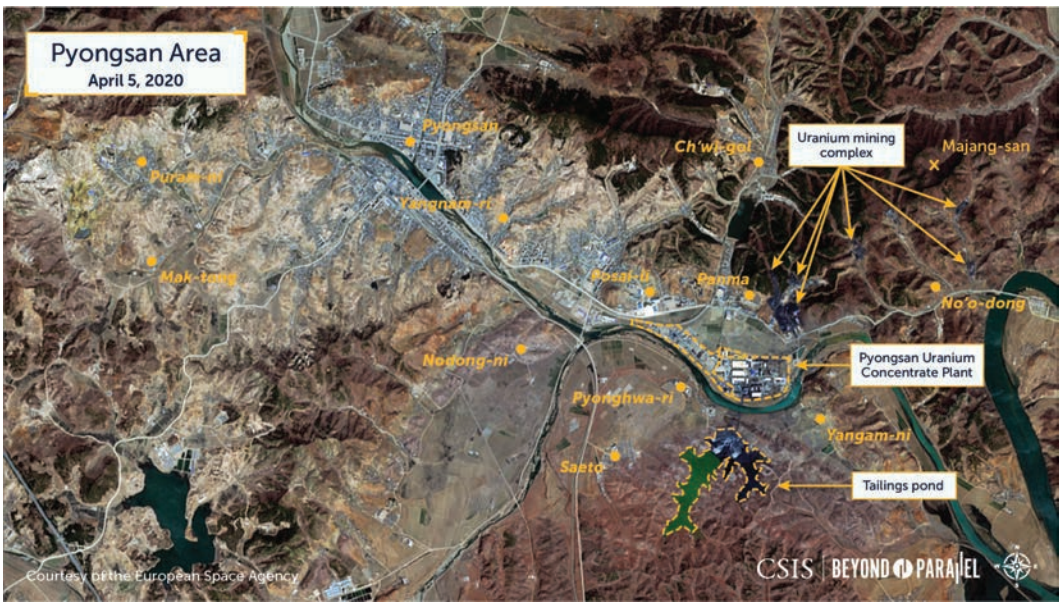
Yongdok-san (Yongdok Mountain) is located approximately 8.3 kilometers north-northwest of the Pyongsan Uranium Concentrate Plant. Spread out in the foothills around and on the slopes of Yongdok-san are a number of small surface and subsurface mines, some of which were initially developed during the same general time period as the early Pyongsan uranium mining complex. Only small-scale mining operations have been observed in both these areas since 2003.

Early concerns that the January Industrial Mine was itself a uranium concentrate plant appear to be misplaced. For example, a year after Hans Blix's visit to the Pyongsan plant, Yi Chang-kon, a researcher at South Korea's Atomic Energy Research Institute (KAERI), stated that there is “a mine in Pyongsan, Hwanghae Province, from which good quality uranium may be obtained. There are an exceptionally large number of buildings in this vicinity. For merely a mine, there is no need for such a large number of buildings. It is thus surmised that uranium reprocessing facilities may be there.”[39]

While not entirely accurate—mining complexes often do have large numbers of structures—the mining complex described here is likely the January Industrial Mine, which transports material to the Pyongsan plant via pipeline.

Yellowcake Production Estimates

The subjects of North Korean yellowcake production, concentrations of uranium in raw ore deposits, and available uranium reserves at the January Industrial Mine, among others, are ones of great confusion that are often compounded by a lack of reliable data and circular verification. Almost all open source references ultimately (and sometimes unknowingly) refer back to a few original sources—some of which are of limited value.[40]



Slide 13: Overview image showing locations of Puram-ni and Yongdok-san in relation to the Pyongsan Uranium Concentrate Plant, April 5, 2020 (Courtesy of the European Space Agency)

A pioneering effort to break through this morass and estimate uranium concentrate production at the Pyongsan Uranium Concentrate Plant, however, was undertaken by Melissa Hanham et al. during 2018. They did so by using satellite imagery, applying known research to estimate the number of counter-current decanters (CCD) at the plant, and applying some of the more consistent open source information concerning North Korean uranium concentrations. This effort produced a preliminary estimate of between 273 and 529 tons of uranium concentrate production per year depending upon concentrations and number of operating CCDs. This estimate serves as the basis for further investigation into the subject.[41]

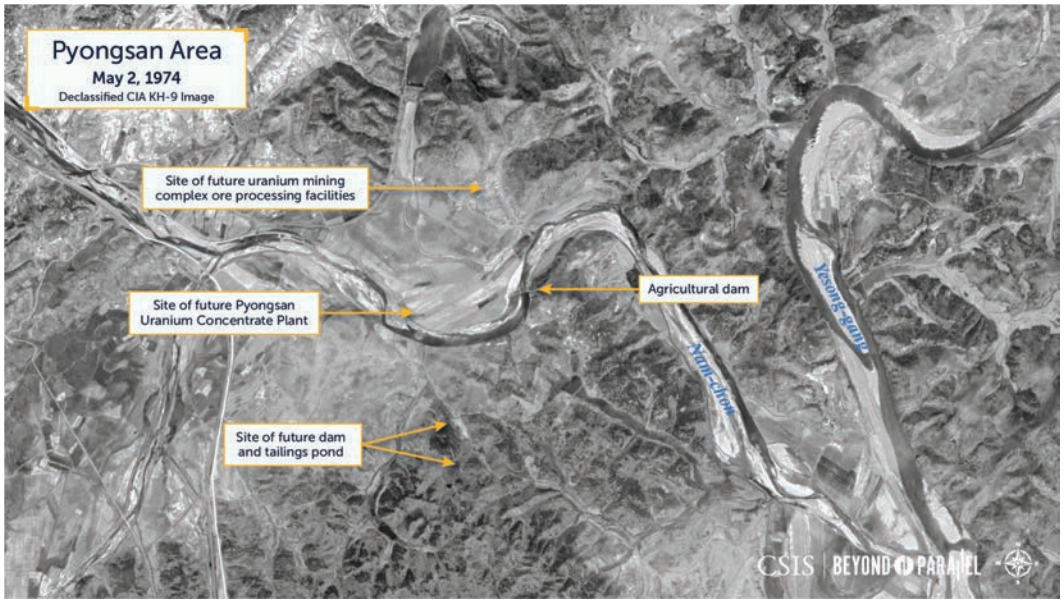
2 | Infrastructure Development

As noted above, many of these processes will provide a unique signature that allows their ready identification (for example, the tailings pond) in satellite imagery. For others, identification is more challenging, but initial functions identified here have been assessed on factors such as required production processes, building formats, and site flow, as well as other inferences.

1980s-2002

Even before North Korea began construction of its 5MWe nuclear reactor at Yongbyon in 1979, North Korean engineers understood that a dedicated uranium concentrate facility was required to produce the quantities of yellowcake necessary to operate such a reactor as neither the Soviet Union nor China were willing to provide it. To develop this capacity in the shortest timeframe, the decision was made to first convert an existing ore processing facility at Pakchon into a pilot uranium concentrate plant. Then, once the uranium concentrate process was validated, North Korean engineers would build an industrial-scale plant elsewhere. The site chosen for this latter facility was 3.9 kilometers southeast of the small city of Pyongsan (평산) that subsequently became the Pyongsan Uranium Concentrate Plant.[42] Due to the secrecy attached to the nuclear program, the new Pyongsan Uranium Concentrate Plant was assigned an internal cover designation of the Nam-chon Chemical Complex as it is located on the northern bank of the Nam-chon.[43] It is by this name that the facility is commonly referred to by North Koreans. This level of secrecy resulted in the area and facility being restricted to small numbers of North Koreans and closed to foreigners.[44] The sole known foreign exception to this restriction was Hans Blix's May 1992 familiarization trip.

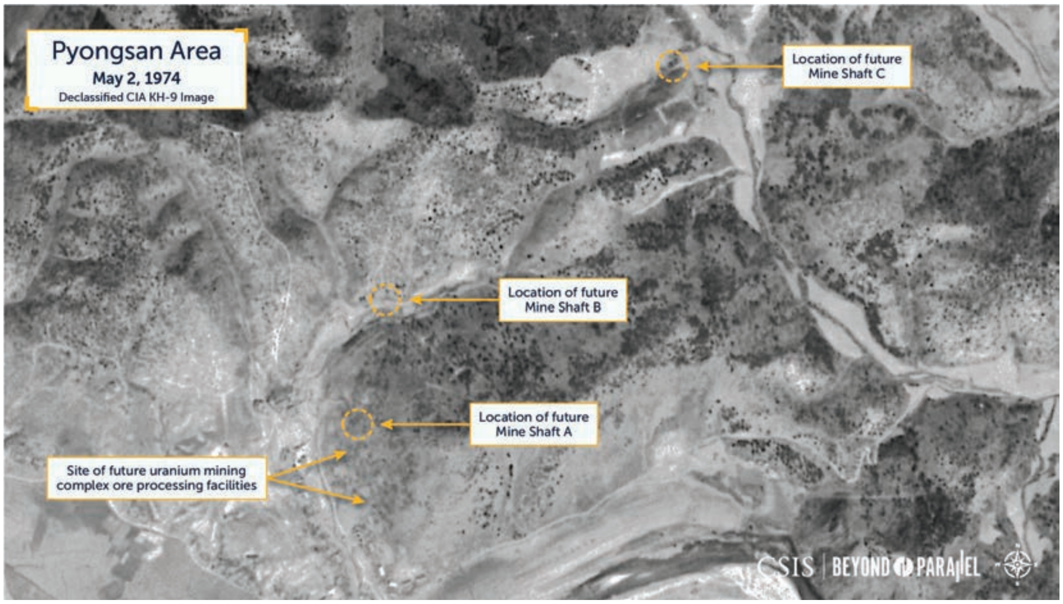
The primary reasons for locating the plant in the Pyongsan area appear to include the ready access to water and the presence of uranium-bearing ore in the area. A Russian source indicates that the mining of uranium in the Pyongsan and Sunchon regions preceded the construction of the 5MWe reactor, dating back to the 1960s.[45] According to a South Korean expert in 1990, the "natural uranium mine in a hilly area north of Pyongsan" was "producing quality ores with a 0.5 percent to 0.8 percent concentration" of uranium.[46]



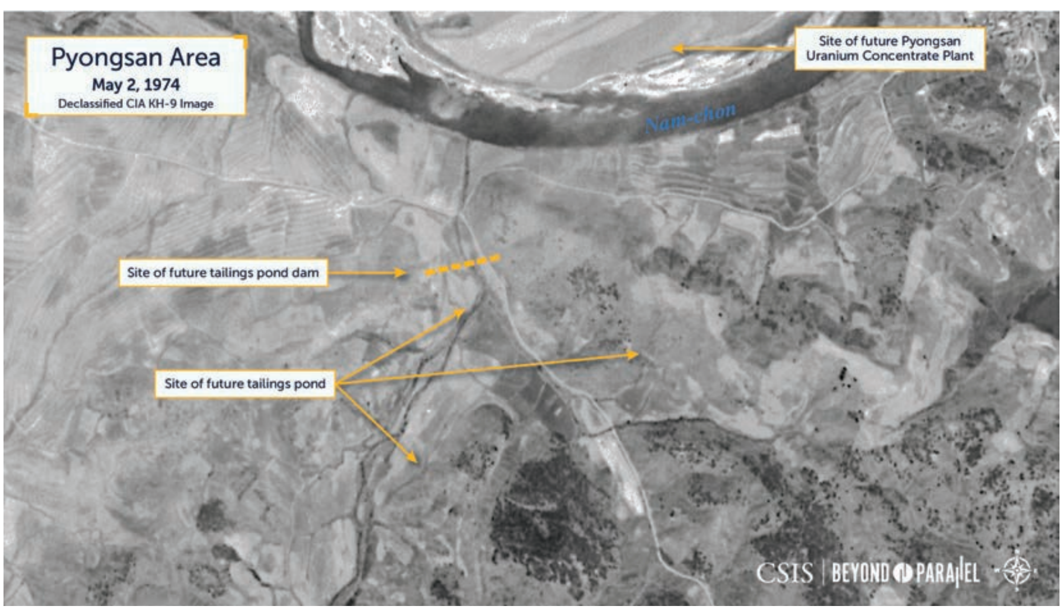
Slide 14: A declassified KH-9 satellite image from May 2, 1974, showing how the area where the Pyongsan Uranium Concentrate Plant would be built looked prior to its construction. (CIA)

Slide 15: A declassified KH-9 satellite image from May 2, 1974, showing a closeup of the area where the main plant would be built and the adjacent agricultural dam. (CIA)

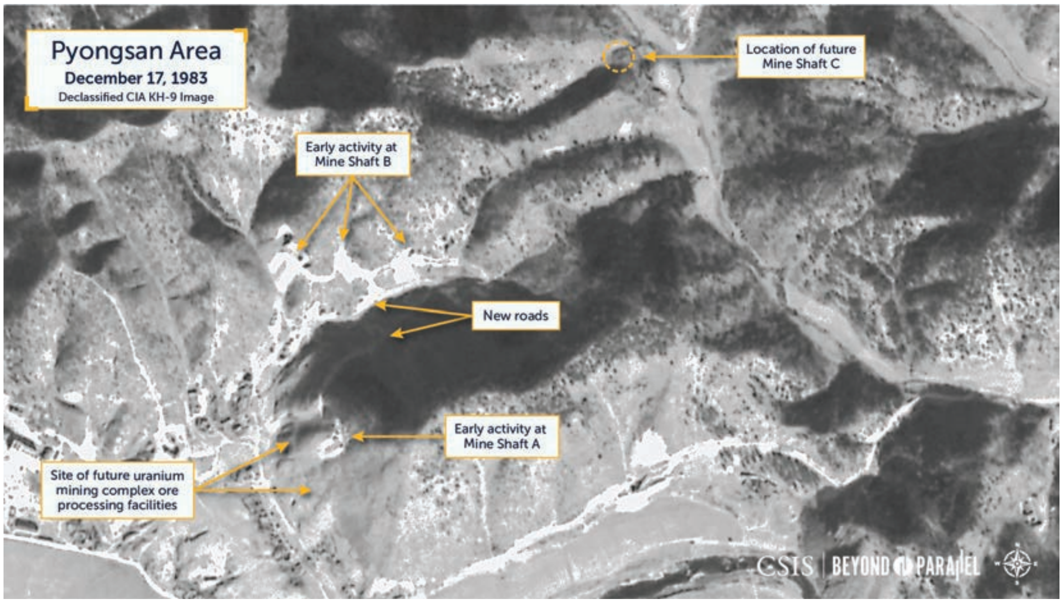
The uranium mining operations described above appear to refer to operations seen on the southern slopes of Majang-san (마장산, Majang Mountain). The complex now known as the January Industrial Mine begins approximately 600 meters to the northeast of the future plant. As best as can be determined from declassified satellite imagery, these uranium mining operations began sometime during the early 1980s. An image from September 17, 1983, shows new buildings in the area and ground scarring that would become the ore processing facility, new roads, and the first two (of what would eventually become five) vertical shaft mines. It is typical North Korean practice to name important mine shafts with a numerical designation and/or an honorific name (e.g., "No. 7 Hero Platoon Pit" or "Youth Hero Mine"). However, the names of these two mine shafts are unknown. They will be identified in this report for readability purposes as Shafts A and B, while subsequent shafts wil be identified as Shafts C through E. This image also shows the sites of the future Pyongsan Uranium Concentrate Plant and tailings pond as they looked approximately 11 years before construction began. At this time, the area consisted of agricultural fields and a preexisting dam (38.317457 N, 126.437333 E) on the Nam-chon, immediately east of the future plant.



Slide 16: A declassified KH-9 satellite image from May 2, 1974, showing a closeup of how the area of the ore processing facility and Shafts A, B, and C looked prior to construction. (CIA)

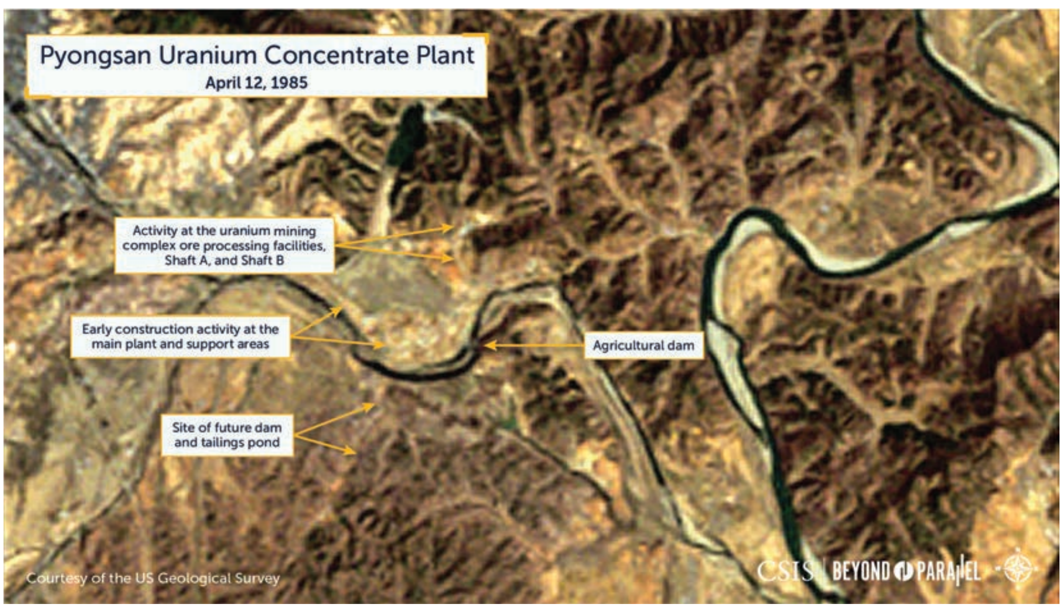


Slide 17: A declassified KH-9 satellite image from May 2, 1974, showing a closeup of where the tailings pond dam would be constructed. (CIA)



Slide 18: A close-up view from a declassified image from December 17, 1983, showing new buildings and roads had been built and initial scarring in the area of Shafts A and B. (CIA)

According to the Institute for National Unification's *Chronicle of the North Korean Nuclear Issue 1955-2009*, construction of the Pyongsan Uranium Concentrate Plant began on November 5, 1985. This assertion may be somewhat refined by a Landsat 5 image acquired on April 12, 1985, that appears to show ground scarring at the future sites of the Pyongsan Uranium Concentrate Plant, west support area, and the uranium mining complex.[47]



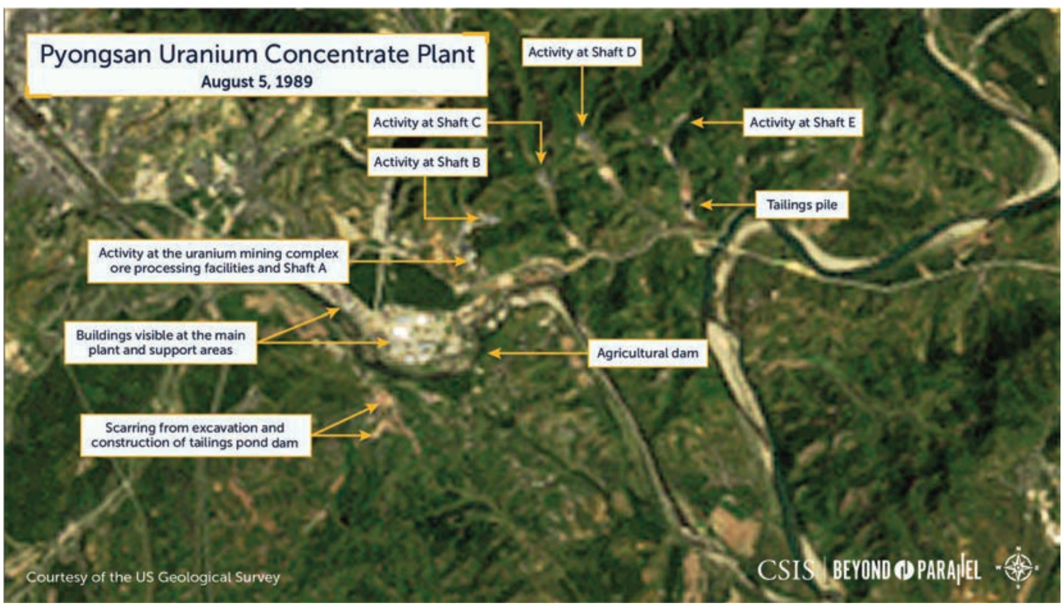
Slide 19: Although of medium resolution, a Landsat 5 image acquired on April 12, 1985, shows ground scarring from early construction activity at the main plant and mining complex. (USGS)

The primary responsibility for construction at Pyongsan was reportedly entrusted to the 47th and 49th Engineer Brigades of the Ministry of Public Security's 3rd Engineer Bureau. These and other units of the bureau are considered elite having specialized equipment and receiving a higher level of resources.[48] Although subordinate to the Ministry of Public Security, operational control of these units was apparently exercised by some combination of the ministry, Second Economic Committee, and the Ministry of Atomic Energy Industry.[49]

To dispose of tailings and waste products from the uranium concentrate and other processes, these same troops began construction of a tailings pond (38.313466 N, 126.430006 E) on the south side of the Nam-chon. The primary focus of this work was the construction of an approximately 200-meter-long dam (38.313516 N, 126.429942 E) across a small valley.[50]

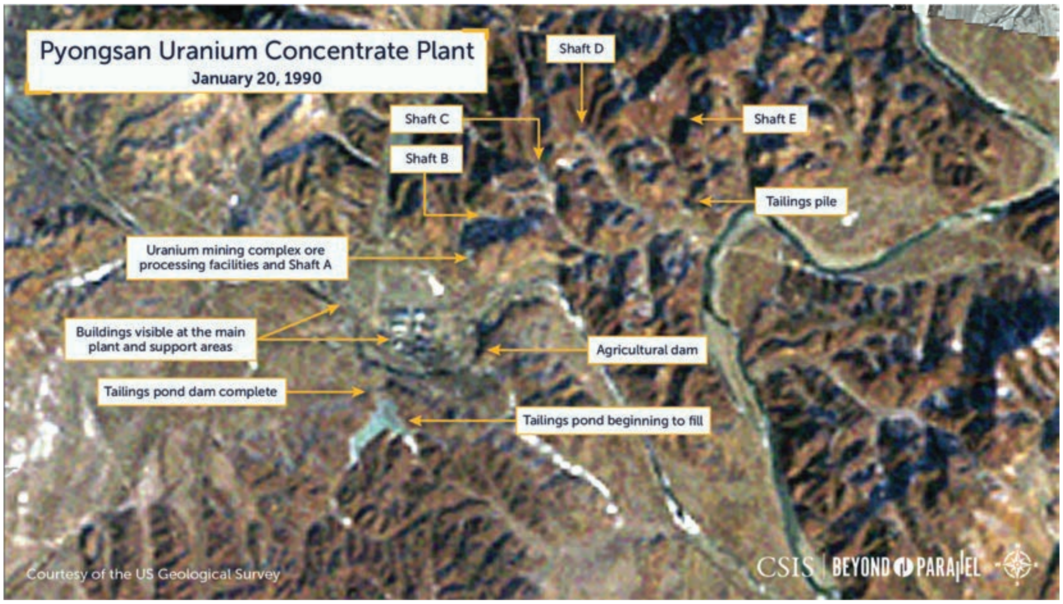
Concurrent with the construction of the plant and tailings pond, work began on building a railroad industrial spur line to the construction site for the new plant. Work also began on construction of a support area on the west side of the plant and expansion of the nearby mining operations into a mining complex that today includes five vertical shaft mines and support facilities.

Although of medium resolution, a Landsat 4 image acquired on August 5, 1989, shows buildings under construction within the main plant and west support area, construction activity at the mining complex's ore processing facilities, ground scarring at Shafts A-E, and the initial construction at the tailings pond dam.[51] Also visible are the first indications of a tailings pile being created south of Shaft E.



Slide 20: Although of medium resolution, a Landsat 4 image acquired on August 5, 1989, shows activity throughout the areas of the main plant, mining complex, and the new tailings pond. (USGS)

A medium-resolution Landsat 5 image acquired the following year on January 20, 1990, shows water starting to collect behind a completed tailings pond dam.[52] Due to a lack of high-resolution commercial or declassified satellite imagery during its construction, it is not possible to determine whether measures to prevent the seepage of waste water and byproducts into the local groundwater or the nearby Nam-chon were taken. Such measures would include installing a subsurface core trench under or in front of the dam or lining the pond with a layer of clay or nonpermeable membrane covered with dirt during construction.



Slide 21: Another medium resolution Landsat 5 image acquired on January 20, 1990, showing that the tailings pond dam had been completed and water was starting to collect behind it. (USGS)

To transport tailings and waste from the main plant's wastewater treatment building to the tailings pond, an approximately 380-meter-long overhead pipeline, which was partially suspended from two towers over the Nam-chon, was constructed.

North Korea states that the Pyongsan Uranium Concentrate Plant "began its first-stage operations in the second half of 1990 following partial trial operations."[53] Sustained operations, however, were not achieved for several years and the Pakchon Uranium Concentrate Pilot Plant (39.710361 125.568141) reportedly continued to operate until the mid-1990s when it was shut down.[54]

CHON CHI-PU

Chon Chi-pu is an interesting individual who would later appear at the six-party talks and was a key individual involved in the construction of the Syrian nuclear reactor at Al Kibar before it was destroyed by Israel in 2007. In one photograph released by Israel, Chon is seen standing alongside Ibrahim Othman, the director of the Syrian Atomic Energy Commission. In a video subsequently released by the Central Intelligence Agency, Chon is described as the "head of North Korea's Nuclear reactor fuel manufacturing plant at Yongbyon."[55]

According to Kim Tae-ho, the Pyongsan Uranium concentrate Plant officially began operations on June 21, 1990.[56] This matches a 1992 KCTV interview with Chon Chi-pu, chief engineer of Yongbyon Fuel Rod Fabrication Plant, who detailed the establishment of the Pyongsan Uranium Concentrate Plant, its production process, and its relation to the Fuel Rod Fabrication Plant.

We have a medium plant which produces uranium ore concentrate from the uranium ore excavated in Sunchon area. Then, based on the experience we have attained from its operation, we built a new uranium ore concentrate production base in Pyongsan area.

The ore concentrate plant built in Pyongsan area began its first-stage operation in the second half of 1990 following partial trial operations. We are producing nuclear fuel rods receiving all the uranium ore concentrate produced in the Pakchon and Pyongsan areas. As for the uranium production processes, high-grade uranium ore is selected from the ore that is excavated. After being powdered, acid is used as a solvent, and following the ion exchange and sedimentation process, ore concentrate is produced. Our plant receives the ore concentrate thus produced and produces metal uranium following various processes, such as an acid treatment process, nuclear purity refining process, metallurgic process, processing and heat treatment process. Only after we cover the metal uranium with a shell and go through the completion process, can we obtain the nuclear fuel rods for burning in the atomic reactor.

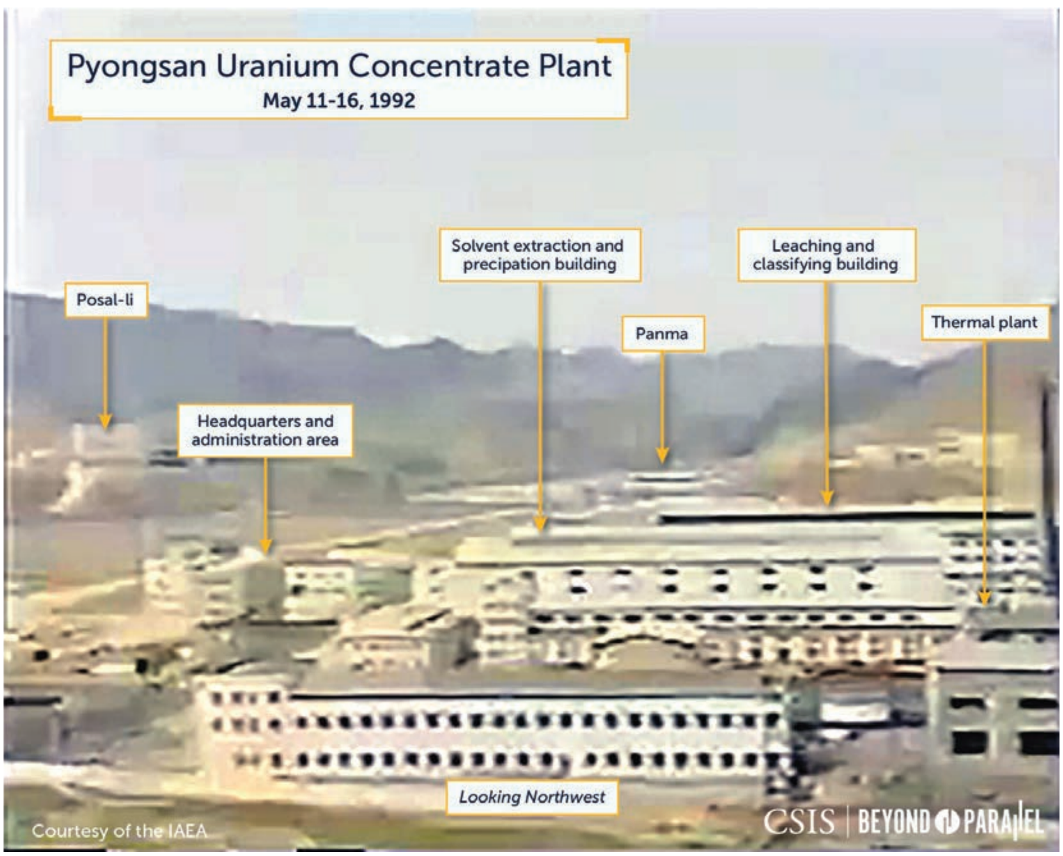
"ION EXCHANGE"[57]

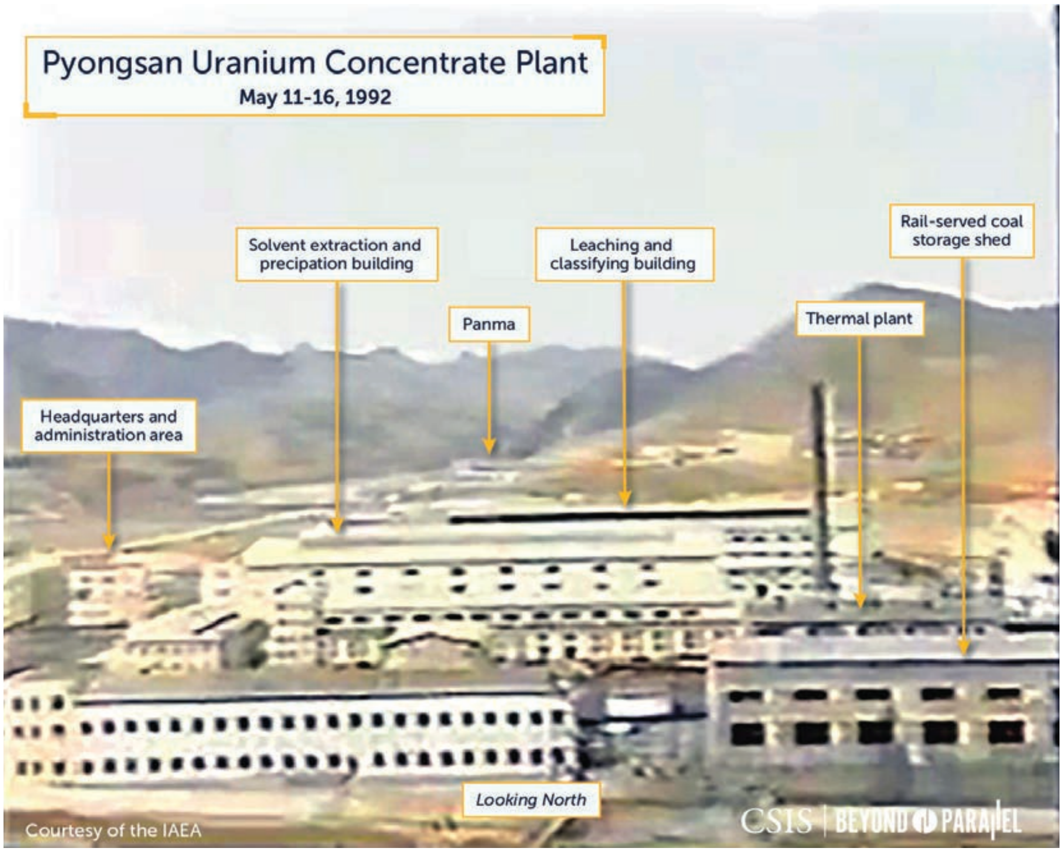
Chon Chi-pu's mention of purification by "ion exchange" as part of the milling process is intriguing as it indicates a particular separation process. There are three primary processes for purifying uranium ore:

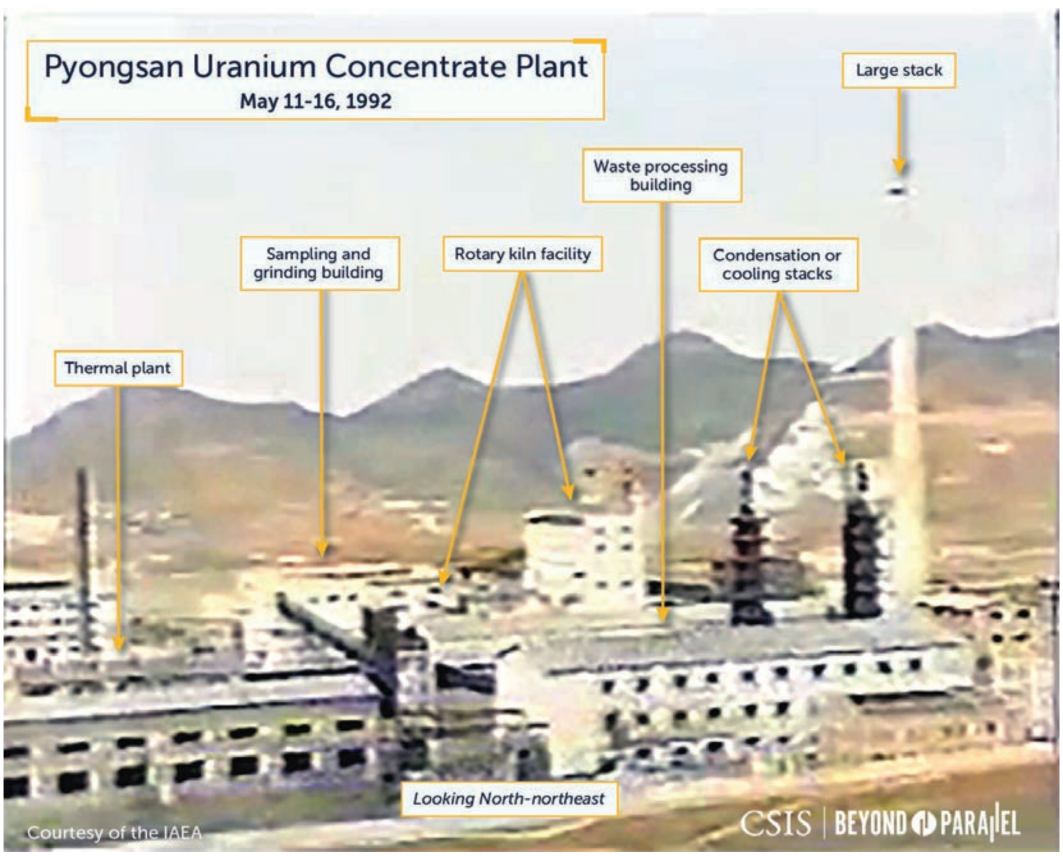
1. *Solvent extraction with tributylphosphate*. Knowledgeable individuals would not call this "ion exchange" because there is no ion exchange in this process. This, however, is a favored process for making nuclear grade uranium. Because that purification happens somewhere else than Pyongsan, it is nearly certain that Pyongsan does not use solvent extraction with tributylphosphate.
2. *Solvent extraction with amines*. This is the favored process in conventional uranium mills and uses either sulfuric acid or alkali carbonate. Chemically, this is an "ion exchange" process, so an individual could refer to this as an ion exchange process, however, knowledgeable individuals would usually refer to this as a solvent extraction process because that's what determines the equipment needed to undertake the separation.
3. *Ion exchange*. This would still use sulfuric acid or alkali carbonate. But instead of doing solvent extraction, the sulfuric acid (or carbonate) leach solution is passed through a column containing a solid material that absorbs the uranyl sulfate (or uranyl carbonate) in an ion exchange process. The solid is called an ion exchange resin, so the process is usually called "ion exchange chromatography" or just "ion exchange." If an individual in the United States were to stand up and state that they were producing yellowcake using an "ion exchange process," this is what people would assume they meant.

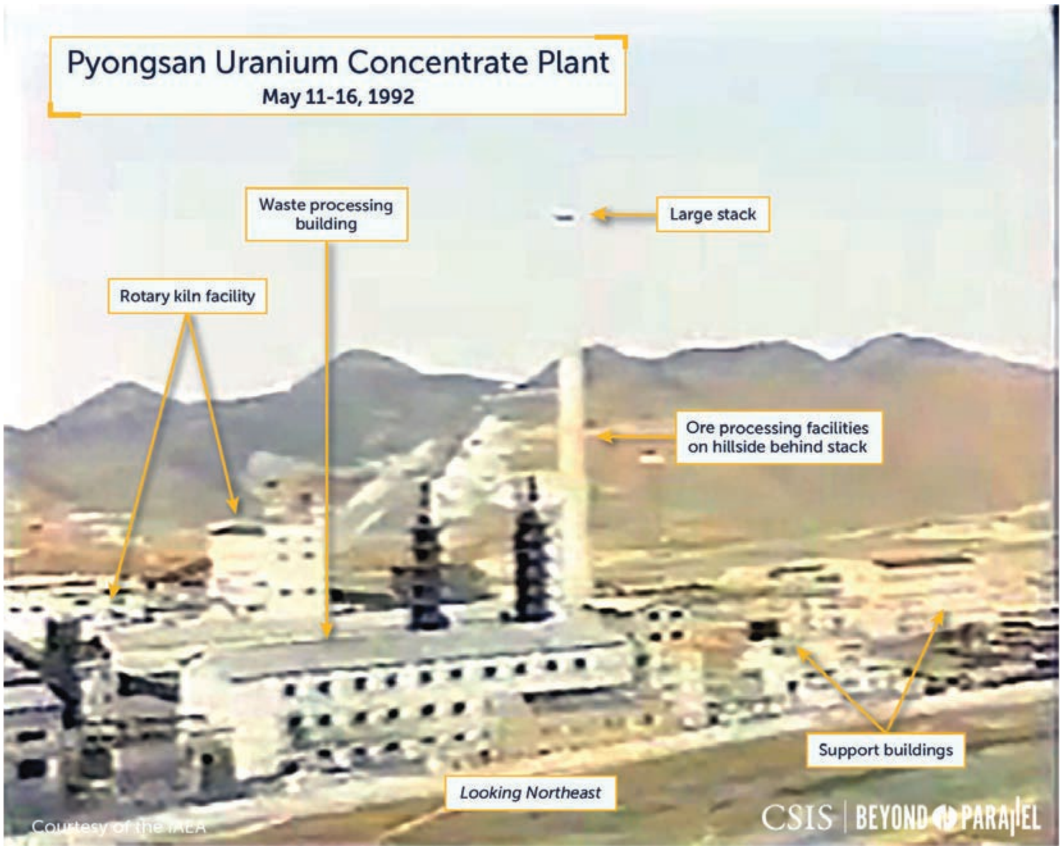
Despite North Korean success in this area, in the early 1990s, North Korea suffered several shocks. These shocks—collectively known as the Arduous March, include the 1991 collapse of the Soviet Union and subsequent loss of aid, the 1994 death of Kim Il-sung, and the multiyear period of repeated drought, famine, and economic collapse that followed his death. The disruptions caused by the Arduous March are likely contributing factors to the shutdown of the Pakchon Plant and may have constrained early operations and development at Pyongsan.

In response to its commitments to both the Treaty on the Nonproliferation of Nuclear Weapons (NPT) and the full scope safeguards agreement, on May 1, 1992, North Korea provided the IAEA with a list of its nuclear facilities.[58] Among the facilities disclosed were two uranium concentration plants—the Pakchon Uranium Concentrate Pilot Plant and the Pyongsan Uranium Concentrate Plant. Between May 11-16, 1992, IAEA Director General Hans Blix visited both plants. At this time, the Pyongsan Plant was observed to be in operation.[59] During Blix's briefing on the Pyongsan Uranium Concentrate Plant, North Korean nuclear experts identified the mining complex adjacent to the plant as the Pyongsan Uranium Mine and explained that the uranium was found within anthracite coal deposits at the mine.[60] Later, defectors identified the Pyongsan Uranium Mine as the January Industrial Mine.[61]




Pyongsan Uranium Concentrate Plant
May 11-16, 1992
Solvent extraction and precipation building
Leaching and classifying building
Rail-served coal storage shed
Panma
Thermal plant
Headquarters and administration area
Looking North
Courtesy of the IAEA
CSIS | BEYOND PARALLEL


Pyongsan Uranium Concentrate Plant
May 11-16, 1992
Large stack
Waste processing building
Sampling and grinding building
Rotary kiln facility
Condensation or cooling stacks
Thermal plant
Looking North-northeast
Courtesy of the IAEA
CSIS | BEYOND PARALLEL



Slides 22-25: A series of ground images of the exterior of the Pyongsan Uranium Concentrate Plant taken at the time of IAEA Director General Hans Blix's familiarization visit during May 11-16, 1992. The images are in sequence looking northwest, north, northeast, and east-northeast. (IAEA)

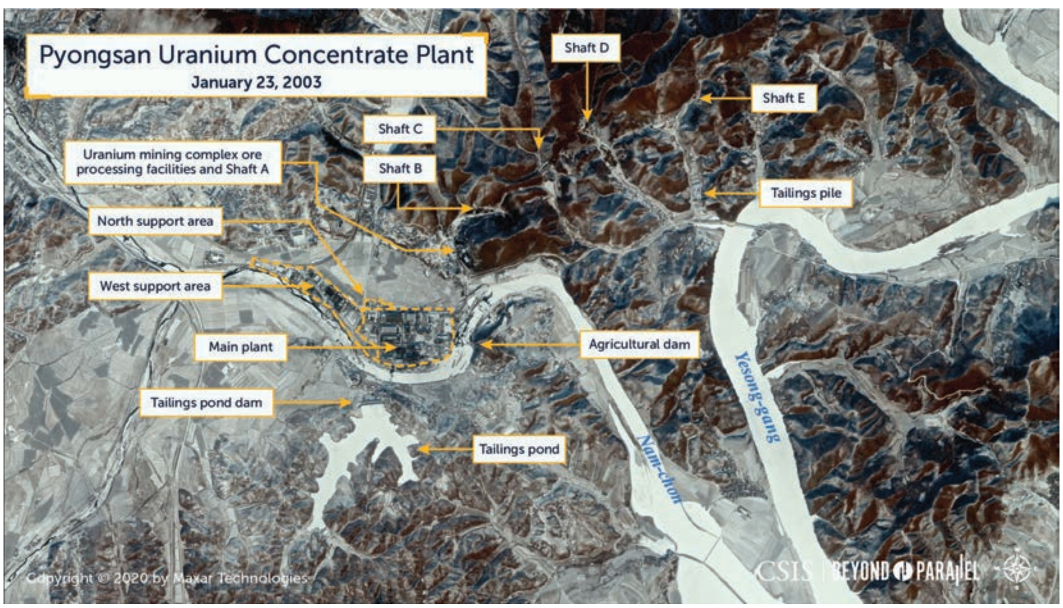
A medium resolution Landsat 5 image, acquired on April 10, 1996, provides an overall view of the plant and tailings pond during the mid-1990s.[62] The tailings pond is relatively full of water (green with a likely algae plume) and what may be early signs of precipitated solid waste visible at the northeast corner of the dam. While details of the mining activities are not visible in this image, the tailings pile south of Shaft E has clearly grown.

Unfortunately, due to a lack of high-resolution commercial or declassified satellite imagery between 1984 and 2002, little detailed information is known concerning the organization and operations of the Pyongsan Uranium Concentrate Plant during this period. Due to North Korea's intransigence and subsequent withdrawal from the NPT on January 10, 2003, the IAEA has not been able to visit the Pyongsan plant since 1992, leaving only satellite imagery and minor open source materials to monitor activity at the plant.[63]

2003

The earliest high-resolution (i.e., less than 1-meter GSD) commercial images that are readily available of the Pyongsan Uranium Concentrate Plant and its associated activities dates to January 23, 2003. This image shows the facility on a winter's day 13 years after production reportedly commenced. Although the image is somewhat difficult to read due to deep winter shadows, various ongoing activities are visible throughout the plant, support areas, uranium mining complex, and tailings pond.

Slide 26: A medium-resolution Landsat 5 image from April 10, 1996, shows general activity throughout the plant and that the water level in the tailings pond had risen to now familiar levels the year that first-stage operations began. (USGS)



Slide 27: Overview of the Pyongsan Uranium Concentrate Plant - January 23, 2003 (Copyright © 2020 by MAXAR Technologies)

As noted above, until more detailed information becomes available, the Pyongsan Uranium Concentrate Plant (excluding the nearby January Industrial Mine) may be provisionally divided into four components: the main plant, north support area, west support area, and tailings pond.

By January 2003, the main plant itself had reached its current size of approximately 24.2 hectares (most of which was enclosed within a security wall) and contained approximately 65-75 significant structures. As noted, until more detailed information becomes available, CSIS has provisionally separated the main plant into six functional areas: headquarters and administration, processing, waste storage and treatment, thermal plant, support, and railyard.[64]

At this time, the headquarters and administration area consisted of approximately only seven buildings (including two greenhouses), a parade ground, and large monument.

The processing area contained approximately 15 buildings. As noted, the conversion of uranium ore to yellowcake requires numerous processes, including the crushing and grinding of the ore, the addition of water to produce a slurry, and then the leaching of that slurry to extract the required uranium. Both the uranium-containing and waste solutions must be processed. Until more detailed information becomes available, the five largest buildings are provisionally identified as the grinding and sampling, leaching and classifying, solvent extraction and precipitation, and yellowcake production and packaging buildings. For example, ore is brought on-site from the adjacent mine via pipe where it feeds into the building identified by CSIS as the probable "sampling and grinding building." In addition to being consistent with the initial processing of uranium ore, further confidence in this identification can be gained from the presence of black exhaust dust over the building. Notable within the area identified by CSIS as likely being involved with yellowcake production and packaging is a rail-served loading/unloading building.

After the ground ore is screened and turned into a slurry, it is piped to the probable "leaching and classifying building." In addition to the piping, additional confidence of this building's purpose can be gained from the discoloration and damage seen on the roof in imagery from 2003 to present day. According to experts interviewed by the author, this is consistent with the use of sulfuric acid in the leaching process that can result in the prolonged condensation on the underside of roof panels, which leads to their slow disintegration. Underground pipes likely lead from this building to the identified "solvent extraction and precipitation building" and the waste storage and treatment area.

A typical North Korean rail-served coal storage shed (KCTV)

The solvent extraction and precipitation building has fewer signatures, although the connection of piping (from the probable leaching and classifying building and out to the probable waste pipe) and its proximity to the probable leaching and classifying building suggest that it is involved in the next steps of chemical processing. This reasoning also supports the identification of the probable yellowcake production and packaging and shipment facilities which are also in this area.

At the southern end of the site is a thermal plant consisting of a boiler plant (with four boilers as indicated by the four small exhaust vents on the roof and a 56-meter-high stack), rail-served coal storage shed, coal storage pens, and a few small buildings.

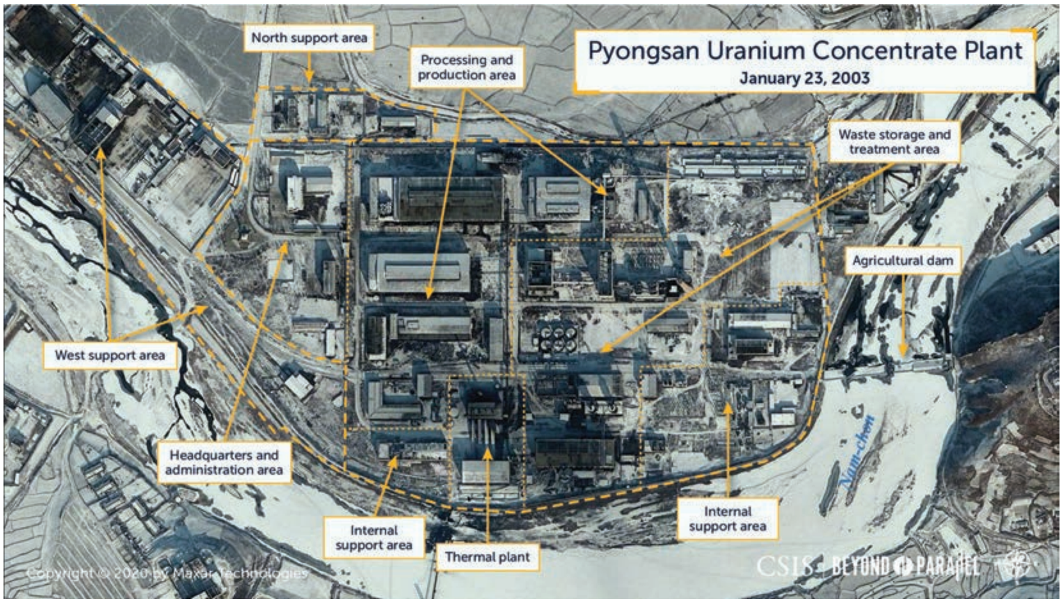
By 2003, the waste storage and treatment area contained approximately 31 significant structures including those consistent with the treatment of waste product. These include the following:

- An approximately 140-by-20-meter above-ground waste storage facility in the northeast corner of the plant consistent with the storage of dirty water, gravel, etc. produced by the grinding and sampling building;
- An idle rotary kiln facility (with rotary kiln, storage tank, processing building, incinerator, large approximately 126-meter-tall stack, and support building);
- Six 12-meter-diameter fixed-top reagent/chemical storage tanks;
- A motor vehicle maintenance and storage facility;
- An incomplete rail-served waste storage building;
- Two new 46-meter-high stacks/silos;
- A wastewater processing building (which processed waste and shipped it to the tailings pond via an approximately 380-meter-long pipeline, partially suspended from two towers over the Nam-chon);
- Several small storage tanks and support buildings; and
- An incomplete building.

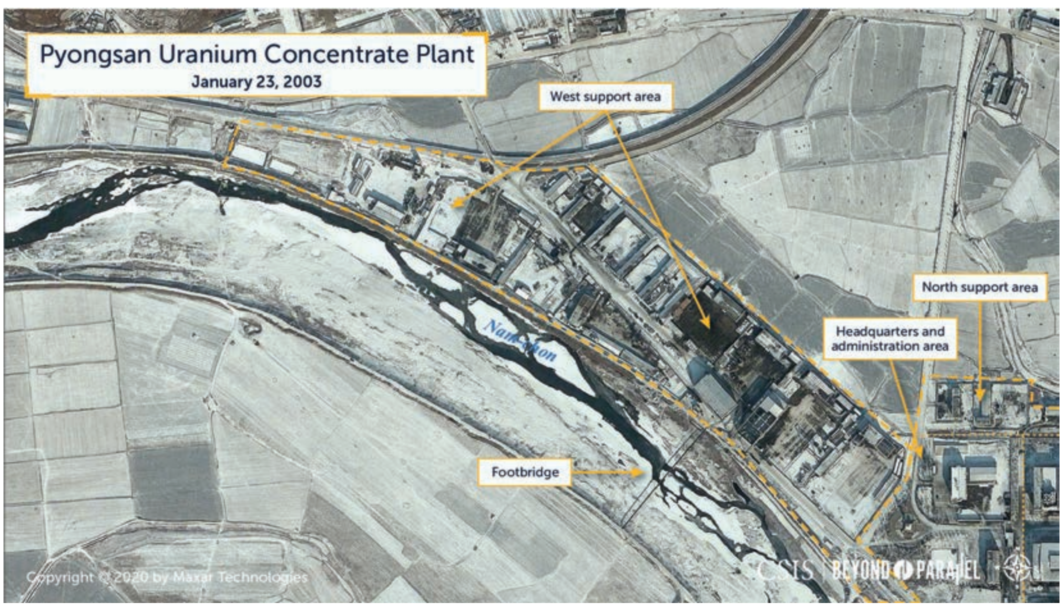
The internal support areas contained approximately 21 small structures, storage tanks, and four incomplete buildings. It is interesting to note that the overhead pipeline leading from the main plant to the tailings pond runs diagonally over the coal storage pens for the thermal plant.

Notable in the 2003 image is the small number of incomplete, partially razed, or idle structures.[65] The underlying reasons for the status of these structures are unknown.

The north support area encompassed approximately 1.1 hectares containing five buildings, including an electric substation, security office, and small support buildings. The west support area encompassed approximately 12.3 hectares with 35-40 buildings and was organized into a number of small activities (e.g., warehouses, open-air storage, vehicle maintenance and storage, foundry, etc.). The main plant and west support area share a small railyard that has dedicated but small locomotive and railcar servicing facilities and terminates in a three-track stub yard within the main plant.



Slide 28: The functional areas of the main plant and north support facility, as well as the suspended pipeline to the tailings pond and the preexisting agricultural dam east of the plant - January 23, 2003 (Copyright © 2020 by MAXAR Technologies)

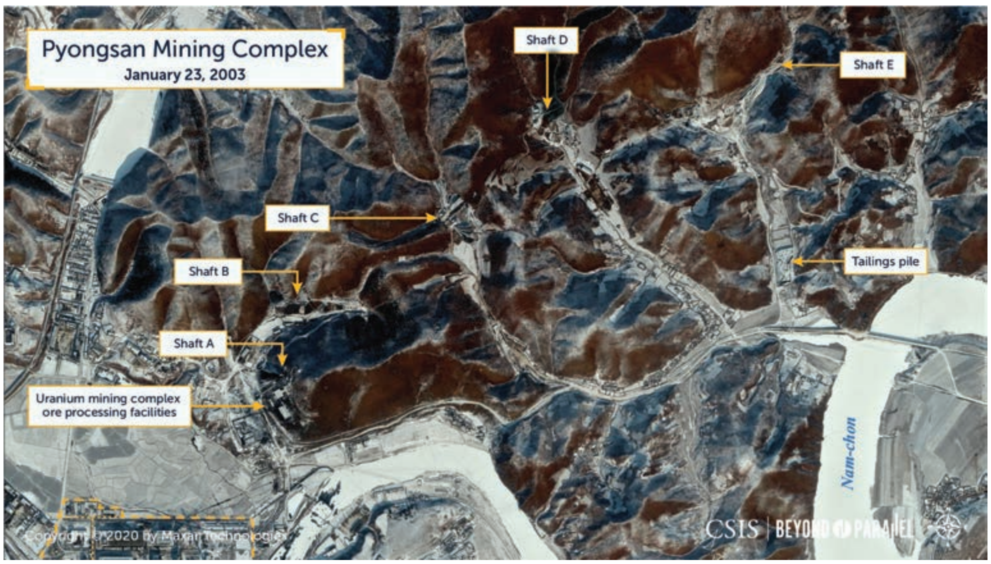


Slide 29: The west support area (including rail facilities) - January 23, 2003 (Copyright © 2020 by MAXAR Technologies)

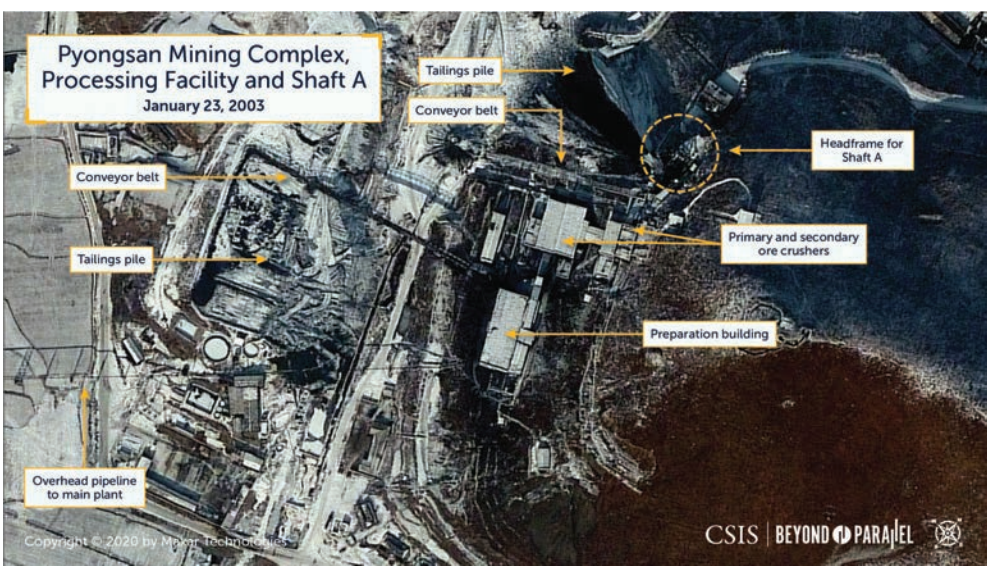
Prior to 2003, the January Industrial Mine's activities, northeast of the main plant, expanded to approximately 235 hectares on the southern slopes of Majang-san. Within this space, the mining complex included five active vertical shaft mines, tailings piles, an ore processing facility, and a variety of smaller support activities around it. The ore processing facility (38.323407 N, 126.437758 E) consisted of primary and secondary crushers, an ore preparation building, and an approximately 515-meter-long pipeline connecting to the Pyongsan Uranium Concentrate Plant to transport crushed uranium ore (likely in a slurry form). All five mine shafts (identified for readability in this report as Shafts A-E) had headframes (i.e., the frame structure above the mine shaft used to raise and lower workers, equipment, and ore) in place and adjacent working tailings piles. Additionally, a large tailings/storage pile had been established approximately 625 meters to the south of Shaft E.

Table 1: Mine Shaft Locations

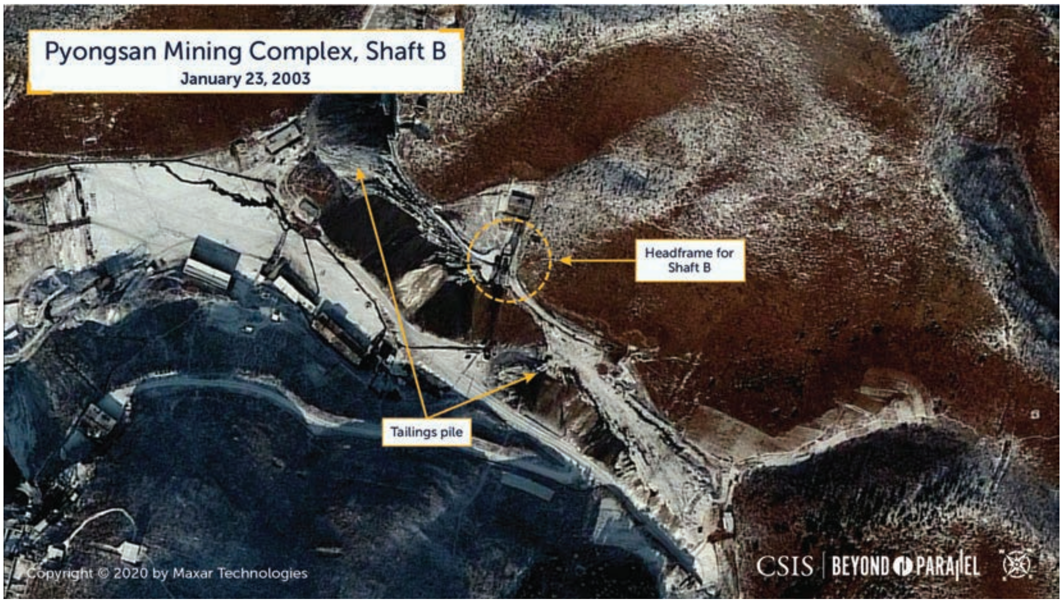
VERTICAL SHAFT	LOCATION
A	38.32416 N, 126.43792 E
B	38.32640 N, 126.43881 E
C	38.32864 N, 126.44391 E
D	38.33171 N, 126.44763 E
E	38.32721 N, 126.45698 E
Tailings/Storage Pile	38.32717 N, 126.45715 E



Slide 30: Overview of the Pyongsan Uranium Mine Complex - January 23, 2003 (Copyright © 2020 by MAXAR Technologies)

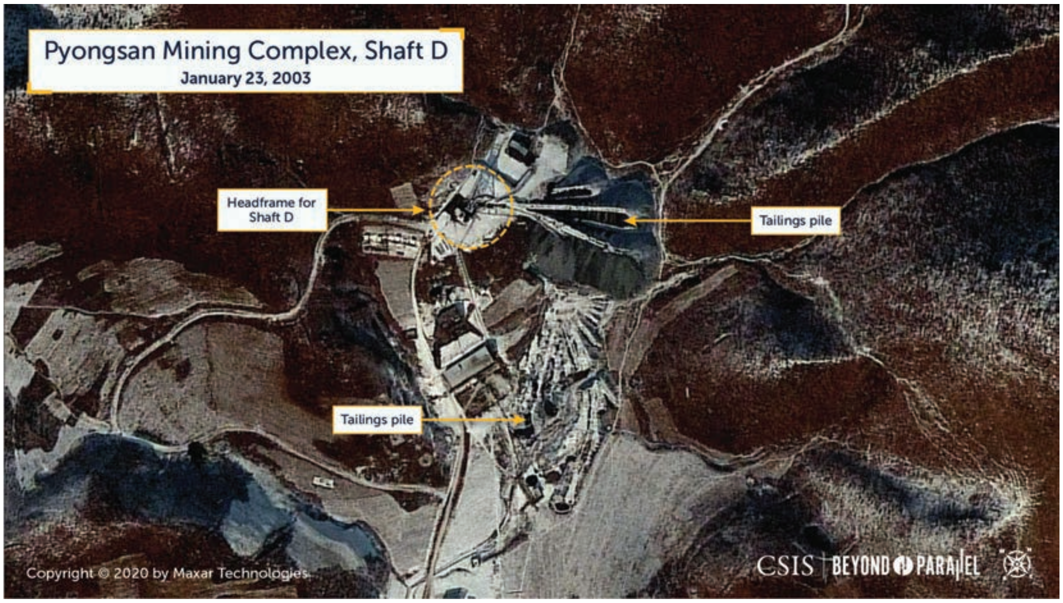


Slide 31: The mine's processing facilities, headframe at Shaft A, and associated tailings piles - January 23, 2003. (Copyright © 2020 by MAXAR Technologies)

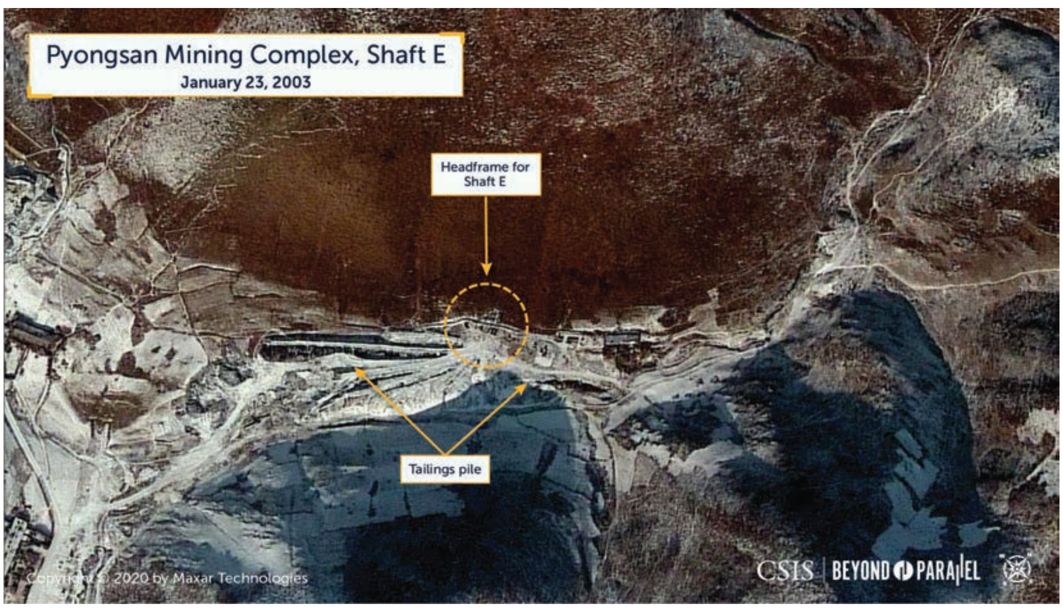


Slide 32: The headframe and tailings piles at Shaft B - January 23, 2003 (Copyright © 2020 by MAXAR Technologies)

Slide 33: The headframe and tailings piles at Shaft C - January 23, 2003 (Copyright © 2020 by MAXAR Technologies)



Slide 34: The headframe and tailings piles at Shaft D - January 23, 2003 (Copyright © 2020 by MAXAR Technologies)



Slide 35: The headframe and tailings piles at Shaft E - January 23, 2003 (Copyright © 2020 by MAXAR Technologies)

Slide 36: The tailings pile south of Shaft E - January 23, 2003 (Copyright © 2020 by MAXAR Technologies)

At this time, the tailings pond covered approximately 23.8 hectares and the precipitated solid waste had a visible footprint of approximately 1.1 hectares. The slurry of liquid and solid waste pumped to the tailings pond arrived at a point just south of the northeast corner of the dam and was initially allowed to naturally spill into the pond and fan out. Subsequently, small ditches were sometimes excavated on top of previously deposited solid waste to further distribute the waste slurry more evenly—first west along the dam and then to the south and southwest. Visible in the image of January 23, 2003, is a small pipeline on the west side of the dam that appears to be draining the basin below the dam.

Slide 37: The tailings pond south of the Pyongsan Uranium Concentrate Plant - January 23, 2003
(Copyright © 2020 by MAXAR Technologies)

Slide 38: A closeup of the tailings pond and dam showing the original waste outflow point, a small pipeline draining the basin below the dam, and the footprint of the solid waste building in the tailings pond - January 23, 2003 (Copyright © 2020 by MAXAR Technologies)

Taken as a whole, the Pyongsan Uranium Concentrate Plant encompassed a total of approximately 37.6 hectares with 100-115 structures. If the plant's tailing pond—approximately 23.8 hectares—is included, this would increase to approximately 61.4 hectares.

Slide 39: The agricultural dam immediately east of the Pyongsan Uranium Concentrate Plant. What appear to be two small breaches can be seen on the top of the dam - January 23, 2003 (Copyright © 2020 by MAXAR Technologies)

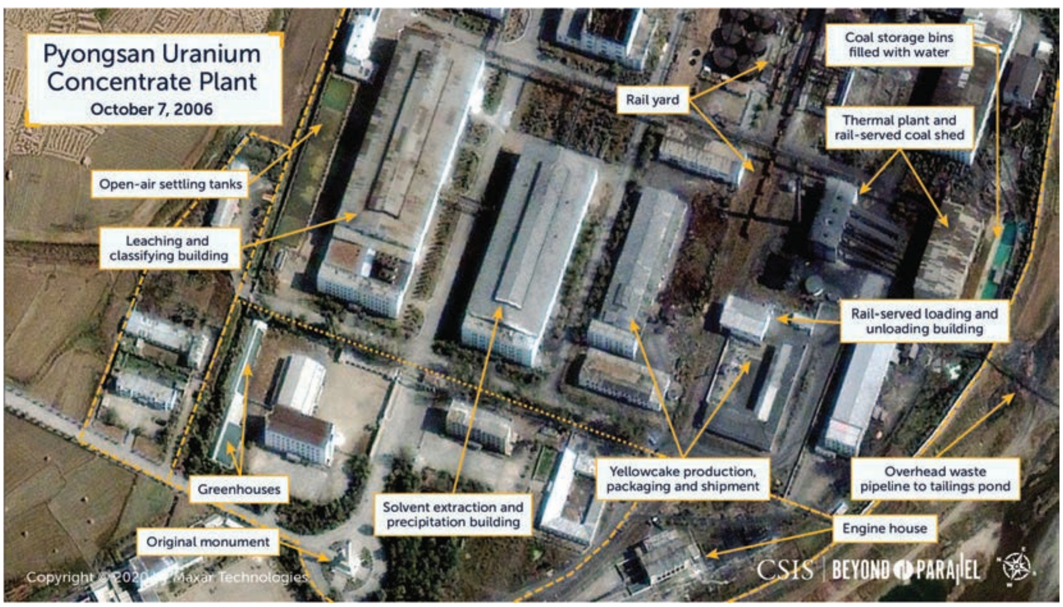
The small dam across the Nam-chon immediately east of the main plant was observed in declassified imagery as far back as a KH-9 image from May 2, 1974. The dam is also clearly visible in the high-resolution image from January 23, 2003. It spans approximately 155 meters and appears to have a small hydroelectric plant and irrigation sluice gate on its south side (38.317404 N, 126.438401 E). The dam does not appear to directly support the Pyongsan Uranium Concentrate Plant. Rather, it appears to have been built to both support local agriculture and provide a measure of flood control. The image from January 23, 2003, shows that the dam is beginning to fail as indicated by two small developing breaches.

Aside from the dam, there are a number of separate, small unidentified activities located around the plant, tailings pond, and mining complex. If and how these are related to the operations of the plant is unknown.

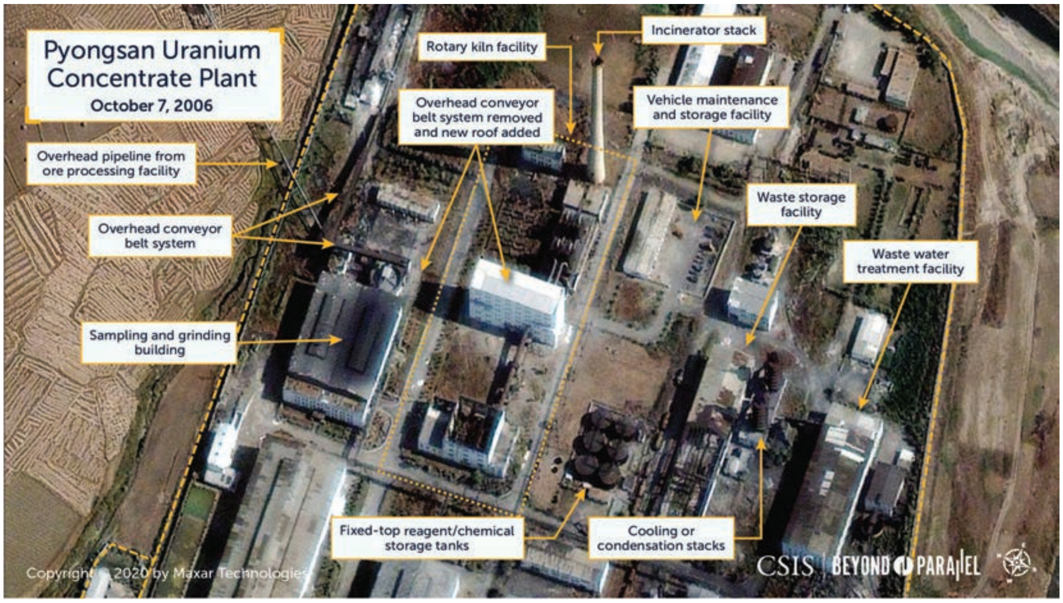
Imagery of the Pyongsan Uranium Concentrate Plant from 2003 serves as a base for assessing developments over the subsequent years.

2004-2013

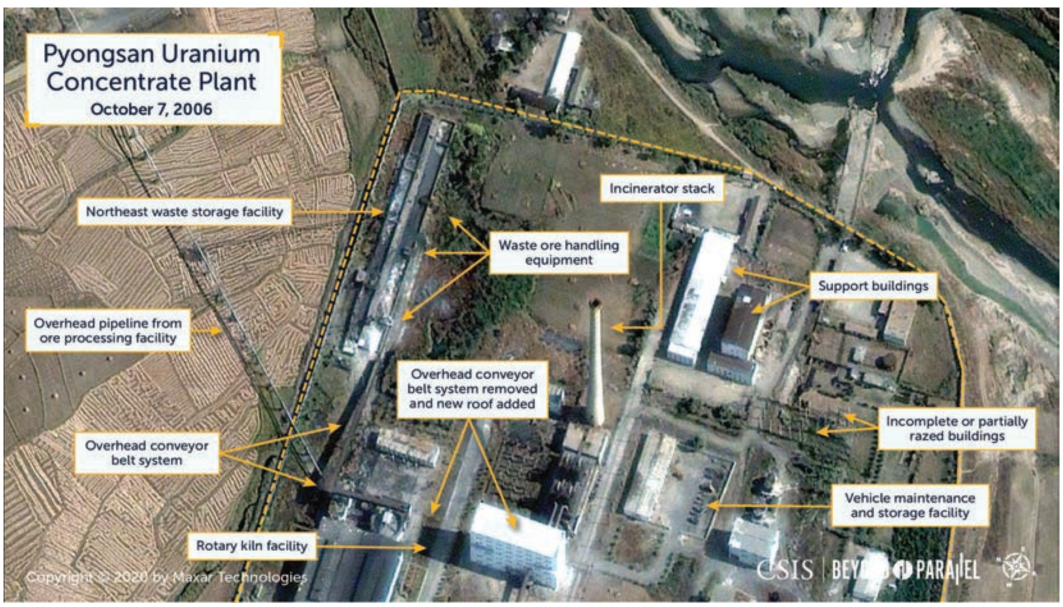
Activity observed in imagery from April 29, 2005, and October 7, 2006, shows that a greenhouse was added on the north side of the headquarters and administration area and a building on the south side was expanded.[66] More significantly, on the north side of the leaching and classifying building, an approximately 100-meter-by-15-meter above-ground structure consisting of six open-air settling tanks had been built. An overhead conveyor belt system connecting the sampling and grinding building to the central building of the rotary kiln facility was removed, and a roof was added to the central building.



Slide 40: Overview of the western section of the main plant showing the headquarters and administration, processing, and thermal plant areas. Notable are the new open-air settling tanks adjacent to the leaching and classifying building - October 7, 2006 (Copyright © 2020 by MAXAR Technologies)

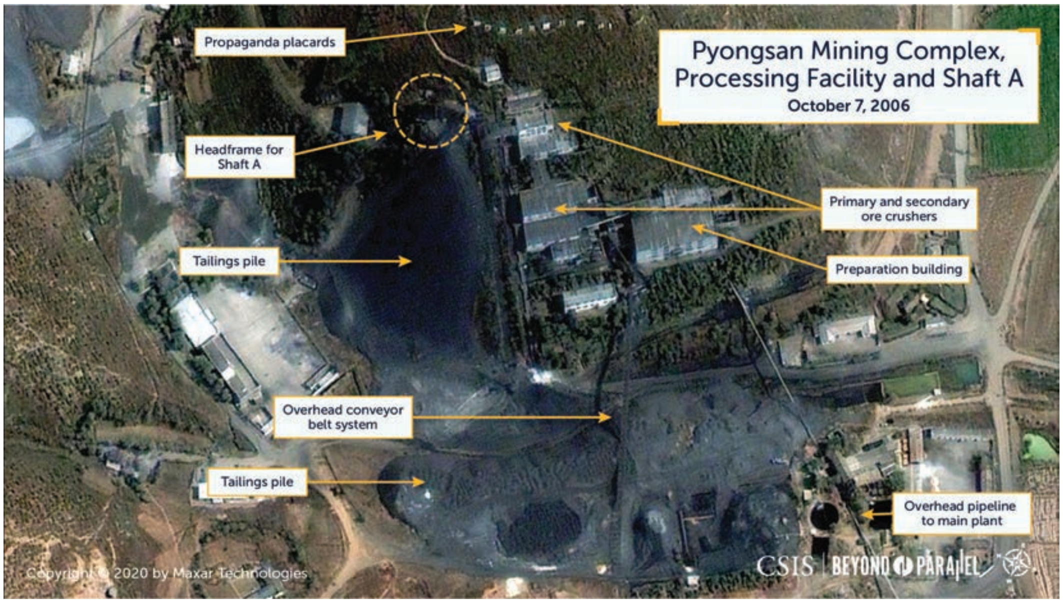


Slide 41: The center section of the main plant showing the thermal plant and processing, yellowcake production and packaging building, and waste treatment areas - October 7, 2006 (Copyright © 2020 by MAXAR Technologies)

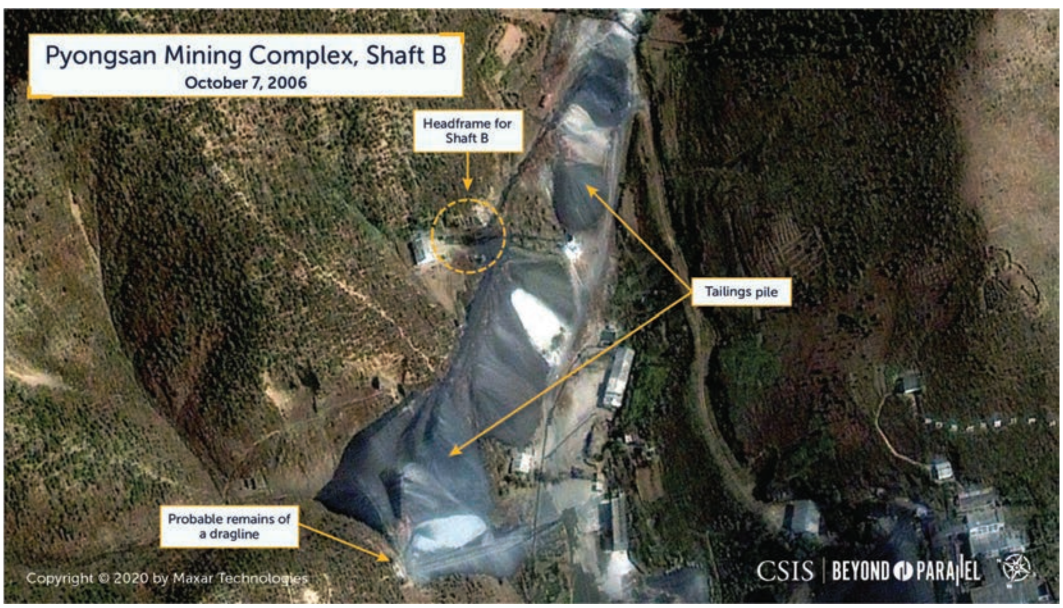


Slide 42: An overview of the eastern section of the main plant showing the northeast waste storage facility and parts of the waste treatment area and support facilities - October 7, 2006 (Copyright © 2020 by MAXAR Technologies)

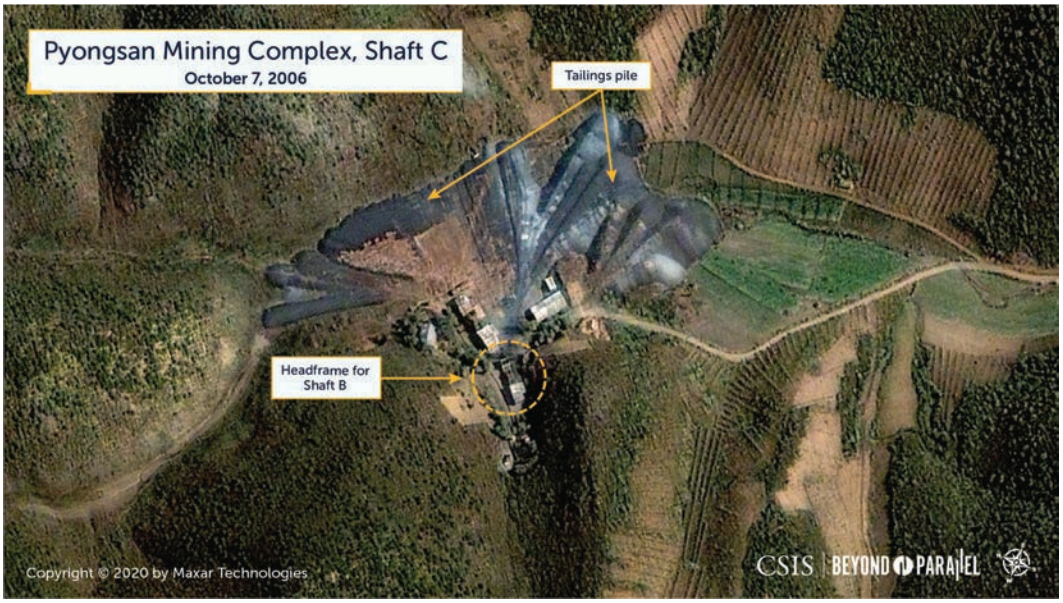
The image for October 7, 2006, also provides a clear, detailed view of the mine shafts, their headframes, and tailings piles.



Slide 43: The mine processing facilities, headframe at Shaft A, and associated tailings piles - October 7, 2006 (Copyright © 2020 by MAXAR Technologies)



Slide 44: The headframe and tailings piles at Shaft B - October 7, 2006 (Copyright © 2020 by MAXAR Technologies)



Slide 45: The headframe and tailings piles at Shaft C - October 7, 2006 (Copyright © 2020 by MAXAR Technologies)

Slide 46: The headframe and tailings piles at Shaft D - October 7, 2006 (Copyright © 2020 by MAXAR Technologies)

Slide 47: The headframe and tailings piles at Shaft E - October 7, 2006 (Copyright © 2020 by MAXAR Technologies)

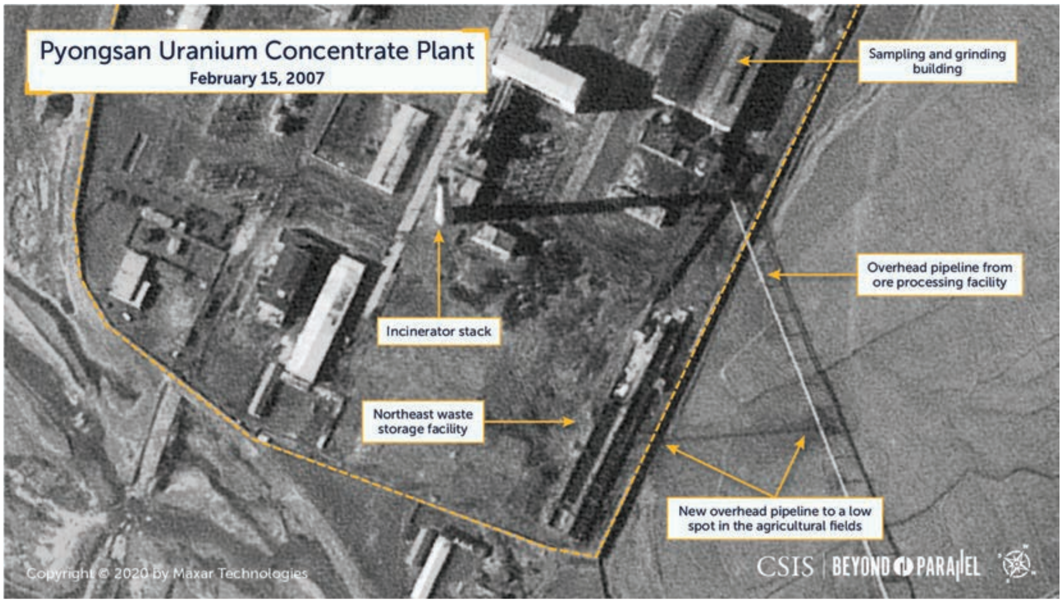
Slide 48 The tailings pile south of Shaft E - October 7, 2006 (Copyright © 2020 by MAXAR Technologies)

It is interesting to note that by October 7, 2006, the overhead pipeline leading from the main plant to the tailings pond was rerouted so as to not pass diagonally over the coal storage pens of the thermal plant. This image also provides a detailed view of the tailings pond, the expanding footprint of the precipitated solid waste in the pond, and that the pipeline delivering the waste to the tailings pond was in the process of being rerouted from along the northeastern shore to now enter approximately 20 meters west of the northeast corner of the dam. Also visible is that the two previously identified small breaches in the agricultural dam (observed in 2003) had developed into a major failure, with a breach measuring approximately 55 meters wide.

Slide 49: A closeup of the tailings pond showing the rerouting of the pipeline that delivers waste and the expanding footprint of the precipitated solid waste in the pond - October 7, 2006 (Copyright © 2020 by MAXAR Technologies)

Slide 50: The agricultural dam has failed as seen by the 55-meter-wide breach - October 7, 2006 (Copyright © 2020 by MAXAR Technologies)

The most significant development during 2007-2009, however, was the commencement of a long-term maintenance and modernization project to update the flow of waste disposal and waste treatment. This modernization project has continued in one form or another until May 2020. The first likely indications of this were observed in imagery from February 15, 2007, when the handling equipment along the length of the northeast waste storage facility was removed and an overhead pipeline was installed. This pipeline runs 110 meters from the facility to a low spot northwest of the plant in the middle of some agricultural fields. While the most likely reason for this was to drain a leak from the overhead pipeline which leads from the ore processing facility to the sampling and grinding building, an argument can be made that this was to empty the northeast waste storage facility, as seen by the subsequent activity there. Concurrently, two openings were created on the facility's west and south sides to allow for the removal of any remaining solid waste.

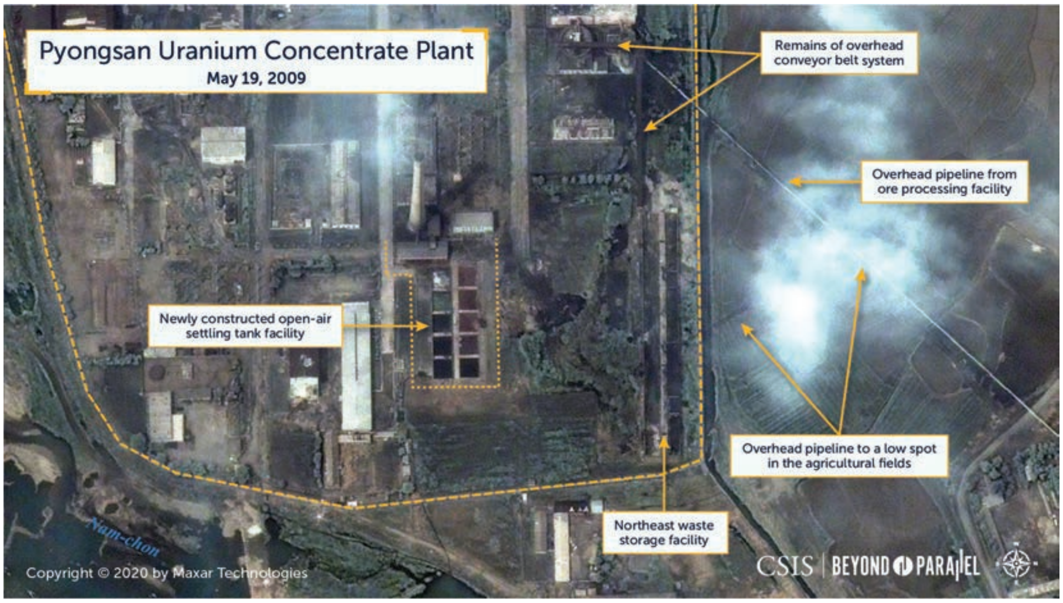


Slide 51: Although of marginal quality, this image shows the eastern section of the main plant and the new pipeline leading away from the northeast waste storage facility - February 15, 2007 (Copyright © 2020 by MAXAR Technologies)

The following year, imagery acquired on May 19, 2009, identified the construction of a new open-air settling tank facility immediately to the east of the rotary kiln facility. This new facility consisted of a single building connected to the incinerator and stack via an overhead pipe and 10 open-air settling tanks (measuring approximately 65 meters by 30 meters overall).

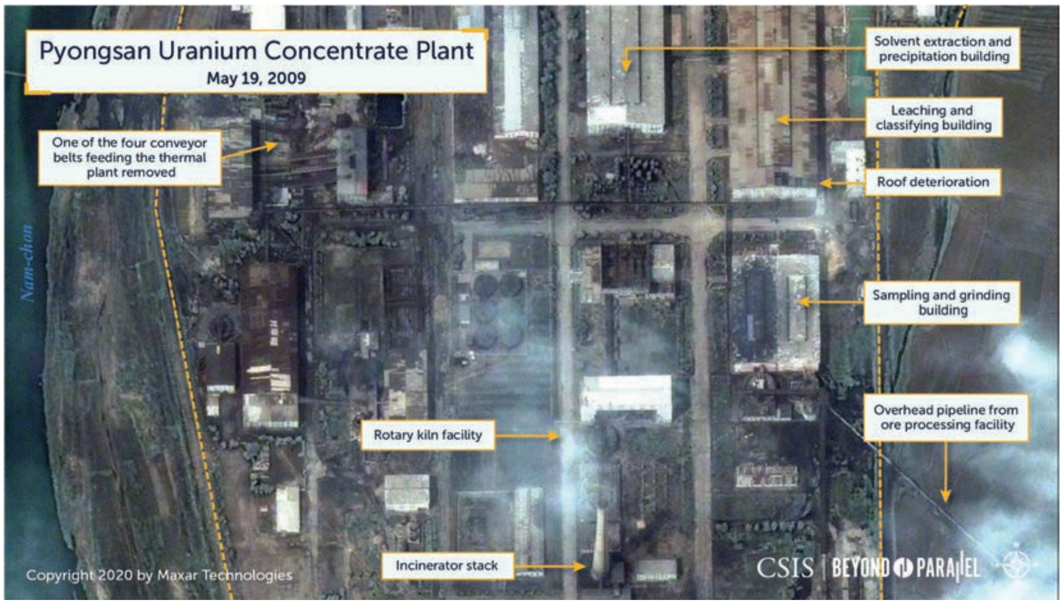
A number of minor infrastructure developments then occurred between February 15, 2007, and May 19, 2009, including the addition of two small buildings. These consist of the construction of one building (likely a guard position) in the north support area, which slightly expanded the support area's overall footprint; the razing of half of the existing greenhouse; the construction of a new building in the headquarters and administration area; the addition of two small settling tanks (measuring a total of six meters by 10 meters) at the leaching and washing building; the construction of a small building among the yellowcake production and packaging buildings; and at the thermal plant, the replacement of a small storage tank and removal of one of the four coal handling conveyor belts connecting the coal storage shed to the boiler building.

Meanwhile, at the tailings pond, imagery from this period shows that the work to reroute the waste pipeline had been completed and that an irregularly-shaped cofferdam measuring approximately 85 meters by 50 meters had recently been constructed at the center of the dam.[67] Though the exact purpose of the cofferdam is unknown, it was likely related to repairs being undertaken on the dam. The visible footprint of precipitated solid waste had also increased.

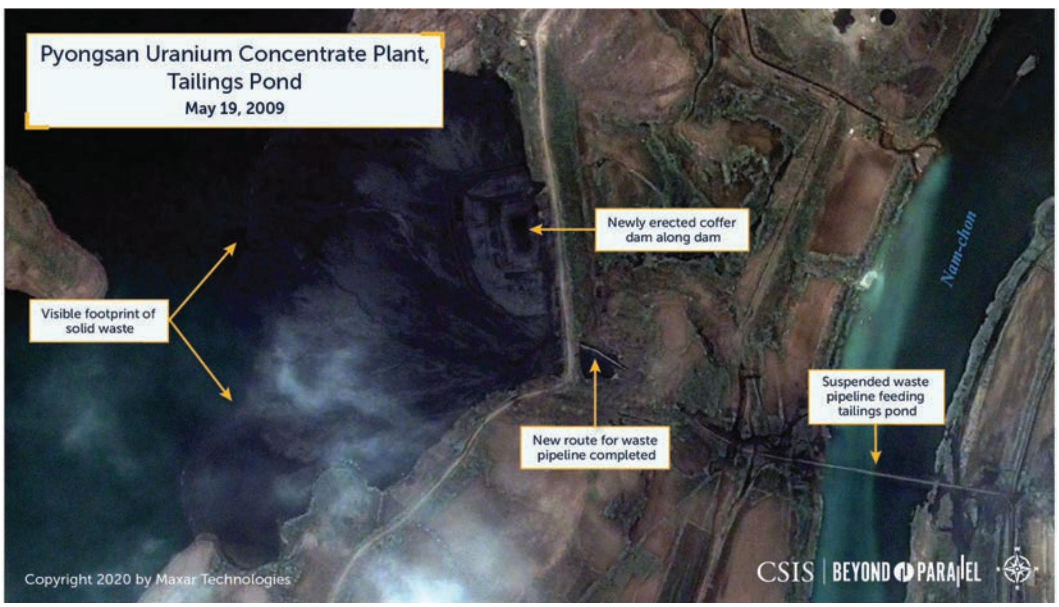


Slide 52: Although again of marginal quality, this image shows the eastern section of the main plant seen two years later and the changes to the northeast waste storage facility and the newly constructed open-air settling tank facility. Although partially hidden by clouds, the pipeline leaving the northeast storage facility is visible - May 19, 2009 (Copyright © 2020 by MAXAR Technologies)

Slide 53: The Overview of the western section of the main plant showing the headquarters and administration, processing, and thermal plant areas - May 19, 2009 (Copyright © 2020 by MAXAR Technologies)



Slide 54: The center section of the main plant showing the thermal plant and processing, waste treatment and areas - May 19, 2009 (Copyright © 2020 by MAXAR Technologies)



Slide 55: The tailings pond showing the rerouting of the waste pipeline had been completed and the recent construction of a cofferdam along the inside face of the dam - May 19, 2009 (Copyright © 2020 by MAXAR Technologies)

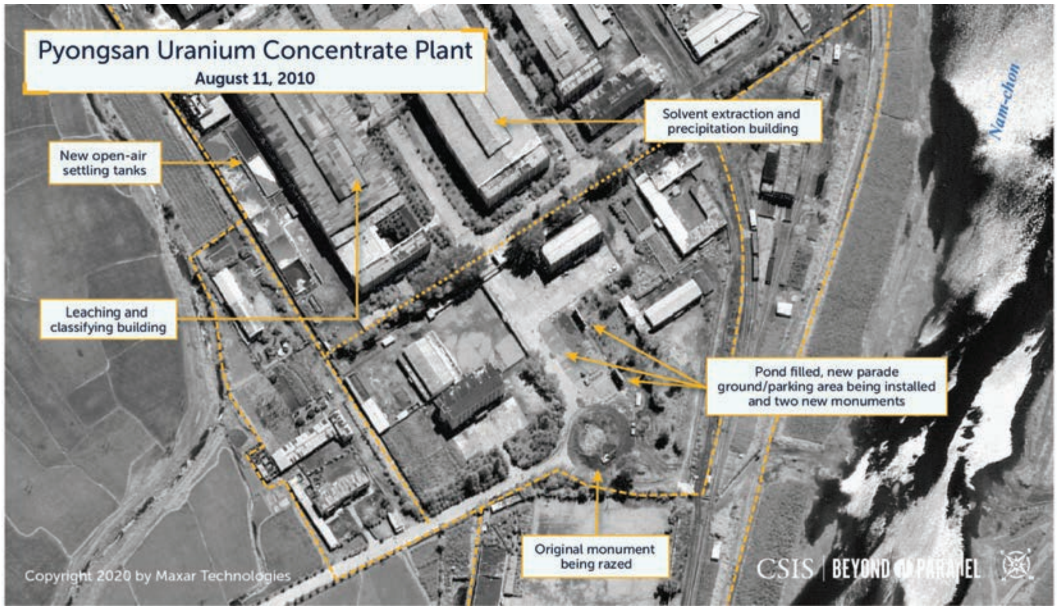
The image for May 19, 2009, shows that the breach in the agricultural dam had been repaired.

It was also during 2007-2009 that deterioration of sections of roofing on a number of buildings became increasingly noticeable. This is particularly evident at the leaching and classifying building where approximately 55m^2 of roofing was missing or deteriorating in 2009. As noted, this is consistent with the use of sulfuric acid in the leaching process that can result in the prolonged condensation on the underside of roof panels. This can lead to their slow disintegration, consistent with the state of these roof panels—several of which were now missing on the east side of the building.[68]

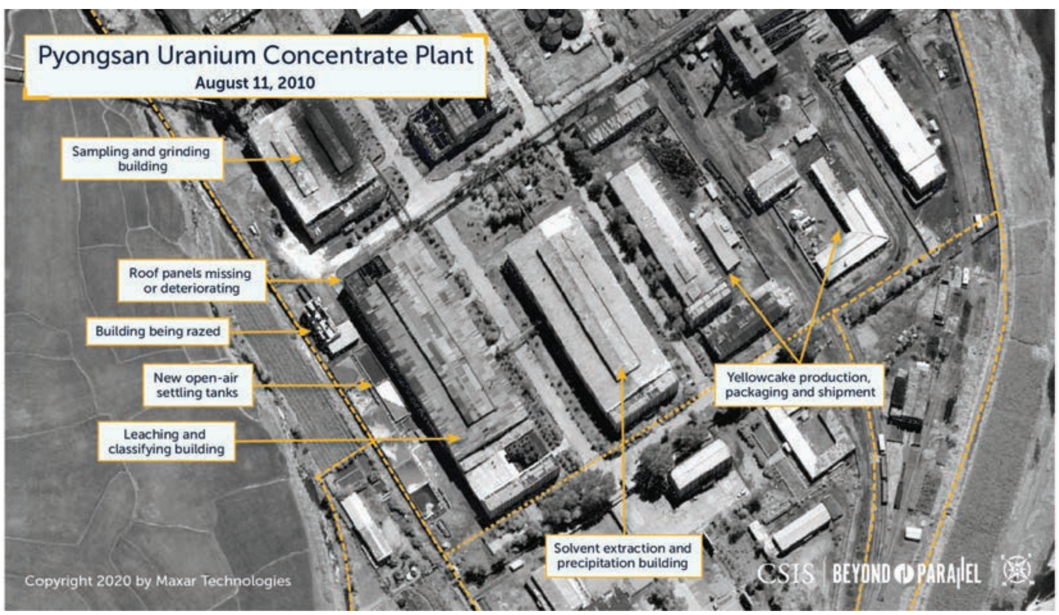
Slide 56: The breach in the agricultural dam had been repaired - May 19, 2009 (Copyright © 2020 by MAXAR Technologies)

During the summer of 2010, the headquarters and administration area witnessed a major renovation. The original monument was being razed to be replaced by a large parking/parade area with two smaller monuments. The small pond immediately to the south was filled and a building further to the south was expanded. On the north side of the leaching and classifying building, two new above ground open-air settling tanks covering approximately 47 meters by 10 meters were added, bringing the total number of tanks to ten. The area of missing or seriously degraded roofing on the building had now increased to approximately 72m^2. A seventh fixed-top reagent/chemical storage tank was under construction, adjacent to the six tanks already present. At the thermal plant, a second conveyor belt between the coal storage shed and boiler building was being razed and a small storage tank adjacent to the west side was removed. Concurrently, a small new building was under construction in the north support area. At the small incinerator/boiler building, on the south side of the rail-served waste storage building, one of the two existing 46-meter-tall cooling/condensing stacks was razed, and a foundation for what would eventually become two new double-walled silos/stacks immediately to the southwest was under construction. Taken as a whole, these changes suggest a concerted effort to increase yellowcake production.

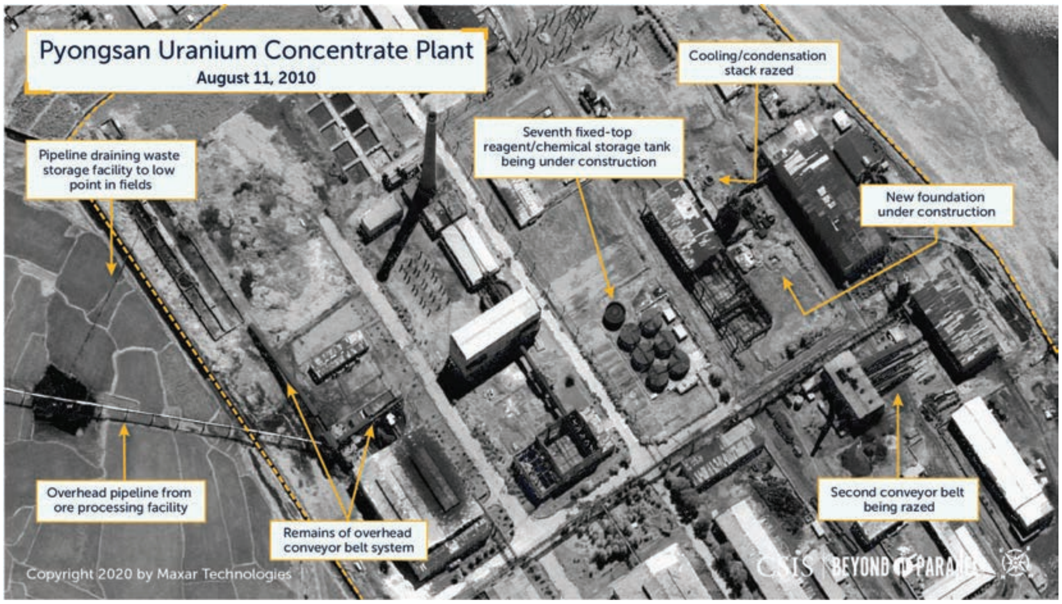
At the tailings pond, the cofferdam remained in place and its configuration had not changed. Ditches were now observed being excavated on the precipitated waste to redirect the waste outflow towards the southwest bay of the pond, and the footprint of the precipitated solid waste increased.



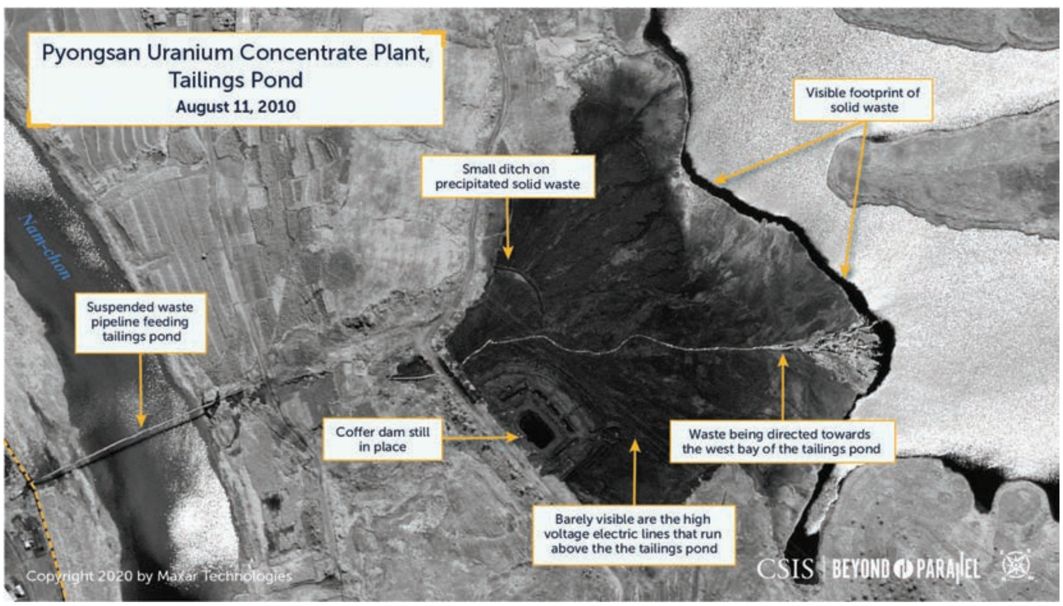
Slide 57: The western section of the main plant showing the razing of the original monument and other changes in the headquarters and administration and north support area - August 11, 2010 (Copyright © 2020 by MAXAR Technologies)



Slide 58: The center section of the main plant showing the two new above ground open-air settling tanks, missing roof panels on the leaching and classifying building, and other changes - August 11, 2010 (Copyright © 2020 by MAXAR Technologies)



Slide 59: The eastern section of the main plant showing the pipeline connected to the northeast waste storage facility, the seventh fixed-top reagent/chemical storage tank under construction, the removal of a cooling/condensing stack, and other changes - August 11, 2010 (Copyright © 2020 by MAXAR Technologies)

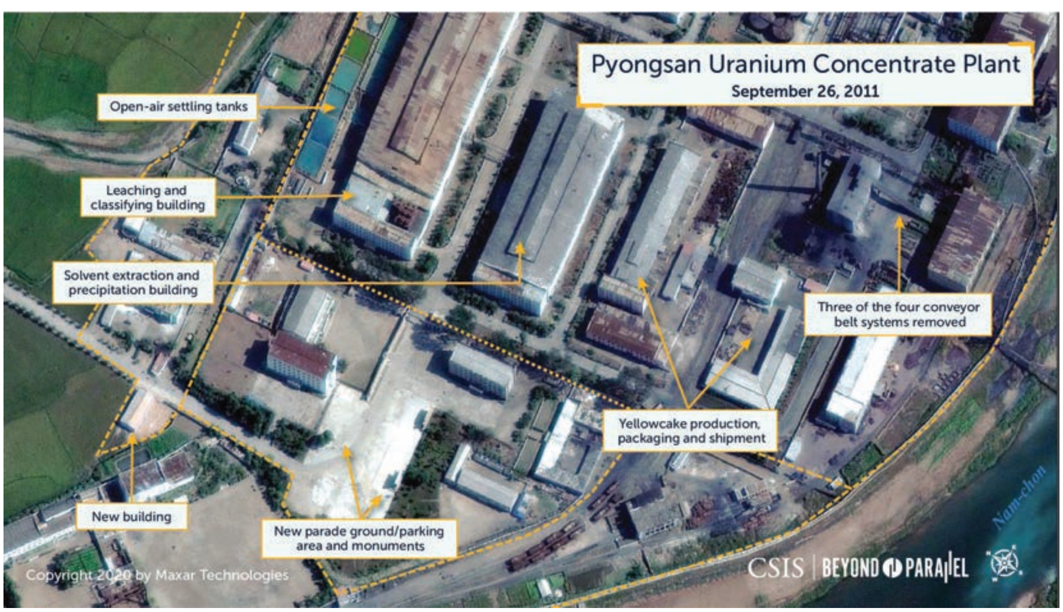


Slide 60: The tailings pond dam showing the cofferdam still in place along the inside of the dam, expanding precipitated solid waste, and ditches being excavated on the precipitated waste to reroute the waste outflow stream - August 11, 2010 (Copyright © 2020 by MAXAR Technologies)

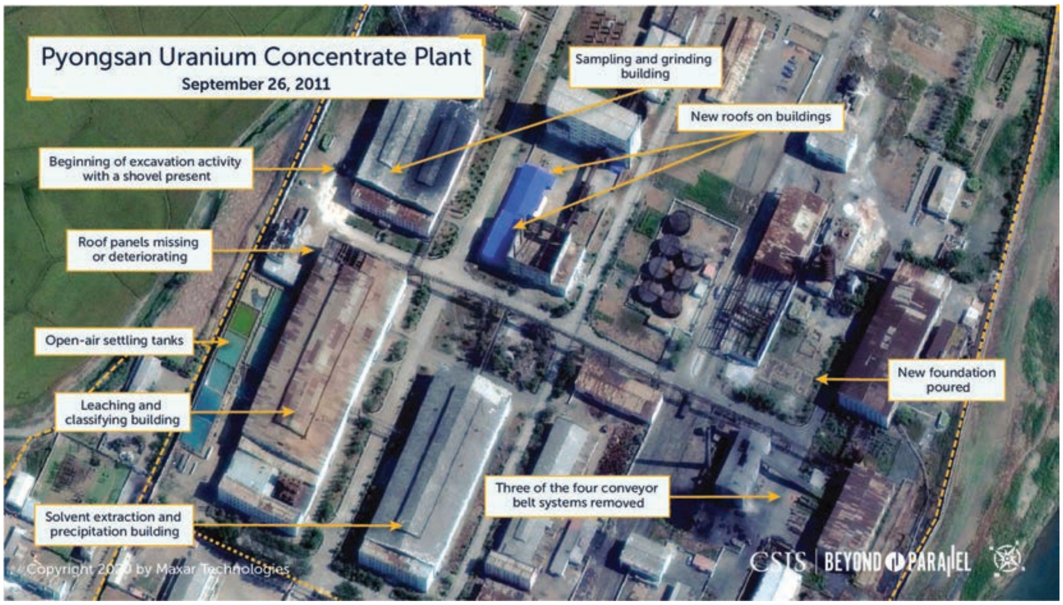
Imagery from September 26, 2011, shows a continuation of the activity that began the previous year. Most notable were ongoing activities that centered around the sampling and grinding building and northeast waste storage facility. These supported the long-term project to update the flow of waste treatment and disposal of waste products, such as gravel and water. Indications of these aims include the following:

- Excavation activity on the north side of the sampling and grinding building where a shovel appears to be removing waste gravel from the side of the building.
- The installation of a small overhead pipeline connecting the sampling and grinding building to the northeast waste storage facility that would subsequently be used to transport a slurry of liquid and waste gravel to the facility. At this time, the southern half of the northeast waste storage facility was essentially empty and there were two large openings in its walls, while the north side appears to still contain some solid waste.
- The removal of the remaining components of the overhead conveyor belt system on top of the buildings and storage tanks attached to both the sampling and grinding building and connecting to the northeast waste storage facility.
- The removal of the overhead pipeline that had been run from the northeast waste storage facility to the agricultural fields to the northwest.

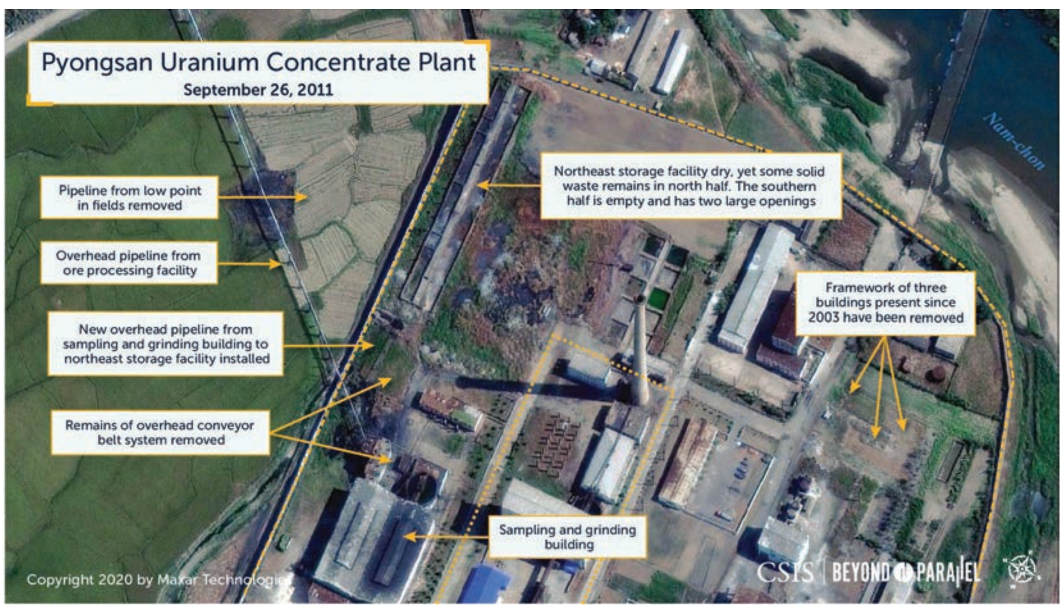
Elsewhere within the main plant, maintenance and modernization efforts continued. The new parade ground/parking area in the headquarters and administration area was completed. Continuing deterioration of roofs throughout the facility was observed but was especially noticeable on the leaching and classifying building where the area of the missing or seriously degraded roofing on the building had now increased to approximately 82m^2. A building on the west side of the rotary kiln facility that had remained idle since 2003 had a roof installed and a new attached building added. It is not clear if this activity was related to a long-term plan to reactivate the rotary kiln. Further to the south, a foundation had been poured for a new building on the southwest corner of the rail-served waste storage building. Within the area of the thermal plant, a third coal handling conveyor belt between the coal storage shed and boiler building was removed—leaving only one. The reason for the removal of the conveyor belts is unknown but likely due to a reduction in the number of operational boilers. Finally, among the support buildings on the east side of the plant, the partial frames of three buildings that had remained incomplete since 2003 were removed.



Slide 61: The headquarters and administration and north support area showing the new parade ground/parking area where the original monument used to be and a new building in the northeast corner of the west support area - September 26, 2011 (Copyright © 2020 by MAXAR Technologies)

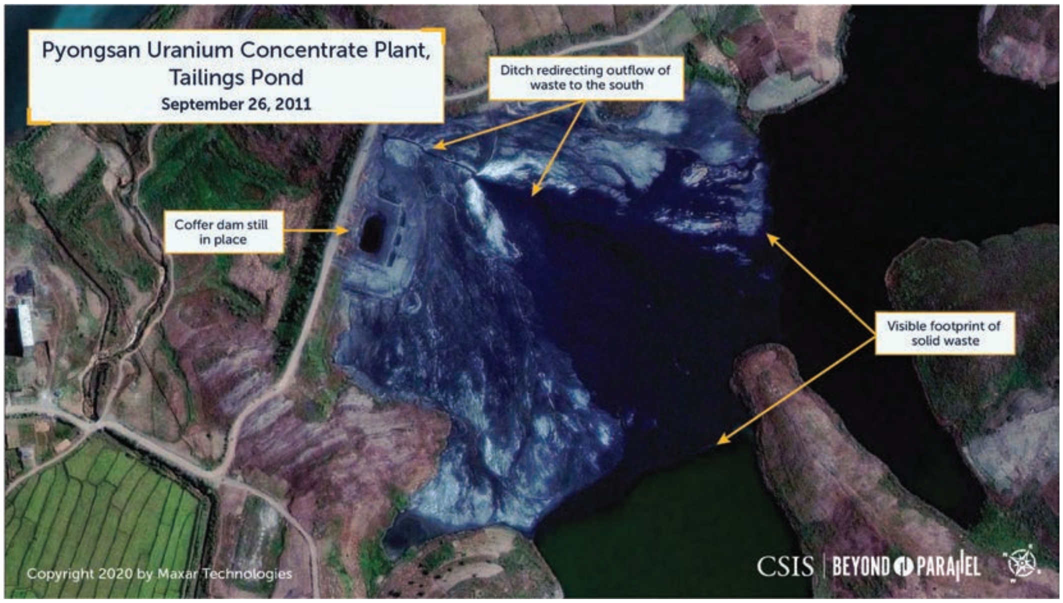


Slide 62: The center section of the main plant showing activity throughout the area, including excavation activity on the north side of the sampling and grinding building, the removal of the remaining components of the overhead conveyor belt system at the sampling and grinding building, and activity around the rotary kiln facility - September 26, 2011 (Copyright © 2020 by MAXAR Technologies)

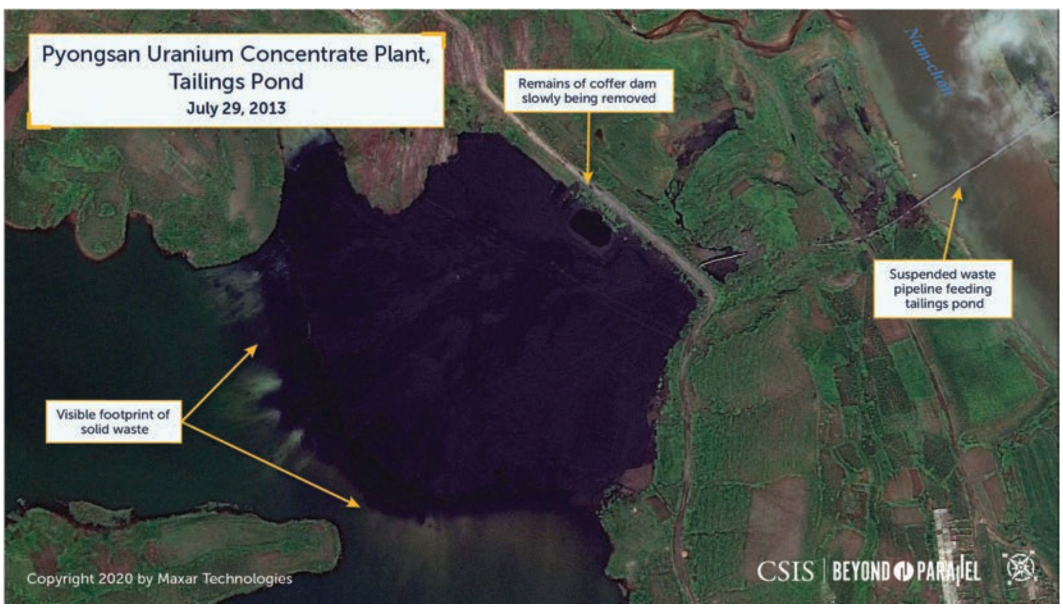


Slide 63: The eastern section of the main plant showing the removal of the overhead pipeline from the northeast waste storage facility to the agricultural fields to the northwest and the installation of a small overhead pipeline connecting the sampling and grinding building to the northeast waste storage facility - September 26, 2011 (Copyright © 2020 by MAXAR Technologies)

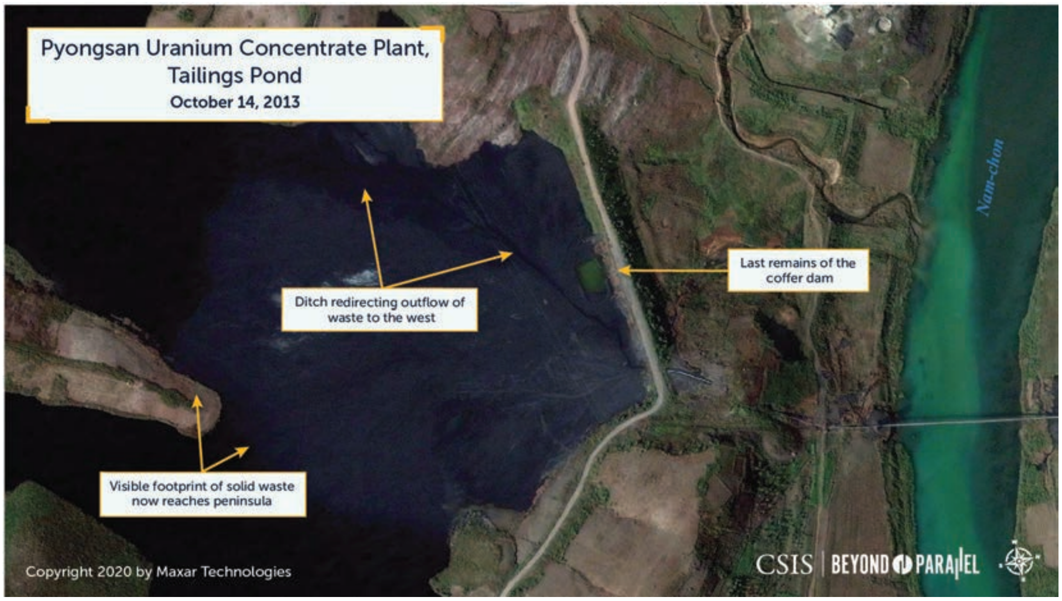
At the tailings pond, the cofferdam first observed during 2009 remained in place until sometime during mid-2013 when imagery from July 29, 2013, shows that the outer berms had been removed. Imagery acquired three months later on October 14, 2013, shows the final remains barely visible. There is no readily apparent explanation for this four-year activity, although its location (adjacent to the center of the dam) and duration suggests structural work on the dam itself.



Slide 64: The tailings pond showing the cofferdam still in place along the inside of the dam, expanding footprint of the precipitated solid waste, and ditches being excavated on the precipitated waste to reroute the waste outflow stream - September 26, 2011 (Copyright © 2020 by MAXAR Technologies)

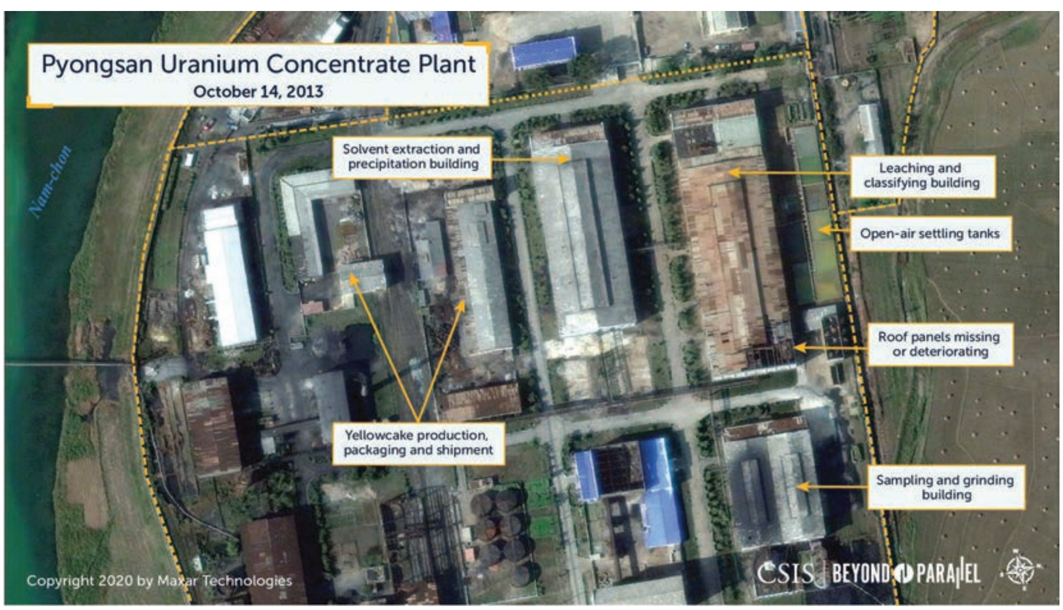


Slide 65: The tailings pond dam showing that the outer berms of the cofferdam have been removed - July 29, 2013 (Copyright © 2020 by MAXAR Technologies)



Slide 66: The tailings pond dam showing the final remains of the cofferdam just visible and the footprint precipitated solid waste now extends to the small peninsula separating the east and west bays - October 14, 2013 (Copyright © 2020 by MAXAR Technologies)

The image from October 14, 2013, also shows several other developments within the main plant during the three months since the July 29 image. The first and most notable of these was the continued deterioration of the roofing at the leaching and classifying building. Approximately 112m^2 of the roof was now missing or significantly degraded. At the northeast waste storage facility, the southern half was now empty but the northern half appears to be partially filled with liquid and solid waste. Finally, seven of the ten open-air settling tanks east of the rotary kiln facility were now dry.



Slide 67: The western and central sections of the main plant showing the significant increase in the degradation of the leaching and classifying building's roof - October 14, 2013 (Copyright © 2020 by MAXAR Technologies)

Slide 68: The eastern section of the main plant showing the changes to the northeast waste storage facility and the open-air settling tanks east of the rotary kiln facility - October 14, 2013 (Copyright © 2020 by MAXAR Technologies)

During 2013, ROK intelligence officials estimated that North Korea had spent between U.S. $2.8 and $3.2 billion on its nuclear development program, including expenses for construction, transport, logistics, etc. Of this amount, they further estimated that the North had spent $600-700 million on building its nuclear reactors, experimental light-water reactor, reprocessing plant, and the Pyongsan Uranium Concentrate Plant. The estimate of the amount spent to construct and operate the plant was not specified.[69]

2014-2017

A satellite image collected on May 2, 2014, shows that several new greenhouses were built in a continuing effort to improve the quality of life for the staff and workers—one within the courtyard of a building in the southern part of the headquarters and administration area and two immediately east of the rail-served waste storage building. This pattern of building additional greenhouses has continued until the present. This same image also shows that the maintenance and modernization projects begun during the previous period continued and, most significantly, that processing operations had likely been suspended. This suspension is indicated by the following:

- Six of the eight open-air settling tanks on the north side of the leaching and classifying building were dry and the remaining two appeared to be drying out.
- Nine of the ten open-air settling tanks at the facility east of the rotary kiln facility were dry and the facility was in the early stages of being razed as indicated by the razing of the associated support building.
- The building attached to the east side of the sampling and grinding building that served as the terminus of the feed pipeline from the mine complex's ore processing building was razed and the feed pipeline had been disconnected.
- Continued excavation activity was also observed on the side of the sampling and grinding building.

The deterioration of the roofs on buildings throughout the facility was noticeable during mid-2014. This was most evident at the leaching and classifying building where the amount of the missing or seriously degraded roofing on the building had now increased to approximately 354m^2 (some of this may have been in preparation for the replacement of the roof later in the year). By September 13, 2014, however, satellite imagery shows that North Korea had begun a significant project to address the serious problem of deteriorating roofs throughout the plant with approximately 19 structures receiving new roofs. By the end of the year, 21 buildings would be reroofed.[70]

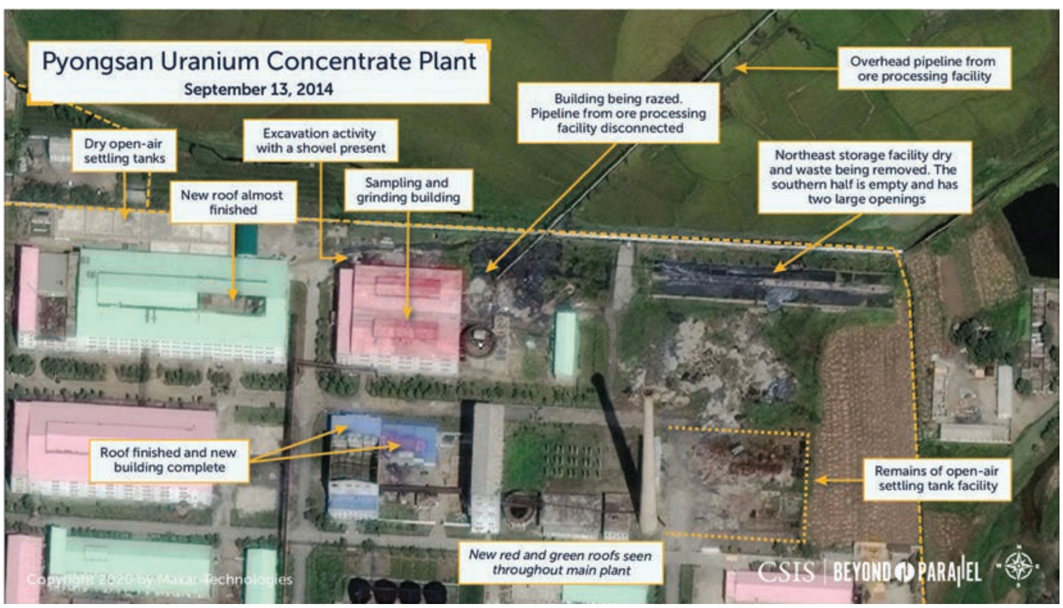
The September 13 satellite image also shows that other aspects of long-term maintenance and modernization projects continued during 2014. Among these developments were

- The start of a beautification project in the headquarters and administration area;
- The expansion of a small building on the south side of a building likely involved in yellowcake production and packaging;
- The razing of a support building on the north side of the leaching and classifying building and east of the open-air settling tanks;
- Within the rotary kiln facility, the roof on the building on the west side of the rotary kiln was now finished and the new building attached to it was externally complete;
- The roof of the rail-served waste storage building, which had remained only partially complete since 2003, was being completed;
- Using foundations poured in 2011, a small building was completed on the southwest corner of the rail-served waste storage building;
- The commencement of construction on the first of what would become two new small double-wall silos/stacks was observed between the rail-served waste storage building and wastewater treatment building;
- All eight open-air settling tanks at the leaching and classifying building were dry and the razing of the ten open-air settling tanks and support building on the east side of the waste treatment area was almost complete.

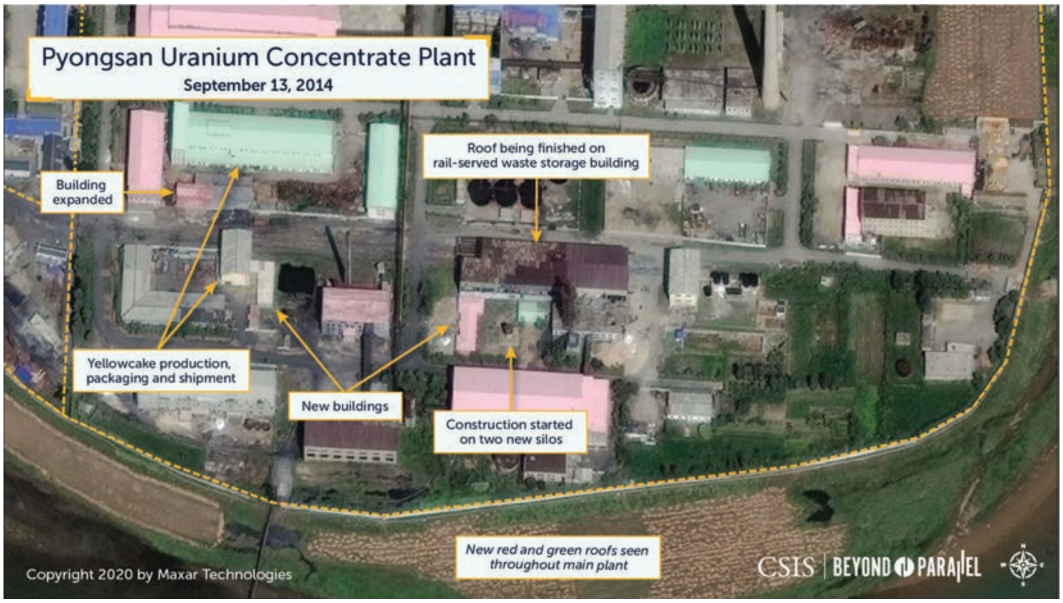
Three months later, an image acquired on December 30, 2014, shows that the open-air settling tanks at the leaching and classifying building remained idle, the razing of the ten open-air settling tanks was complete, the foundation for an eighth large fixed-top reagent/chemical storage tank was under construction, and a greenhouse on the east side of the waste treatment area had been completed.

While available imagery from early 2015 is limited, a March 5 image shows that the open-air settling tanks on the north side of the leaching and classifying building remained dry and covered with snow. Six months later, a September 9 image shows that the processing of ore and production of yellowcake had likely resumed as the open-air settling tanks at the leaching and classifying building were gradually refilling. Additionally, the pipeline from the ore processing facility to the sampling and grinding building had been reconnected and black exhaust dust was once again accumulating on the roof of the sampling and grinding building, indicating that it was again operational.

Slide 69: The headquarters and administration area and northwest section of the main plant showing the progress of the ongoing roof replacement project, the dry open-air settling tanks on the north side of the leaching and classifying building, and the razing of the building adjacent to the sampling and grinding building - September 13, 2014 (Copyright © 2020 by MAXAR Technologies)



Slide 70: The north-central and northeast sections of the main plant showing the progress of the ongoing roof replacement project, the dry open-air settling tanks adjacent to the leaching and classifying building, the pipeline from the ore processing facility to the sampling and grinding building is disconnected, the drying out northeast waste storage facility, and the final remains of the open-air settling tank facility east of the rotary kiln facility - September 13, 2014 (Copyright © 2020 by MAXAR Technologies)



Slide 71: The southern section of the main plant showing the progress of the ongoing roof replacement project. Note the finishing of the roof of the rail-served waste storage building - September 13, 2014 (Copyright © 2020 by MAXAR Technologies)

Slide 72: The headquarters and administration area and northwest and central sections of the main plant showing the dry open-air settling tanks on the north side of the leaching and classifying building, foundation for an eighth fixed-top storage, and the new greenhouse - December 30, 2014 (Copyright © 2020 by MAXAR Technologies)

The construction, operation, and subsequent razing of the open-air settling tank east of the rotary kiln facility during 2009 to 2014, while the original open-air settling tanks at the leaching and classifying building continued to operate, suggests three likely explanations:

1. North Korea's nuclear weapons program had a dramatically increased requirement for yellowcake during the five-year period from 2009 through April 2014
2. This was undertaken in anticipation of the forthcoming suspension of processing to allow for the replacement of roofs and other major maintenance projects

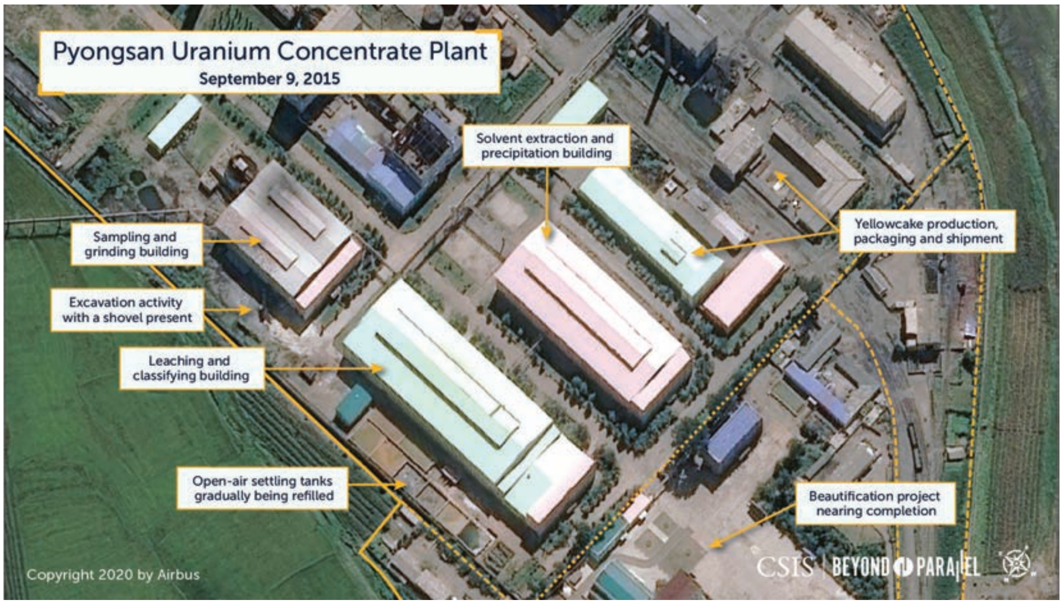
3. A combination of both the above

This five-year period from 2009 to 2014 was followed by seven to twelve months during which uranium processing operations were likely suspended. This suspension is indicated by the rerouting of the ore supply pipe at the sampling and grinding building during April-August 2014 and the dry open-air settling tanks at the leaching and classifying building from April 2014 through mid-2015. Although no information is available, this year-long period of large-scale maintenance and modernization and temporary suspension of uranium processing operations would have been an opportune time for the refurbishment or modernization of equipment within the larger production buildings.

The image from September 9, 2015, shows that other aspects of the maintenance and modernization project had also continued. The beautification project within the headquarters and administration area was nearing completion. The open-air settling tanks adjacent to the leaching and classifying building were gradually being refilled. Construction of the eighth large fixed-top reagent/chemical storage tank was now complete. At the northeast waste storage facility, the breaches in the south half were closed and the facility was once again beginning to store waste from the sampling and grinding building. Finally, on the site formerly occupied by the ten open-air settling tanks east of the rotary kiln facility, two large greenhouses were built.

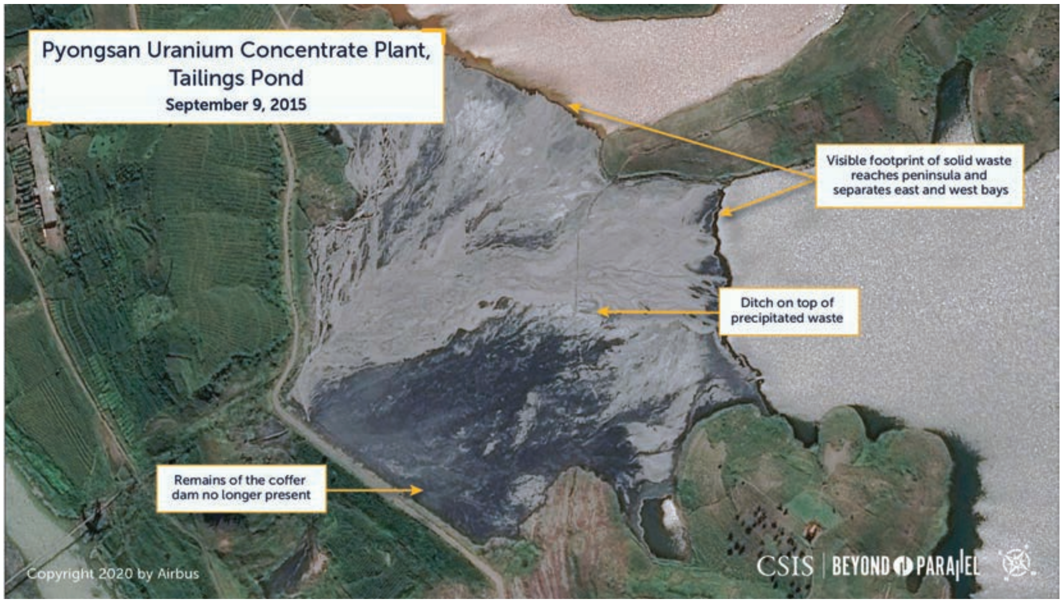
Slide 73: The headquarters and administration area and northwest section of the main plant showing the roof replacements on the buildings in these areas, foundations for the new greenhouse, finishing stages of the beautification project, and the gradual refilling of the open-air settling tanks on the north side of the leaching and classifying building - September 9, 2015 (Copyright © 2020 by Airbus)

At the tailings pond, the level of waste sediment continued to accumulate and close off the mouths of both the east and west bays. By September 9, 2015, it apparently became more challenging to both evenly distribute and deposit the sediment further away from the dam. To address these issues, a pumphouse was built at the northeast corner of the dam sometime between October 5, 2016, and May 2, 2017, to provide additional pressure to pump the waste further south and away from the dam. Subsequently, as the solid waste continued to accumulate on the north end of the tailings pond, the small ditches that were previously being excavated to distribute the waste evenly were no longer alone adequate to the task. Imagery from July 26, 2017, shows that while the excavation of ditches continued, a new solution was also being put into effect. This solution included connecting what appear to be lightweight pipes directly to the outfall from the pumphouse in an effort to transport and distribute the waste even greater distances to the south.

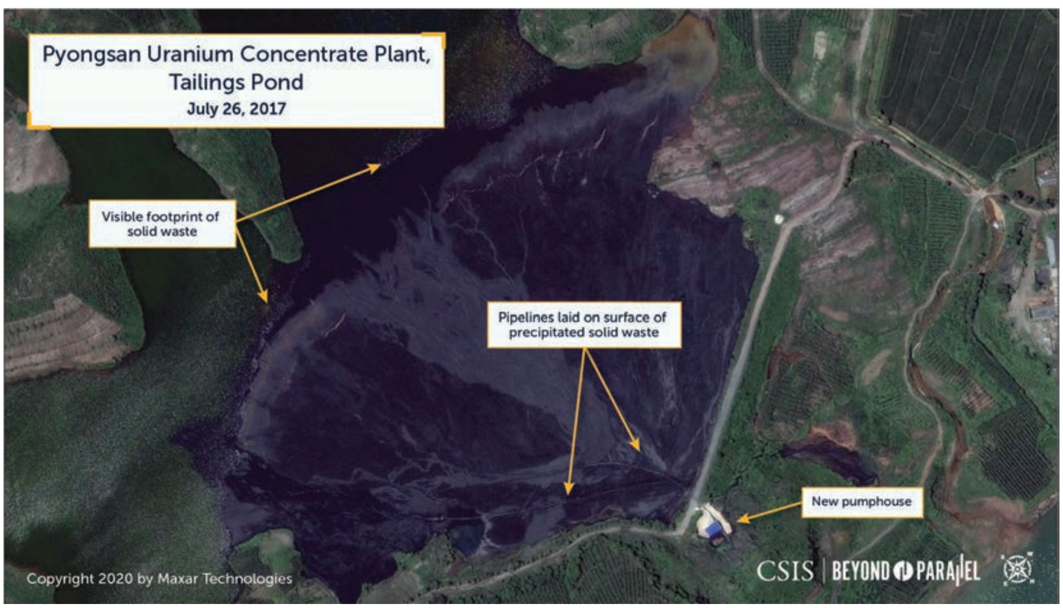


Slide 74: The central section of the main plant showing the roof replacements on the buildings in these areas. The pipeline from the ore processing facility to the sampling and grinding building was now connected, and the open-air storage tanks at the leaching and classifying building were being used again - September 9, 2015 (Copyright © 2020 by Airbus)

Slide 75: The eastern section of the main plant showing the construction of two large greenhouses had begun on the site of the former settling tank facility east of the rotary kiln facility and that the northeast waste storage facility was beginning to be used again - September 9, 2015 (Copyright © 2020 by Airbus)



Slide 76: By September 2015, the mouths of both the east and west bays had been closed by accumulated precipitated solid waste. A small ditch is visible on top of the precipitated waste leading to the west bay - September 9, 2015 (Copyright © 2020 by Airbus)

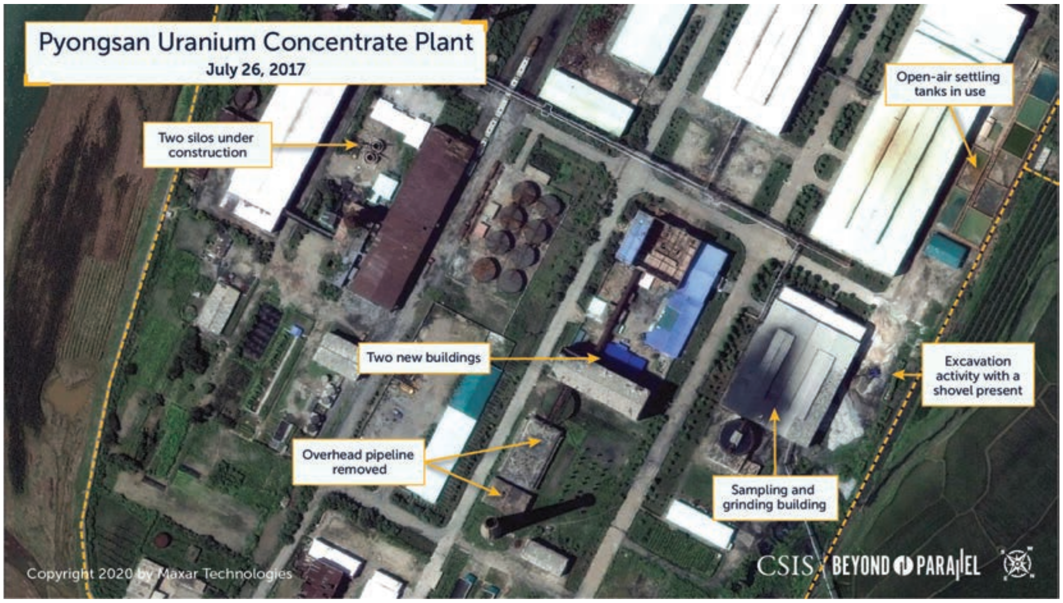


Slide 77: Visible in this 2017 image of the tailings pond are the new pumphouse and that the mouths of both the east and west bays have been closed by the accumulation of precipitated solid waste - July 26, 2017 (Copyright © 2020 by MAXAR Technologies)

With the larger maintenance and modernization projects completed, an image from July 26, 2017, now shows that a number of smaller but important projects were being undertaken. These included the construction of a small building (likely a guard booth) and greenhouse within the headquarters and administration area, the pouring of a new building foundation between the coal storage shed and the thermal plant, the removal of an overhead pipe leading from the center building to the incinerator and stack, the construction of two small buildings within the rotary kiln facility, and the continued construction progress on the two double-wall silos/stacks between the rail-served waste storage building and wastewater treatment building. On the east side of the plant, two greenhouses were completed, two new support buildings were built or under construction, and the northeast waste storage facility that had the openings closed-in was again being used to store waste from the sampling and grinding building.

Slide 78: The headquarters and administration area and northwest section showing the construction of a small building (likely a guard booth) and a new greenhouse – July 26, 2017 (Copyright © 2020 by MAXAR Technologies)

Slide 79: The western section of the main plant showing the active use of the open-air settling tanks adjacent to the leaching and classifying building, the addition of a new building among the yellowcake production and packaging buildings, a new building foundation between the coal storage shed and the thermal plant, and two silos/stacks under construction south of the rail-served waste storage building – July 26, 2017 (Copyright © 2020 by MAXAR Technologies)



Slide 80: The center section of the main plant showing the two silos/stacks under construction, removal of an overhead pipeline and new buildings within the rotary kiln facility, and the rapidly accumulating exhaust dust and excavation activity at the sampling and grinding building - July 26, 2017 (Copyright © 2020 by MAXAR Technologies)

Slide 81: The eastern section of the plant showing the removal of an overhead pipeline within the rotary kiln facility - July 26, 2017 (Copyright © 2020 by MAXAR Technologies)

While the above developments were taking place during 2009-2017, significant changes had also occurred at the uranium mining complex with a number of shafts being decommissioned or idle:

- Shaft A continued operations until early-2015 when the headframe was removed.
- Shaft B remained in operation until about late 2013 when it appears to have suspended operations. The headframe, however, remained in place.

- Shaft C continued operations until sometime between 2009-2011. At that time, operations appear to have decreased to minimal levels. The headframe, however, remained in place.
- Shaft D continued operations until sometime between 2007-2011. The headframe was removed during early to mid-September 2015.
- Shaft E continued operations until sometime between August 2010 and March 2011. The headframe was partially removed sometime between 2011 and 2013 and completely removed by July 2017.
- The large tailings/storage pile south of Shaft E remained relatively untouched until 2011 when small sections of it were excavated. It then remained unchanged through 2018.
- The large tailings piles immediately west and north of the ore processing facility continued to grow steadily through 2013. Starting during 2014 and continuing through 2017, they rapidly expanded up the small valley to the north.

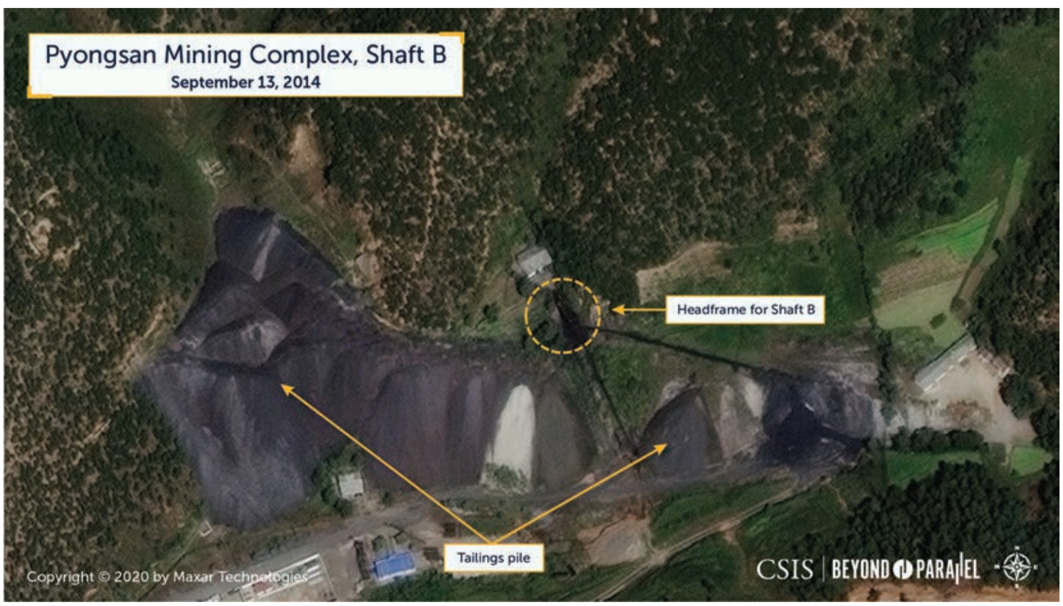
2018-Present

A satellite image collected on July 4, 2018, shows that while newer maintenance and modernization projects continued, they were less ambitious in nature and at a slower rate than the previous four years. Among these were

1. The construction of a new building in the headquarters and administration area
2. Completion of a building between the coal storage shed and the thermal plant
3. Completion of the two double-wall silos/stacks on the small incinerator/boiler building located between the rail-served waste storage building and wastewater treatment building
4. The construction of a small building adjacent to the eight reagent/chemical fixed-top storage tanks
5. The pouring of a foundation for a new building on the east side of the sampling and grinding building
6. Partially filling the northeast storage facility with waste from the grinding and sampling building
7. The pouring of a foundation for a new greenhouse in the support area on the east side of the plant

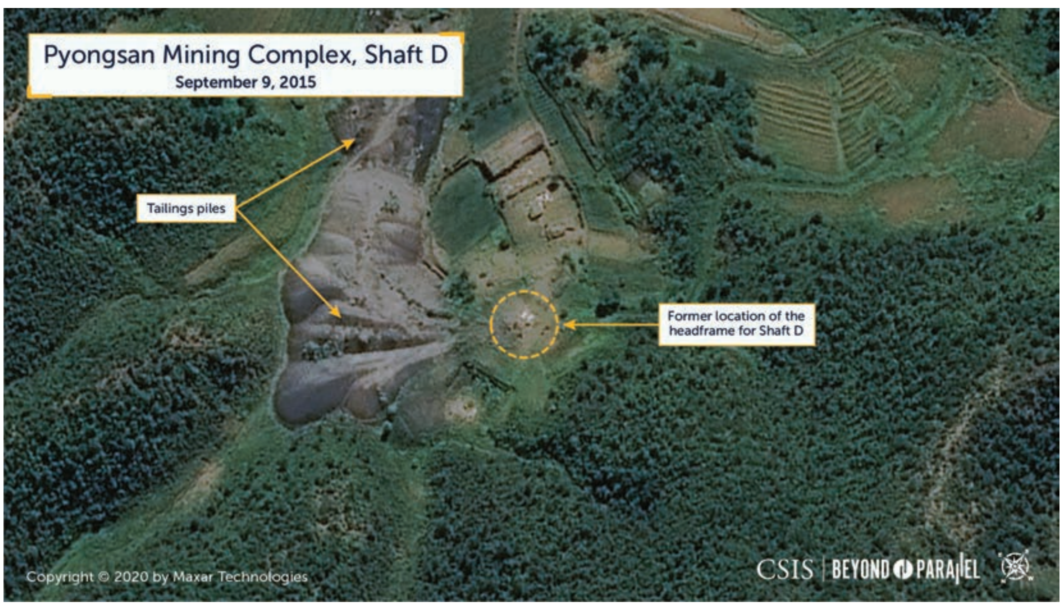
At the tailings pond, the use of lightweight pipes attached directly to the outfall from the pumphouse had helped somewhat to transport and distribute the waste; however, it ultimately proved to be inadequate to the growing task. Therefore, construction began of a second pumphouse. The foundation for this second pumphouse was first observed in imagery collected on July 4, 2018. The foundation sits approximately 175 meters south-southeast of the original pumphouse along the east shoreline, and the pumphouse would become operational shortly afterward. Patterns of waste distribution on the tailings pile indicate that waste slurry was subsequently being switched back and forth from being directly pumped into the waste pond from the first pumphouse to being pumped from the first pumphouse to the second pumphouse via a pipeline. The second pumphouse then pumps the waste further to the south into the east bays of the tailings pond.

Slide 82: The ore processing facilities and the former location of the Shaft A headframe, which has been removed - September 9, 2015 (Copyright © 2020 by MAXAR Technologies)

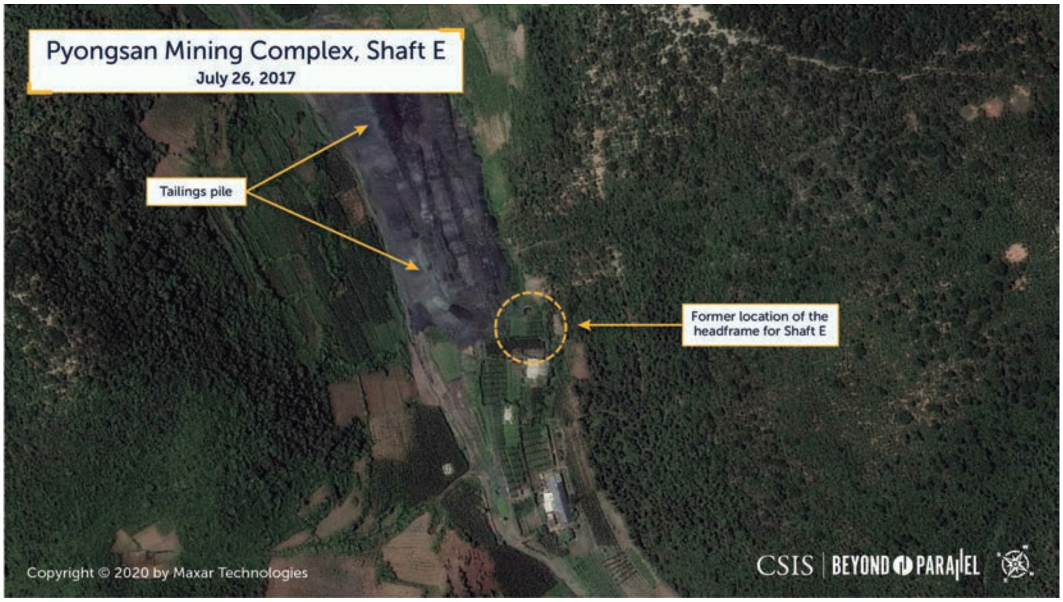


Slide 83: The headframe and tailings piles at Shaft B - September 13, 2014 (Copyright © 2020 by MAXAR Technologies)

Slide 84: The headframe and tailings piles at Shaft C - May 19, 2009 (Copyright © 2020 by MAXAR Technologies)

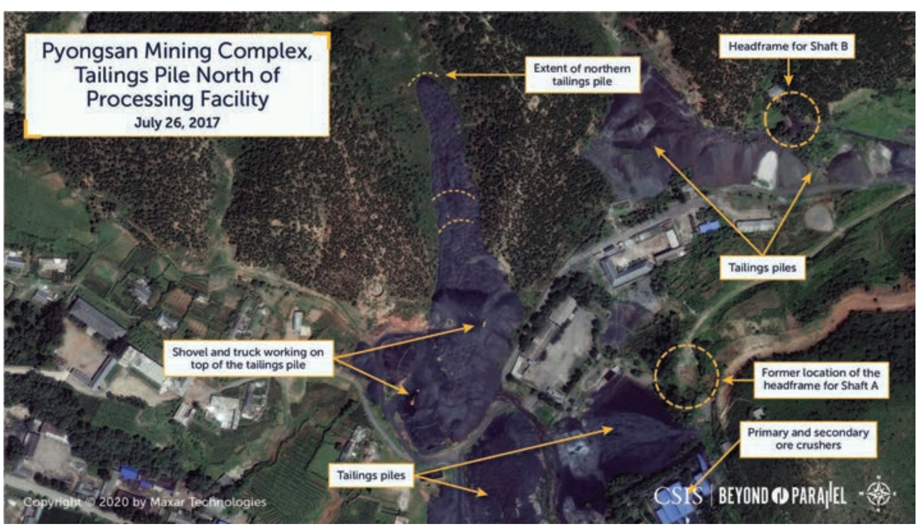


Slide 85: The headframe and tailings piles at Shaft D - September 9, 2015 (Copyright © 2020 by MAXAR Technologies)

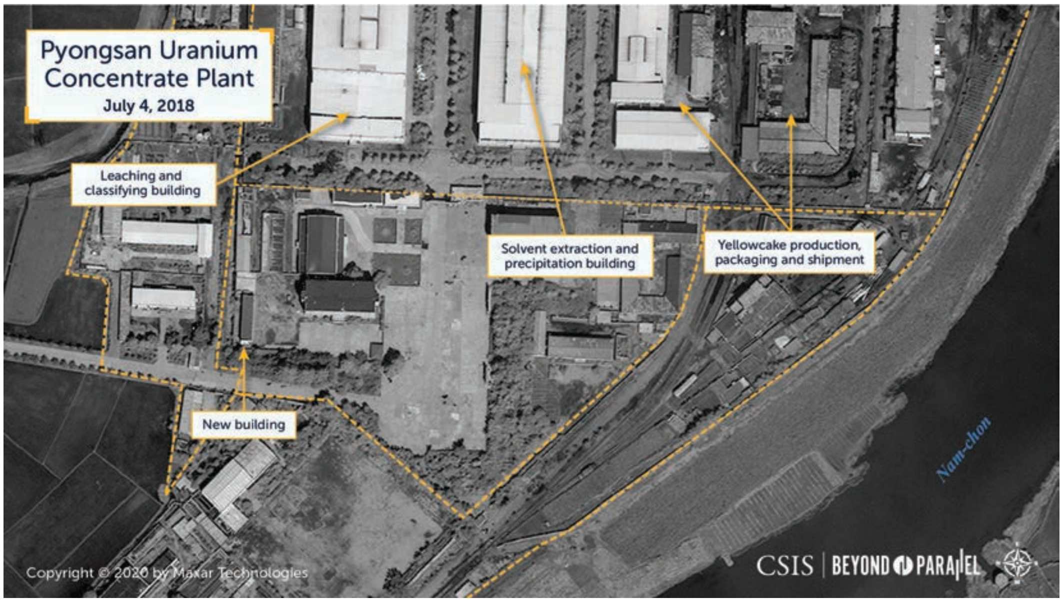


Slide 86: The headframe and tailings piles at Shaft E - May 26, 2017 (Copyright © 2020 by MAXAR Technologies)

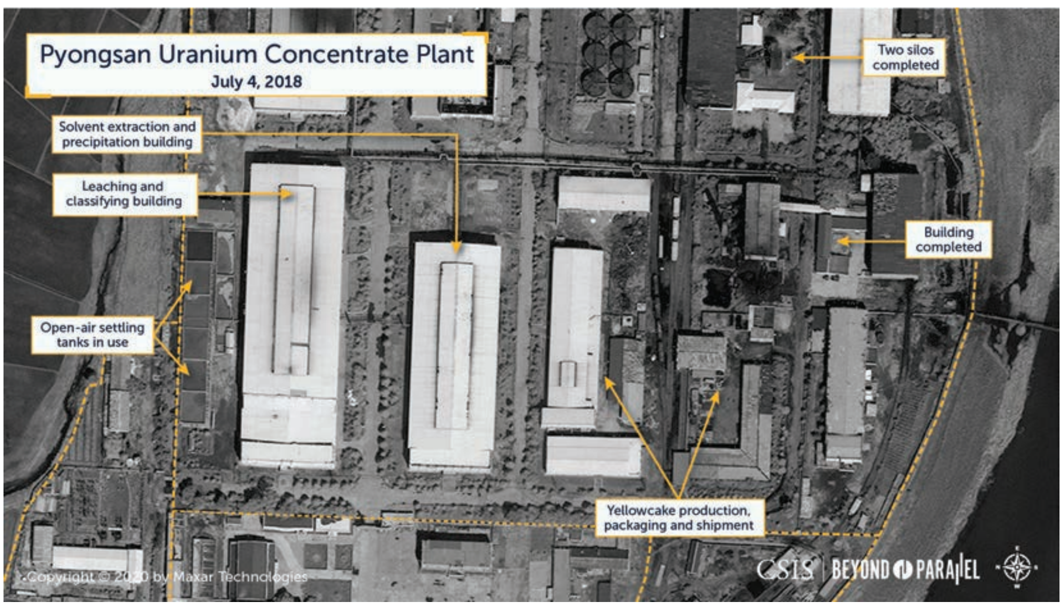
Slide 87: The tailings pile south of Shaft E - July 26, 2017 (Copyright © 2020 by MAXAR Technologies)



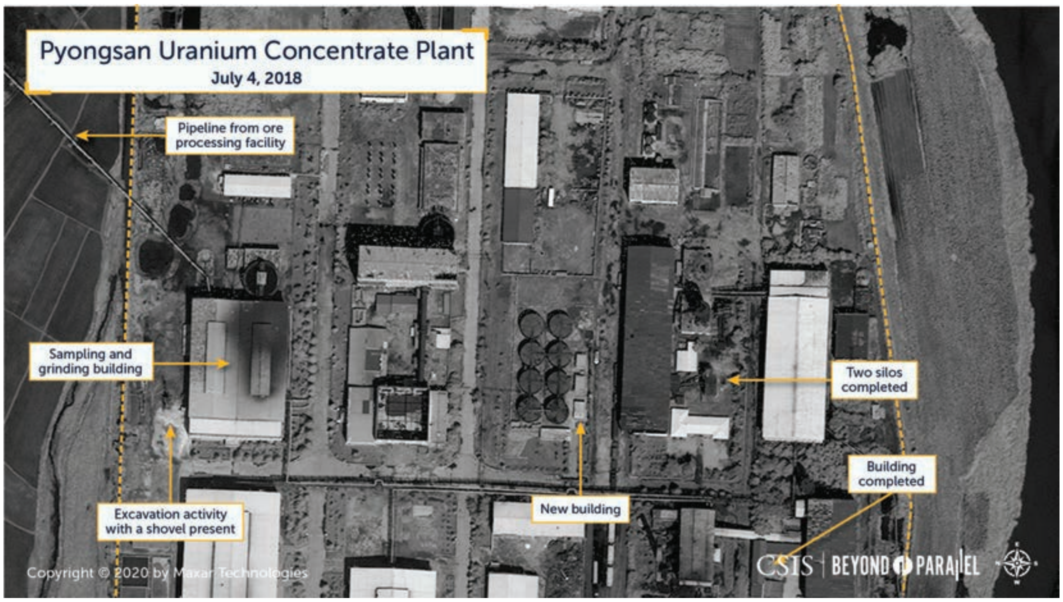
Slides 88–90: A series of images showing the growth of the tailings pile north of the ore processing facility - 2013-2017 (Copyright © 2020 by MAXAR Technologies)



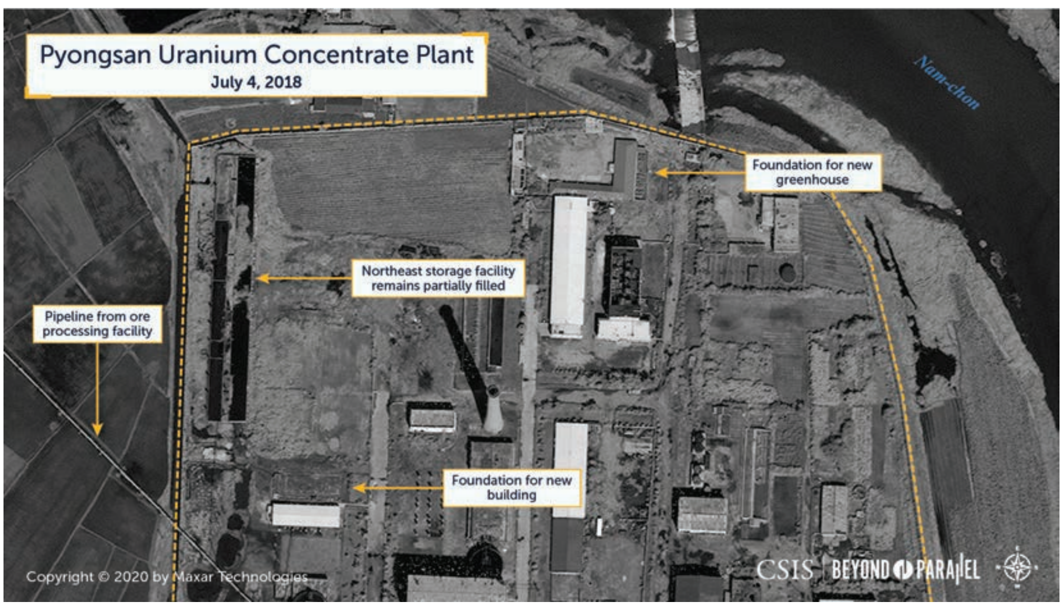
Slide 91: The headquarters and administration area showing the newly completed building – July 4, 2018 (Copyright © 2020 by MAXAR Technologies)



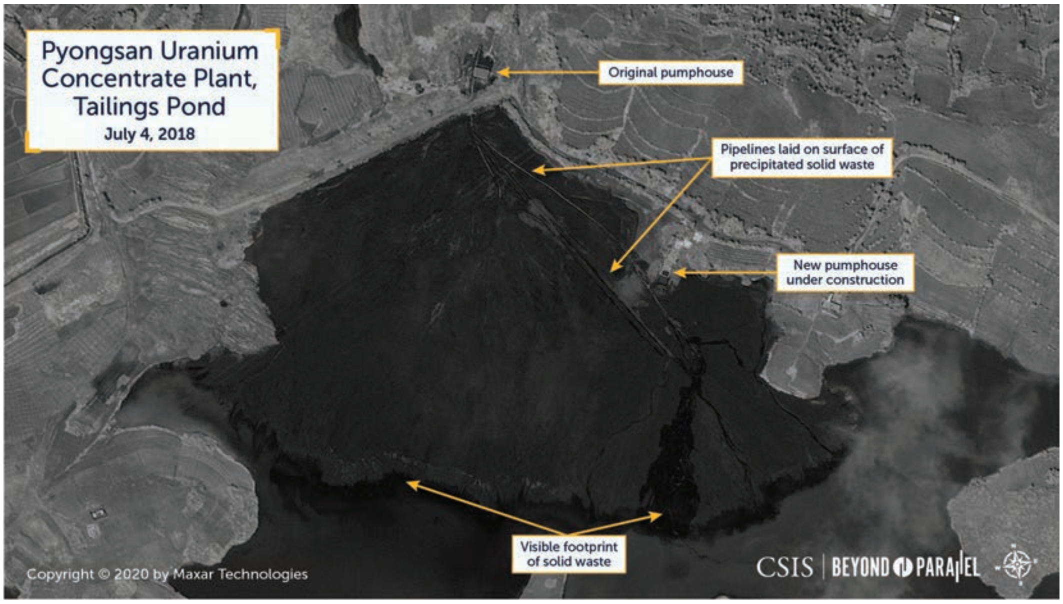
Slide 92: The western section of the main plant showing the active use of the open-air settling tanks adjacent to the leaching and classifying building, the completion of a new building adjacent to the thermal plant, and the completion of the two silos/stacks south of the rail-served waste storage building - July 4, 2018 (Copyright © 2020 by MAXAR Technologies)



Slide 93: The center section of the main plant showing the completed two silos/stacks, the new building adjacent to the fixed-top reagent/chemical tanks, and continuing excavation activity at the sampling and grinding building - July 4, 2018 (Copyright © 2020 by MAXAR Technologies)

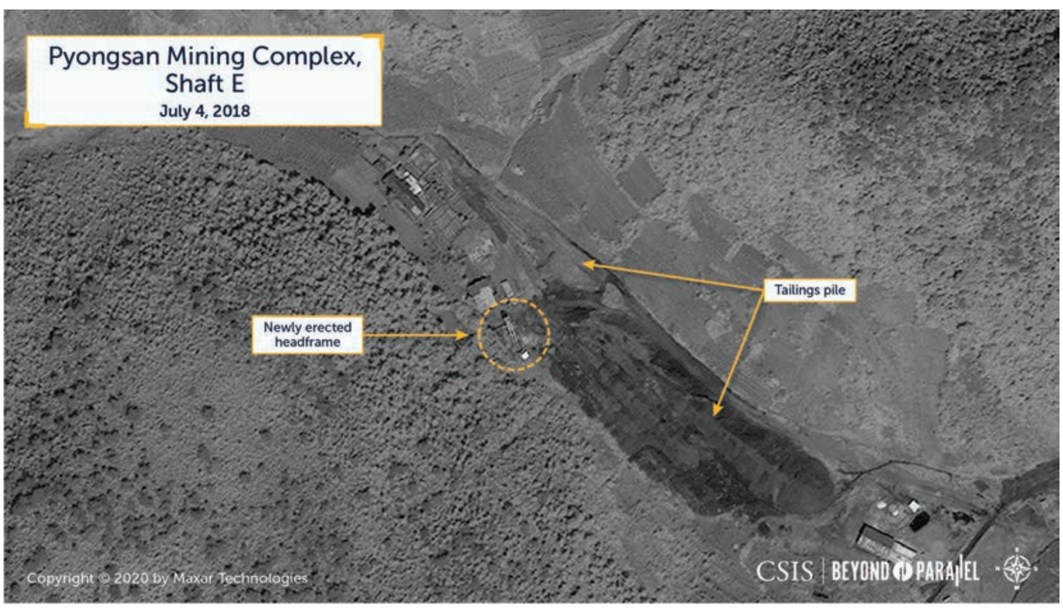


Slide 94: The eastern section of the main plant showing the foundation of a new building east of the sampling and grinding building, the use of the northeast storage facility for storing waste from the grinding and sampling building, and the foundation of a new greenhouse in the support area on the east side of the plant - July 4, 2018 (Copyright © 2020 by MAXAR Technologies)



Slide 95: The tailings pond showing the original pumphouse and the second pumphouse under construction. Also visible are the lightweight pipes laid on top of the precipitated solid waste to direct the waste outflow - July 4, 2018 (Copyright © 2020 by MAXAR Technologies)

The image for July 4, 2018, also shows a newly erected headframe over Shaft E. The original headframe here was partially removed sometime between 2011 and 2013 and completely removed by July 2017.

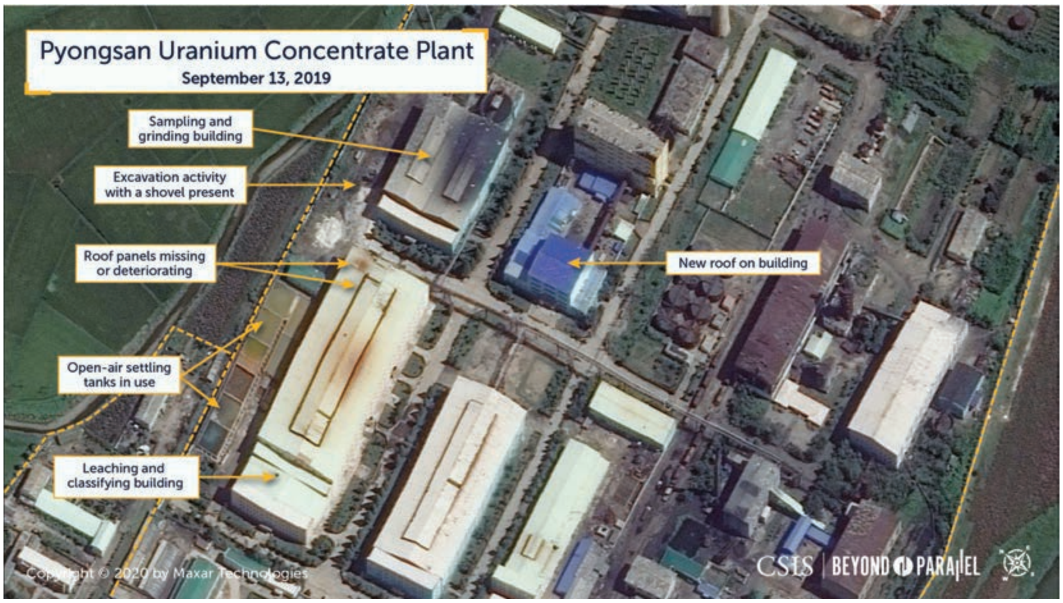


Slide 96: The new headframe installed at Shaft E - July 4, 2018 (Copyright © 2020 by MAXAR Technologies)

In a report issued by the International Campaign to Abolish Nuclear Weapons in 2020, it was estimated that North Korea spent an estimated $620 million on its nuclear program during 2018, and a similar amount is believed to have been spent during 2019.[71] No separate estimates, however, were made on the amount spent on operating the Pyongsan Uranium Concentrate Plant and its associated facilities.

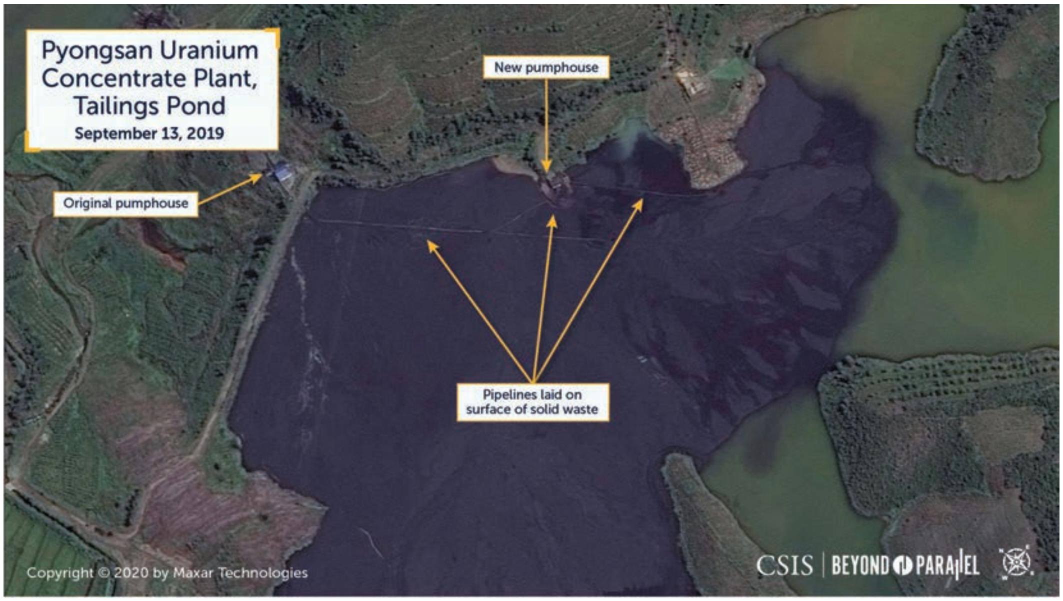
Developments observed in satellite imagery collected between July 4, 2018, and September 13, 2019, confirm that the plant was operational and minor elements of the long-term maintenance and modernization project continued. The open-air settling tanks at the leaching and classifying building were largely full; however, damage to the roof of the leaching and classifying building had once again become significant. Excavation activity was again noted on the north side of the sampling and grinding building and a shovel was still present. The westernmost building at the rotary kiln facility, which had remained without a roof since at least 2003, had a roof installed. Portions of the tailings/storage pile south of Shaft E was observed to have been excavated once again. The reasons for this are unknown, though it may be related to the recovery of small quantities of uranium ore. Finally, at the tailings pond, both pumphouses were operational and pipes were laid on top of the precipitated solid waste. These extend both from the first pumphouse to the second and onto the east bay, as well as from the first pumphouse directly to the west bay. Earlier this year, imagery collected on March 22, 2020, showed ongoing activity. The damage on the clerestory and roof of the leaching and classifying building had become significant enough that sections of the roof in the northeast corner of the building had once again been repaired or replaced. While operations here may have been suspended to undertake these repairs, any such suspension does not appear to have been for any significant length of time as ongoing activity at the adjacent settling ponds is noted. Both a new building east of the sampling and grinding building and a greenhouse in the support area on the east side of the plant were completed.

Continuing excavation activity was noted at the sampling and grinding building and some piles were now being placed near the northeast corner of the leaching and classifying building. This excavation activity appears to have been for the removal of ore waste from inside the building. During January-March 2020, this waste was then spread out along the northern security wall extending from the sampling and grinding building over the northern (presumably razed) section of the northeast waste storage facility and then out a new opening in the northeast corner of the security wall. It was then extended approximately 160 meters to the east. Most recently, an image collected on April 14, 2020, shows that the opening at the northeast corner of the security wall was closed. While the activities observed at the sampling and grinding building and northeast waste storage facility are likely for the removal of accumulated waste material from the interior of the building and major equipment repairs or replacement, they could potentially be early indicators of an intention to supply ore to the plant by truck sometime in the future.

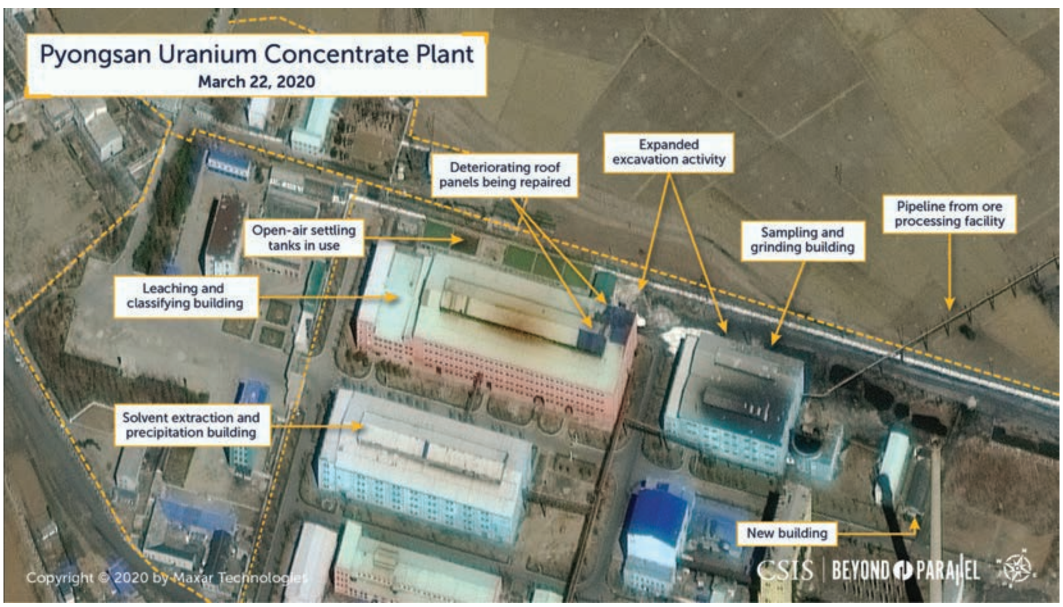


Slide 97: The center section of the main plant showing the roof added to the westernmost building of the rotary kiln facility and a slight deterioration to the roof panels on the northeast corner and clerestory of the leaching and classifying build - September 13, 2019 (Copyright © 2020 by MAXAR Technologies)

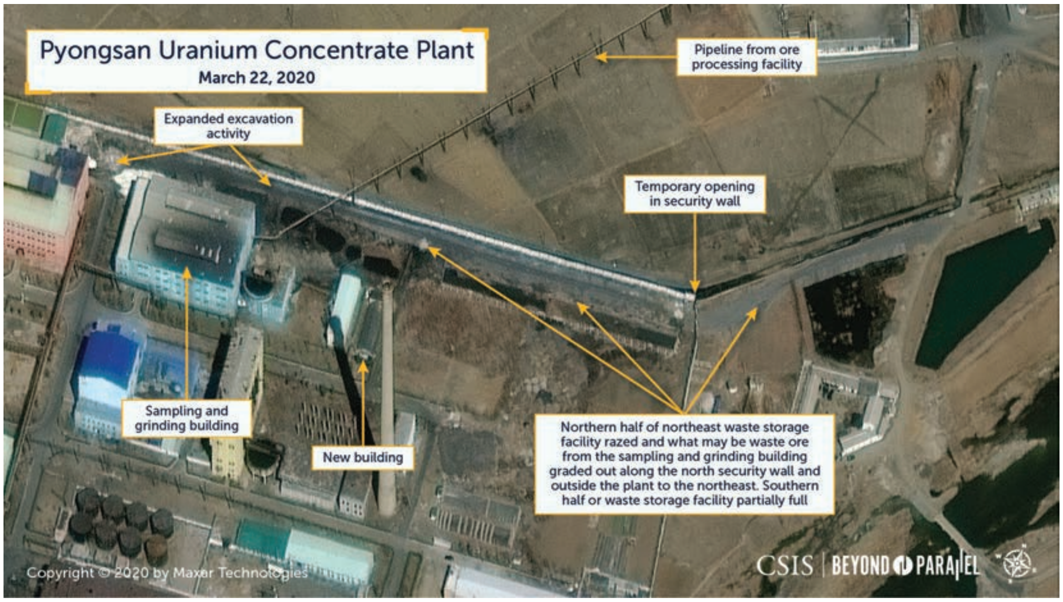
Slide 98: A view of the excavation activity at the tailings pile south of Shaft E - September 13, 2019 (Copyright © 2020 by MAXAR Technologies)



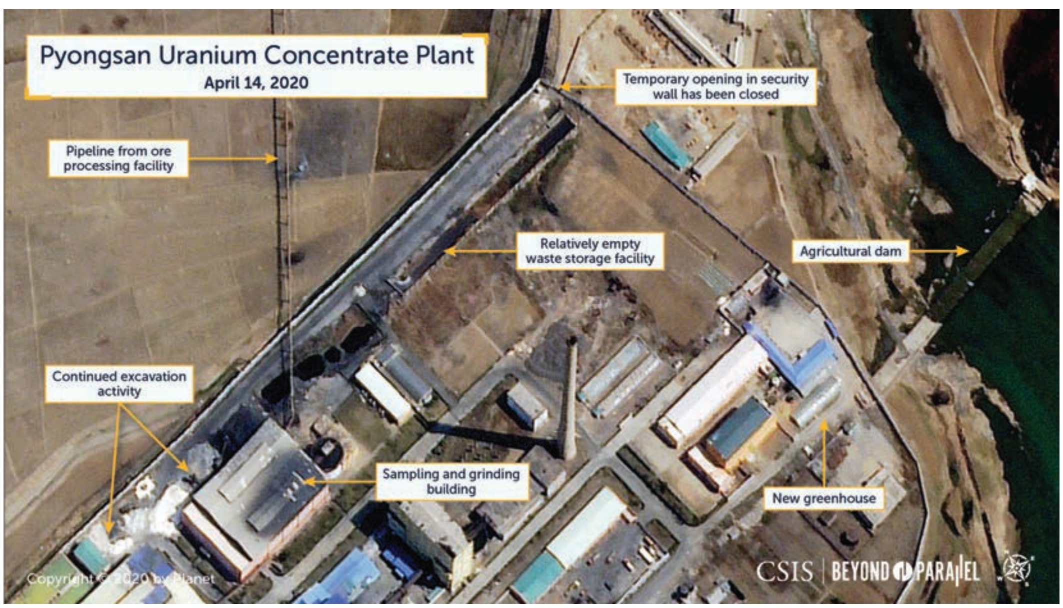
Slide 99: The tailings pond showing the pipes laid on top of the accumulated solid waste connecting the first and second pumphouse and directing the waste flow to the east bay - September 13, 2019 (Copyright © 2020 by MAXAR Technologies)



Slide 100: The center section of the main plant showing the repairs undertaken on the roof and clerestory of the leaching and classifying building, the open-air settling tanks in use, and the continuing excavation activity at the sampling and grinding building - March 22, 2020 (Copyright © 2020 by MAXAR Technologies)



Slide 101: The northeast waste storage facility showing the razing of the northern half and the graded out of gravel or waste ore along the north security wall and outside the plant to the northeast. Also visible is the completion of a new building east of the sampling and grinding building - March 22, 2020 (Copyright © 2020 by MAXAR Technologies)



Slide 102: The northeast section of the main plant showing continued excavation activity at the sampling and grinding building, the graded area along the north security wall, the southern portion of the northeast waste storage relatively empty, and the new greenhouse in the support area on the west side of the plant - April 14, 2020 (Copyright © 2020 by Planet)

Satellite imagery acquired on April 14, 2020, confirms that the Pyongsan Uranium Concentrate Plant and its associated support areas, tailings pond, and January Industrial Mine remain operational and are continuing to be maintained and updated.

3 | Summary

Analysis of commercial medium- and high-resolution imagery from the 1970s to present and declassified satellite imagery from the mid-1970s through the early 1980s, combined with limited open source information and author interview data, indicates that the Pyongsan Uranium Concentrate Plant and its associated support areas, tailings pond, and uranium mining complex have been operational since the early to mid-1990s. These facilities have been and are actively being maintained, refurbished, or modernized throughout this period. Given the current level of development and activity observed at the plant and its associated facilities, barring unforeseen developments, it is highly likely to remain active for the foreseeable future.

This same body of data also indicates that the plant represents a critical component in North Korea's nuclear research and weapons programs as the sole verified producer of uranium concentrate (yellowcake) in the country.[72]

4 | Research Note

This report is, in part, based upon an ongoing study of North Korea's nuclear program and infrastructure begun by Joseph S. Bermudez Jr. in 1988. Various parts of this study were subsequently published by the author over the years.[73] The information presented here supersedes or updates these and other previous works by the author on these subjects.

About the Authors

Joseph S. Bermudez Jr. is an internationally recognized analyst, award-winning author, and lecturer on North Korean defense and intelligence affairs and ballistic missile development in developing countries. He is concurrently senior fellow for Imagery Analysis at the Center for Strategic and International Studies (CSIS); senior adviser and imagery analyst for the Committee for Human Rights in North Korea (HRNK); author for IHS Markit (formerly the Jane's Information Group); and publisher and editor of KPA Journal. Formerly, he has served as founder and chief analytics officer of KPA Associates, LLC, senior imagery analyst for 38 North at Johns Hopkins SAIS, chief analytics officer and co-founder of AllSource Analysis, Inc., and senior all-source analyst for DigitalGlobe's Analysis Center.

He has authored four books and more than 400 articles, reports, and monographs on numerous defense-related subjects. Mr. Bermudez has consulted and lectured extensively in academic and government environments both in the United States (e.g., National Defense University, Columbia University, Federal Bureau of Investigation, Los Alamos National Laboratories, Stanford University, U.S. Marine Corps University, U.S. Army Intelligence, U.S. Naval Intelligence, U.S. Navy Postgraduate School) and internationally (e.g., United Nations, Israel Defense Forces, International Institute for Strategic Studies, Republic of Korea National Defense College). He has also testified before the United Nations and U.S. Congress as a subject matter expert concerning North Korea's ballistic missile and nuclear, chemical and biological warfare programs, satellite imagery of North Korean political prisoner camps, and ballistic missile development in the developing countries.

Victor Cha joined the Center for Strategic and International Studies in Washington, D.C. in May 2009 as a senior adviser and the inaugural holder of the Korea Chair. He is professor of government and holds the D.S. Song-KF Chair in the Department of Government and the School of Foreign Service (SFS) at Georgetown University. In July 2019, he was appointed vice dean for faculty and graduate affairs in SFS. He left the White House in 2007 after serving since 2004 as director for Asian affairs at the National Security Council (NSC). At the White House, he was responsible primarily for Japan, the Korean peninsula, Australia/New Zealand, and Pacific Island nation affairs. Dr. Cha was also the deputy head of delegation for the United States at the Six-Party Talks in Beijing and received two outstanding service commendations during his tenure at the NSC. He is the author of five books, including the award-winning *Alignment Despite Antagonism: The United States-Korea-Japan Security Triangle* (Stanford University Press, 1999) (winner of the 2000 Ohira Book Prize) and *The Impossible State: North Korea, Past and Future* (Harper Collins Ecco, 2012), which was selected by *Foreign Affairs* as a "Best Book on the Asia-Pacific for 2012." His newest book is *Powerplay: Origins of the American Alliance System in Asia* (Princeton University Press, 2016). He is also writing a new book on Korean unification. He has published articles on international relations and East Asia in journals, including *Foreign Affairs*, *Foreign Policy*, *International Security*, *Political Science Quarterly*, *Survival*, *International Studies Quarterly*, *International Journal of the History of Sport*, and *Asian Survey*.

Dr. Cha is a former John M. Olin National Security Fellow at Harvard University, two-time Fulbright Scholar, John D. and Catherine T. MacArthur Scholar at Columbia University, and Hoover National Fellow, CISAC Fellow, and William J. Perry Fellow at Stanford University. He is currently a fellow in Human Freedom (non-resident) at the George W. Bush Institute in Dallas, Texas. Dr. Cha serves on 10 editorial boards of academic journals and is co-editor of the *Contemporary Asia* Book Series at Columbia University Press. He is a member of the Council on Foreign Relations and the Fulbright Association. He has been the principal investigator on 21 major research grant projects, ranging between $40,000 and $1.6 million from private foundations and the U.S. government. He has testified before Congress numerous times on Asian security issues. In 2018, he joined NBC and MSNBC as a contributor. Prior to joining NBC, he had been a guest analyst for various media including CNN, ABC, CBS, The Colbert Report, *Sports Illustrated*, ESPN, Fox News, PBS, *HuffPost*, *Wall Street Journal*, CNBC, BBC, and National Public Radio. His op-eds have appeared in the *Washington Post*, *New York Times*, *Los Angeles Times*, *Bloomberg*, *USA Today*, *Foreign Policy*, *Japan Times*, *FEER*, and *Financial Times*. He works as an independent consultant helping clients in sectors ranging from business and finance to entertainment. Dr. Cha received his Ph.D. in political science at Columbia University in 1994, his Master's in international affairs from Columbia in 1988, an M.A. with honors in philosophy, politics, and economics from Oxford University (Hertford College), and an A.B. in economics from Columbia in 1979.

Bonny Lee was a research assistant for imagery analysis with the iDeas Lab and Korea Chair at the Center for Strategic and International Studies (CSIS). By utilizing imagery in close liaison with program partners, Mr. Lee's work strived to provide a unique visual perspective to enhance research. Prior to joining CSIS, Mr. Lee earned a B.A. in political science and international relations from Carleton College.

Endnotes

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During the layout of this report a blog posting by *Arms Control Wonk* was published covering the Pyongsan Uranium Concentrate Plant. See: dave Schmerler, "A Satellite Imagery Review of the Pyongsan Uranium Mill," Arms Control Wonk, July 1, 2020, https://www.armscontrolwonk.com/archive/1209625/pyongsan-uranium-mill/.

2 Joseph Bermudez and Victor Cha, "Pakchon Uranium Concentrate Pilot Plant," August 21, 2019, Beyond Parallel (CSIS Korea Chair), https://beyondparallel.csis.org/pakchon-uranium-concentrate-pilot-plant/.

3 Since the late-1990s, there have been occasional private and public reports of additional uranium concentrate and other nuclear-related activities at different locations in North Korea. While it is likely that there are or have been such activities, almost all of the readily available reports have internal inconsistencies, remain to be verified, and should be viewed with caution.

Although called yellowcake because of the general yellowish color of the final product, it can vary in color from yellow to dark green depending upon the temperature at which it was dried. "Nuclear explained – The nuclear fuel cycle," EIA, https://www.eia.gov/energyexplained/nuclear/the-nuclear-fuel-cycle.php; "Yellowcake," NRC, https://www.nrc.gov/reading-rm/basic-ref/glossary/yellowcake.html.

4 Author interview data; D. M. Hausen, "Characterizing and classifying uranium yellow cakes: A background," *Journal of The Minerals* 50, no. 12 (December 1998): 45-47; "Development at 'Dangerous Point,'" Yonhap, May 9, 1994.

A declassified Hungarian report from 1979 states, "I heard from the Soviet ambassador that the DPRK has two important uranium quarries. In one of these two places, the uranium content of the ore is 0.26 percent, while in the other it is 0.086 percent." It is important to note that this report neither specifically identifies the Pyongsan area and significantly predates the start of mining activities at the Pyongsan mining complex. See: Balazs Szalontai and Sergey Radchenko, *North Korea's Efforts to Acquire Nuclear Technology and Nuclear Weapons: Evidence from Russian and Hungarian Archives* (Washington, DC: Wilson Center, 2006), 43, https://www.wilsoncenter.org/sites/default/files/media/documents/publication/WP53_web_final.pdf; Jeffrey Lewis, "Recent Imagery Suggests Increased Uranium Production in North Korea, Probably for Expanding Nuclear Weapons Stockpile and Reactor Fuel," *38 North*, August 12, 2015, http://38north.org/2015/08/jlewis081215/.

Uranium ore concentrates (yellowcake) can be any one of a number of chemical compounds including U_3O_8, UO_2, $Na_2U_2O_7$, $(NH_4)\ U_2O_7$, or UO_4. They also usually aren't highly purified and will often contain leftover water, some impurities from the ore, and possibly impurities from the chemical processing. So 80 percent U3O8 is a reasonable average estimate for yellowcake. Author interview data.

5 Kim, *I Saw the Truth About the North Korean Nuclear*, 9-21; "Visit by IAEA Director General Hans Blix to DPRK, May 11-16, 1992," YouTube video, 12:54, December 6, 2017, https://www.youtube.com/watch?v=Y2p7-mRslPg.

6 Takashi Kawada, “North Korea Defector Confirms Plutonium Extraction in 1988,” *Yomiuri Shimbun*, May 20, 1994; “Further on Defector’s Remarks,” Yonhap, May 20, 1994; “Atomic Power Industrial Base Constructed Independently in Our Country,” KCTV, April 12, 1992.

7 “Nuclear explained,” EIA; “Yellowcake,” NRC.

8 “How is uranium made into nuclear fuel?” World Nuclear Association, https://world-nuclear.org/nuclear-essentials/how-is-uranium-made-into-nuclear-fuel.aspx.

9 The footprint of the tailings pond is dependent upon a variety of factors including precipitation, seasonality, turbidity of the accumulated water, the quantity of precipitated solid waste, etc. The figure used here is based upon a satellite image from January 25, 2020.

10 “Nuclear explained,” EIA.

11 This division into functional areas should be viewed as provisional until additional, more detailed information becomes available.

12 Kim, *I Saw the Truth About the North Korean Nuclear Plant*, 169-183. The currently assessed yellowcake packing and shipping buildings are on the same track as the building identified in this report as the rail-served waste storage building. It is unclear what, if any, connection there is between the two activities.

13 For comparison, a similar but shorter rotary kiln can be found within the Namhung Youth Chemical Plant at 39.655597 N,125.669767 E.

14 Kim, *I Saw the Truth About the North Korean Nuclear Plant*, 51-63 and 130-135. Kim also reports that during 1987 that “Research Institute No. 501” was detached from the Yongbyon Nuclear Research Center and subordinated to the Pyongsan Uranium Concentrate Plant.

15 The imagery used for this estimate was selected to account for seasonality, turbidity (cloudiness) of the water, rainfall and snowmelt, etc.—all of which have an impact upon the visible footprint of the solid waste sediment.

16 “Development at ‘Dangerous Point,” Yonhap.

17 Kim, *I Saw the Truth About the North Korean Nuclear Plant*, 9-21.

18 Author interview data.

19 There are also several reserve airfields and highway airfields (emergency recover airfields) in the general area, however, these are not currently in use.

20 Author interview data; “Pyongsan Uranium Mine," North Korea Resource Institute, November 22, 2010, http://www.nokori.or.kr/bin/minihome/neo_main987.htm; “DPRK Reportedly Earns $500 Million Annually in Arms Exports,” Chollian News Database Service, November 3, 1996; Takashi Kawada, “North Korea Defector Confirms Plutonium Extraction in 1988;” “Development at ‘Dangerous Point,” Yonhap.

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21 Ibid.

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23 "Development at 'Dangerous Point," Yonhap.

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27 "Development at 'Dangerous Point," Yonhap.

28 For example, Edward Yoon, *Status and Future of the North Korean Minerals Sector* (San Francisco, CA: Nautilus Institute for Security and Sustainability, 2011), 23-24.

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32 Yun Sang-jik, "North Pungggye-ri Nuclear Test Station's radioactive materials flow into the East Sea," YTN, October 7, 2019, https://www.ytn.co.kr/_ln/0101_201910072216030376; "Workers at Nuclear Sites at Risk of Disease and Death," Daily NK, July 20, 2018.

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Uranium Factories 'Could Seep into Sea,'" *Chosun Ilbo*, August 19, 2019, http://english.chosun.com/site/data/html_dir/2019/08/19/2019081901197.html.

34 Author interview data; "South Korea Analyzes Seawater for Nuclear Waste Contamination from North Korean Uranium Mine," Radio Free Asia, August 29, 2019, https://www.rfa.org/english/news/korea/nk-pyongsan-uranium-08282019180529.html; "Gov't analyzing seawater amid reports of possible radioactive waste leak from N.K.," Yonhap, August 28, 2019, https://en.yna.co.kr/view/AEN20190828005200325.

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37 "Radioactive Waste From Uranium Mining and Milling," U.S. Environment Protection Agency, https://www.epa.gov/radtown/radioactive-waste-uranium-mining-and-milling.

38 Interview data; Joseph S. Bermudez Jr., "Facility Analysis: Pyongsan Uranium Concentrate Plant," *Jane's Satellite Imagery Analysis*, September 8, 2017.

39 Kang In-son, "Unification Will Become Difficult if North Korea Acquires a Nuclear Weapon," *Wolgan Choson* (May 1993): 342-346.

40 A sampling of the sources which touch upon these subjects include Bu-won Kwon, "The reality of threats, Dr. Kun-mo Jung speaks about North Korea's nuclear development potential before 1993," *Kyunghyang Sinmun*, April 29, 1991; Mang-ho Choi, "North Korea's Nuclear Development, What Level is it at?" *Dong-a Ilbo*, June 11, 1992; "DPRK Drive for Science, Technology Analyzed," *Sin Tong-a*, no. 12 (December 1990): 212-228; "Pyongsan Uranium Mine," North Korea Resource Institute; Sang-Mo Koh, Gill Jae Lee, and Edward Yoon, *Status of Mineral Resources and Mining Development in North Korea*, (Daejeon, South Korea: Korea Institute of Geoscience and Mineral Resources, 2013), https://www.researchgate.net/publication/264169945_Status_of_Mineral_Resources_and_Mining_Development_in_North_Korea; Sung-taek Shin, "The Seeds of North Korea's Nuclear Development Are the 'Natural Uranium in North Korea,'" *News Hankuk*, December 26, 2006, http://www.newshankuk.com/news/content.asp?news_idx=20061226104359042150; Yu-dong Kim, Hong-soo Park, Seong-yong Kim, and Jae-ho Lee, *A Study on the Mine Development of North Korea and the Inter-Korean Mineral Resources Competition*, (Daejeon, South Korea: Korea Institute of Geoscience and Mineral Resources, 2003), http://www.kseeg.org/journal/download_pdf.php?spage=197&volume=38&number=2.

41 Melissa Hanham, Grace Liu, Joseph Rodgers, Mackenzie Best, Scott Milne, and Octave Lepinard, *Monitoring Uranium Mining and Milling in China and North Korea through Remote Sensing Imagery* (Monterey: Middlebury Institute of International Studies, 2018).

42 Transliteration of Korean place names into English almost always presents a challenge, and among the more common alternate spellings for Pyongsan include P'yo'ngsan, P'yong-san, and Pyongsan. Additionally, the Pakchon Uranium Concentrate Pilot Plant is sometimes identified in English as a "natural uranium manufacturing plant" or "uranium refinement facility."

The Pyongsan Uranium Concentrate Plant, as the name indicates, produces uranium concentrate (yellowcake) from raw uranium-bearing ores using chemical processes. *It is not an enrichment facility* as sometimes erroneously reported.

43 Identified variously as the Nam-ch'ŏn Joint Chemical Industrial Company, Nam-ch'ŏn Chemical Joint Venture Company, Nam-ch'ŏn Chemical Company, or Nam-ch'ŏn Chemical Enterprise.

North Korean practice over the years has been to frequently assign multiple names to its critical facilities such as a public name, internal designation (frequently just a number), and a cover designation.

44 Mikhail Morozov, "It Has Not Yet Been Possible to Find a Nuclear Bomb in the Dark Dungeon," *Komsomolskaya Pravda*, July 13, 1994.

45 It is significant to note that "From 1987 through 1994, IAEA spent about $396,000 in technical assistance for two projects on uranium prospecting and exploration in North Korea. According to IAEA's April 1997 project status reports, the objectives of these projects were (1) to enable North Korea to better assess the potential of its nuclear raw materials in view of its increasing commitment to nuclear power and (2) to provide support for North Korea's uranium exploration program. Under the uranium prospecting project, which was completed in 1994, the status report shows that IAEA contributed a considerable amount of uranium exploration equipment to North Korea, as well as a microcomputer and software for data processing. IAEA spent more than one-third of the $87,000 budgeted for the follow-on project on uranium exploration before the project was canceled following North Korea's withdrawal from IAEA." U.S. General Accounting Office, *Concerns With the International Atomic Energy Agency's Technical Cooperation Program*.

Interest in the exploration for and mining of uranium and monazite (which contains uranium oxide and thorium oxide) in Korea dates to the Japanese colonial period and was continued by the Soviet Union until their departure in the 1940s. It was then continued by the North Koreans, who exported the ores to the Soviet Union during the 1950s and into the 1960s. During this same period, North Korea sought assistance and technology from both China and the Soviet Union to explore and mine uranium. It is unclear when North Korea identified and began mining uranium in the Pyongsan area. Szalontai and Radchenko, *North Korea's Efforts*; Lewis, "Recent Imagery Suggests Increased Uranium Production;" Song Ui-ho, "Manpower in North Korea's Nuclear Development Program: Its Personal Relationships, Training and Taboos," *Wolgan Chungang* (March 1994): 252-267.

46 "DPRK Drive for Science, Technology Analyzed," *Sin Tong-a*, no. 12 (December 1990): 212-228. It is unclear if these figures were derived from independent data or if they were derived from the sources cited in footnote #3.

47 Cho Min, Kim Chin-ha, and Cho Hu'ng-nae, *Chronicle of the North Korean Nuclear Issue 1955-2009* (Seoul, South Korea: Institute for National Unification, 2010); Cho Min, *Chronicle of the North Korean Nuclear Issue 1955-2014* (Seoul, South Korea: Korea Institute for National Unification, 2014), http://repo.kinu.or.kr/bitstream/2015.oak/2332/1/0001468021.pdf; "Energy Institute Reports Status of DPRK Nuclear Facilities," *Tonga Ilbo*, July 8, 1993; "North Korean Logging Operations in Siberia to Stop Next Year - Uranium Ore Then Charged," *North Korea News*, no. 694 (August 2, 1993): 5; Song, "Manpower in North Korea's Nuclear Development Program;" "Atomic Power Industrial Base," KCTV, April 12, 1992. For example, see Landsat 5 image LT05_L1TP_116033_19850412_20170219_01_T1.

48 Joseph S. Bermudez Jr., *Shield of the Great Leader: The Armed Forces of North Korea*. (Sydney: Allen & Unwin, 2001 and London: I.B. Taurus, 2001), 209-211; and Kim, *I Saw the Truth About the North Korean Nuclear Plant*, 9-21.

49 Ibid.

50 Author interview data. There is some minor debate as to the composition of this dam, with different reliable sources saying that it is concrete (now overgrown with vegetation) or that it is of rock and earthen construction.

51 Landsat 4 image: LT04_L1TP_116033_19890805_20170202_01_T1.

52 Landsat 5 image, LT05_L1TP_116034_19900120_20170131_01_T1.

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54 Author interview data; Bermudez and Cha, "Pakchon Uranium Concentrate Pilot Plant."

55 Central Intelligence Agency, "Syria's Covert Nuclear Reactor at Al Kibar," video, 2008; Erich Follath, and Holger Stark, "The Story of 'Operation Orchard': How Israel Destroyed Syria's Al Kibar Nuclear Reactor," *Der Spiegel*, November 2, 2009, http://www.spiegel.de/international/world/the-story-of-operation-orchard-how-israel-destroyed-syria-s-al-kibar-nuclear-reactor-a-658663.html; Yaakov Katz and Amir Bohbot, *The Weapon Wizards* (New York: St. Martin's Press), 217.

56 Kim, *I Saw the Truth About the North Korean Nuclear Plant*, 183.

57 Author interview data.

58 Available evidence indicates that the listing of facilities provided by North Korea was incomplete.

59 IAEA, *Safeguards 2011*, 7.

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61 Yonhap, “Development at ‘Dangerous Point.’”

62 Landsat 5 image, LT05_L1TP_116034_19960410_20170105_01_T1.

63 IAEA, *Safeguards 2011*; *Safeguards 2016*; *Safeguards 2017*; *Safeguards 2018*; *Safeguards 2019*; “List of Nuclear Facilities Related to Nuclear Industry, letter of Choi Hak Gun, Minister of Atomic Energy of the DPRK to IAEA Director General,” IAEA, 1 May 1992.

64 This division into functional areas should be viewed as provisional until additional, more detailed information becomes available.

65 As high-resolution declassified satellite imagery from the mid-1980s through late 1990s is not currently available, it is impractical to come to a definitive assessment as to whether these structures were never completed or completed but subsequently partially razed.

66 The construction of new greenhouses would become a regular feature of the maintenance and modernization activity at the Pyongsan Uranium Concentrate Plant that has continued until the present. This might seem unusual to outsiders; however, it has been common practice in North Korea since at least the 1990s. This is both a result of large industrial concerns and military facilities having the responsibility to grow a certain portion of their own food and the intermittent disruption of the food supply network in the country. Construction of new greenhouses at large industrial complexes is also an indication of official favor and the leadership’s concern over morale.

67 Bermudez Jr., “Facility Analysis: Pyongsan Uranium Concentrate Plant.”

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70 Lewis, “Recent Imagery Suggests Increased Uranium Production.”

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