Humboldt Bay Power Plant Decommissioning Progress Update - 16358

*Kerry Rod, ** John Gilbert *** Alan Brown **** Matt King
** PG&E Utility, Humboldt Bay Power Plant, 1000 King Salmon Ave. Eureka, CA 95503*
*** CB&I Environmental & Infrastructure, 1000 King Salmon Ave. Eureka, CA 95503*
**** CB&I Federal Services 150 Royall Street, Suite 103, Canton, MA 02021*
***** Whitchurch Engineering, Inc. 610 9th Street, Fortuna, CA 95540*

ABSTRACT

Decommissioning of the Pacific Gas and Electric (PG&E) Company Humboldt Bay Power Plant (HBPP) Unit 3 nuclear facility achieved several significant milestones in the summer and fall of 2015 when the RPV Segmentation Project completed, the Caisson Removal project began and the Unit 3 Refueling building (RFB) and Main Plant Ventilation system were released for Open Air Demolition (OAD). At the end of 2014 the Civil Works prime contractor Chicago Bridge and Iron (CB&I) was also awarded the contract to complete the RPV Segmentation. This work scope continued to use the First of a Kind (FOAK) segmentation equipment that was designed and fabricated for the HBPP Reactor Project. The preparation for RFB OAD was part of the original Civil Works contract scope. It was important that this work and the segmentation of the reactor shell be finished to allow a portion of the Refueling building to be demolished to continue the installation of the perimeter water cutoff wall and the caisson Support of Excavation (SOE) shoring system.

The CB&I Civil Works contract endorsed the October 2012 HBPP Caisson Removal Feasibility Study approach to install a perimeter cutoff wall intended to stop movement of groundwater by installation of cement-bentonite (CB) backfill in a slurry wall trench excavated to a depth of 53 meters and tied into the Unit F clay layer.

The CB&I on-site project manager and principal engineer from their home office re-evaluated the design approach outlined in their proposal and awarded contract. As CB&I further developed design plans, an option to complete the perimeter wall with Cutter Soil Mixing (CSM) technology was developed. CB&I described the CSM process as a modified trench cutter technique, to be used for both perimeter groundwater cutoff, and for caisson demolition SOE. CSM technology blends slurry while mixing soil on the down stroke, and injects cement into the blended soil cuttings on the upstroke to create a cemented “cutoff wall.” CB&I proposed several variations for three key support elements: the perimeter cutoff wall; the dewatering well system; and the caisson SOE shoring system. The proposed alternatives brought

many enhancements in the design and integration of the work to be executed. CB&I personnel were persistent in seeing their vision through that resulted in a significant benefit in worker safety and schedule enhancement (early finish by 5 months).

Baseline Approach

The 2012 Feasibility Report provided a "*proof of concept*" level analysis and plans for the caisson excavation and demolition (see Figure 1), consisting of the following support of excavation elements:

- a cement bentonite slurry wall surrounding the Unit 3 Refueling Building and Turbine Building to minimize groundwater infiltration,
- sloped soil nail wall for support of the upper caisson excavation, and
- 24 meter diameter sheet pile wall and ring beam shoring system for support of the lower caisson excavation.

The Feasibility Study considered lateral movement of the study excavation system, and potential settlements resulting from the installation of the system, with particular attention to the adjacent Humboldt Bay Generating Station.

The backfill approach included in the Feasibility Study was to compact spoil from the installation of the slurry wall in multiple lifts.

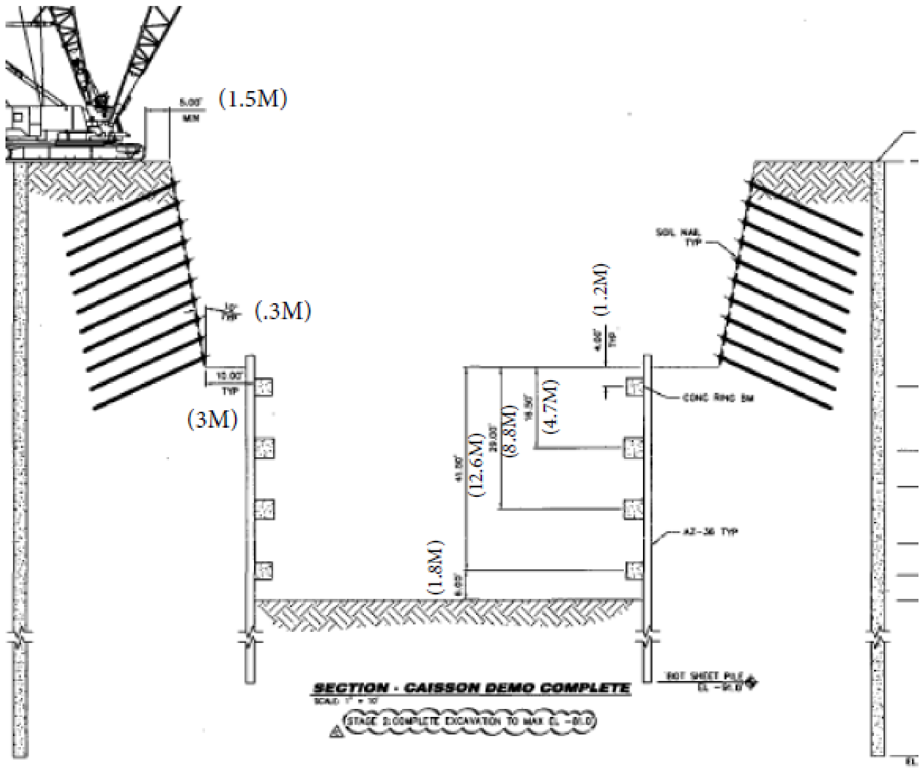


Figure 1 - Feasibility Approach

The CB&I Baseline approach included the installation of the 209-meter perimeter slurry wall identified in the 2012 Feasibility Study and a 27.4-meter diameter, 0.76-meter thick Cutter Soil Mix (CSM) shoring system with eight separate levels of ring beam steel reinforcement to El -24.1 meter (see Figure 2). Once the Unit 3 caisson and tremie pad concrete were removed and the Final Status Survey completed the shaft was to be backfilled to El 3.55 meters in lifts. As backfilling operations progressed, ring steel reinforcement was to be removed, leaving the CSM support of excavation elements left in place.

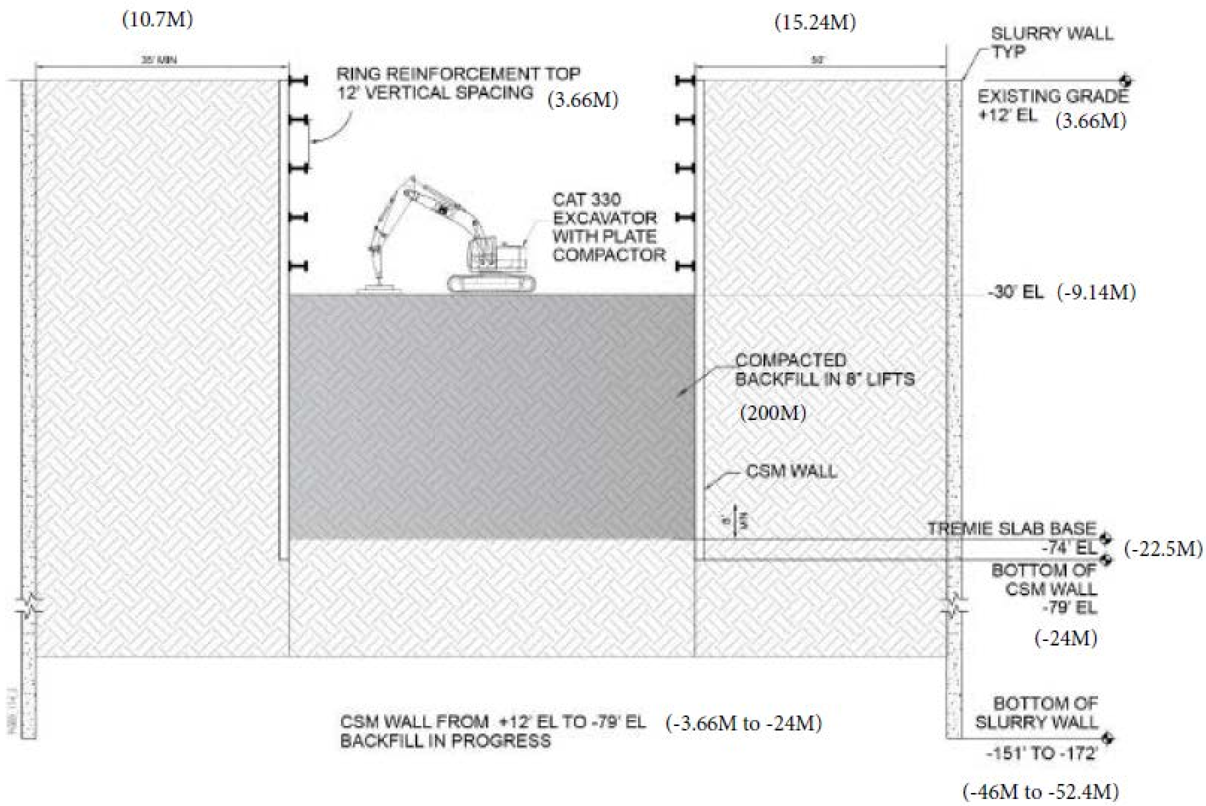


Figure 2 - CB&I Baseline Approach

Baseline Work Plan Development

CB&I contracted with a specialty contractor to install the perimeter slurry wall. During Work Plan development, specialty contractor continued to revise their planned slurry wall installation approach through the 60% then 90% Work Plan development stage. During this time the installation cost for the perimeter slurry wall steadily rose. In addition, during the development of the design, the specialty contractor expressed concern that the tight vertical tolerances could only be met with great effort, potentially impacting cost and schedule further. The specialty contractor ultimately settled on a combined clam shell and hydrophase approach to install slurry wall panels.

PG&E and CB&I personnel traveled to Rocaville, Canada on September 9, 2014 to visit a slurry wall project operation first hand being performed by the specialty contractor. All in attendance were convinced that the slurry wall technology posed environmental challenges that would challenge the HBPP Project site. It should be noted that problems with groundwater conditions kept the specialty contractor from completing the project visited.

Observations and insights from slurry wall operations were:

- Clamshell rig actively excavating relatively shallow bites (6 to 9 meterdeep) along a trench in an open field
- With light wind there was sparse slurry spray from the bucket standing 23-meters away
- Considering a switch to a hydromill, perhaps for all panels, but at least for primary panels with a clamshell for secondary panels
- There might be a need to case the “pre-drilled” holes in order to control verticality
- Hydromill verticality is greatly improved over a clamshell

Alternate CSM Approach

CB&I had concerns with the following:

- Specialty Contractor inability to control verticality,
- HBPP environmental challenges, and
- The perimeter slurry wall identified in the Feasibility Report and deep shoring components, appeared to have been analyzed separately as components and not collectively as a system.

As such, CB&I retained Drill Tech Drilling and Shoring (Drill Tech), of Antioch, California and later Jacobs Associates (Jacobs), of San Francisco, to analyze the Feasibility Report approach and options identified by CB&I. Both companies are leaders in their fields and experts in deep foundation design, installation and water cutoff wall.

Drill Tech and Jacobs analyses confirmed that the perimeter slurry wall and deep shoring option in the Feasibility Report would only work if the slurry wall was greater than 30.5-meter from the deep shoring to eliminate excessive hydrostatic water pressure. With existing site restrictions, the slurry wall could not be moved from the location identified in the Feasibility Report.

The Drill Tech and Jacobs analyses also confirmed that installed CSM shoring could not be removed as the excavation was backfilled to the surface. Hydrostatic pressures at depth were too great. With Regulator acknowledgement that CSM materials were to remain in place like the original perimeter slurry wall, CSM alternatives that did not include ring steel where considered.

PG&E and CB&I personnel traveled to Los Angeles September 23, 2014 to visit a Drill Tech CSM project to see a CSM operation first hand. All in attendance were convinced that the CSM technology was the best fit for the challenges of the HBPP Project site.

Observations and insights from use of CSM technology were:

- Cutter soil mixing operation for the LA Metro Expo line extension
- Contractor currently has two mixing rigs drilling panels 30 meter deep
- Equip Manufacturer makes a bigger rig that can reach 42.7 to maybe 48.8 meter, if needed, however none currently exist in the US.
- Possibly using CSM to replace slurry walls for water containment, in conjunction with CSM for shaft support
- Prime Contractor sees an advantage in the simplicity of mobilizing just one subcontractor for two or three operations in lieu of 2 or 3 subcontractor

PG&E also re-evaluated the bids received and reconsidered one of the bidder's proposal to apply the CSM (Cutter Soil Mixing) method in lieu of slurry because this method provides equal or better groundwater control. That is, better impermeability can be achieved, and based on their experience the method is an equally cost-effective and environmentally advantageous alternative. The original design considered a wall with permeability of 1 x 10-6 cm/sec. To date, permeability measured in the installed CSM cutoff wall is lower than 1 x 10-7 cm/sec, an order of magnitude less permeable than the original design. Mixing soil in place and using it in the resulting slurry wall considerably decreases the spoil volume compared to traditional walls and stockpile areas can be minimized – a valuable asset on the small footprint of the HBPP.

CB&I Final Design

By addressing the Unit 3 Turbine Building foundation piles with a shallow dewatering system, it allowed CB&I to design a much tighter cutoff wall thus reducing construction costs. The alternative approach deep shoring and cutoff wall CSM rings included five concentric rings to varying depths allowing for an excavation to a depth of 29.3-meter.

CB&I increased the originally proposed 24.4-meter inside diameter shoring system to 33.5-meter inside diameter to encompass the RFB allowing for deep segments of the building to be removed and to capture any potential contamination release from beneath the spent fuel pool area (see Figure 3).

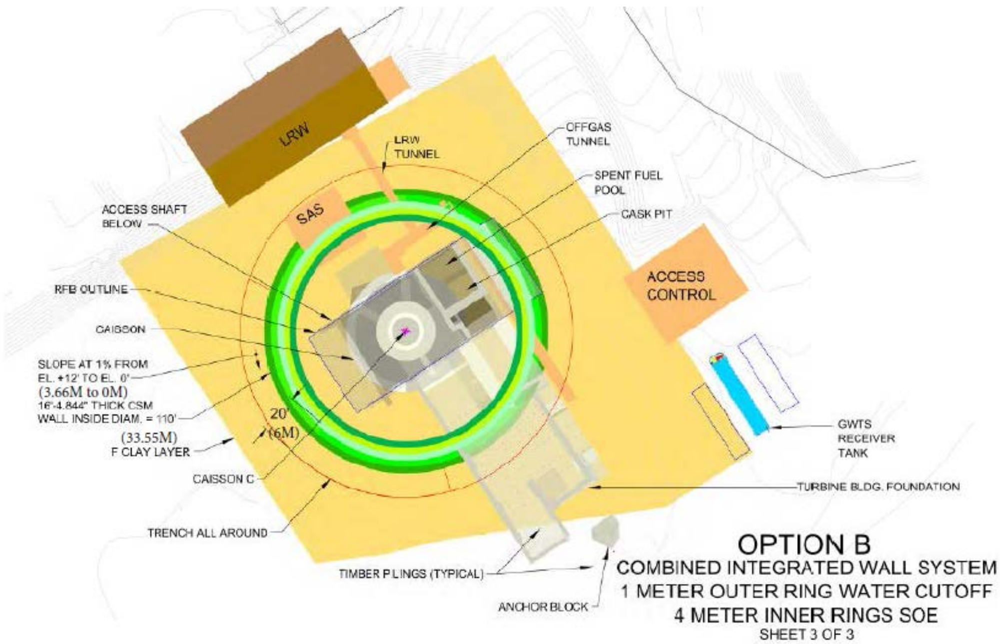


Figure 3 – CB&I Final Design

The CB&I final design (see Figures 4 and 5) included the following elements:

- Install 33.5-meter, 3.96-meter thick CSM Shoring System (No Ring Steel) with outside Ring tied into Unit-F Clay Layer; and
- Because the circular shoring is the cut-off wall, the water pressures cause a perfect circular compression load and are much easier to resist than the non-uniform load imposed by the perimeter wall cut off proposed in the Feasibility Report.

Wet spoils produced from this operation are being transported to the Discharge Canal and stored temporarily and allowed to dry. Dried out CSM spoils will most likely be utilized as backfill material after caisson removal.

Drill Tech and Jacobs completed FLAC3D analyses on the CB&I final design considering 100- and 500-yr earthquake events. Compared to the seismic demands for the 100-yr earthquake event, the stresses caused by the 500-yr event were estimated to be about 25 to 30% higher. Overall the CB&I final design was considered to have adequate capacity to resist the seismic effect caused by a 500-yr earthquake event.

Additionally, PG&E Subject Matter Experts on Seismic Design has thoroughly reviewed the CB&I final design and considers the design conservative.

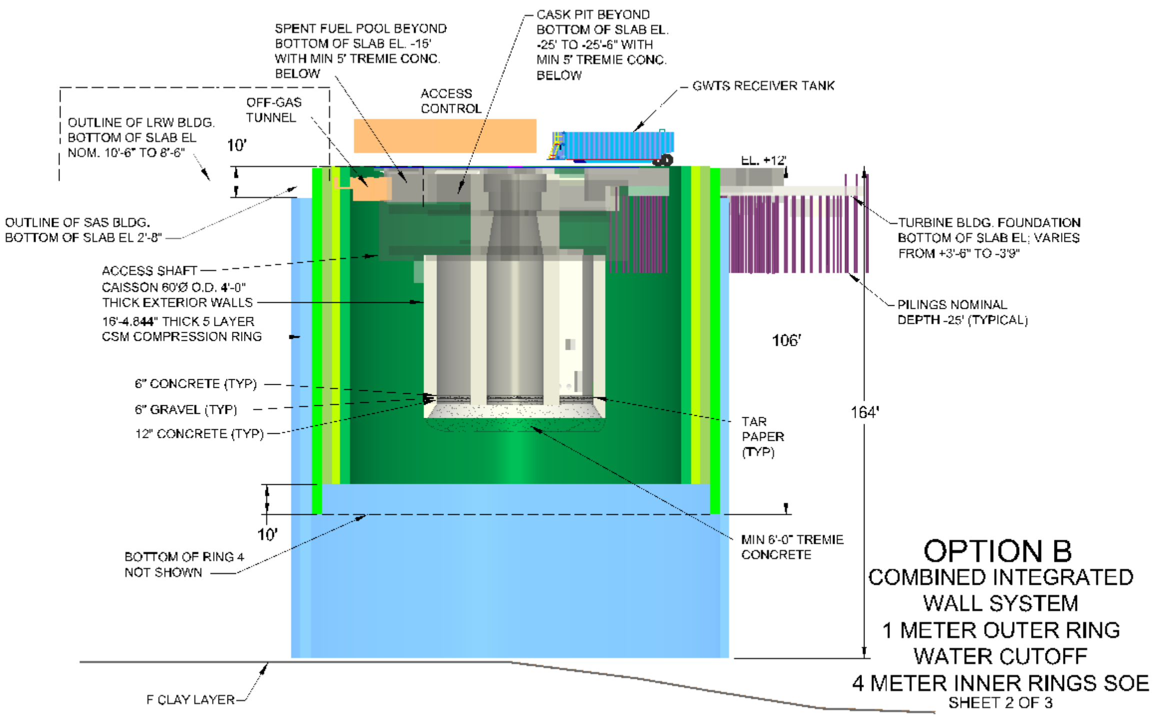


Figure 4 – CB&I Final Design

Key Elements Facilitating Change to Final Design

The Feasibility Report completed four geotechnical boring investigations to in part, confirm the presence of the Unit F Clay. This report identified the Unit F clay layer at El – 46.9 to El -52.1 meter. CB&I completed an additional five geotechnical investigations to more completely define the extent of the Unit F clay through the perimeter slurry wall alignment. The CB&I investigation more completely identifies the top of the Unit F clay layer at El -45.1 to El -52.1 meter below site grade. More importantly the additional geotechnical investigations identify the depth of the Unit F clay through the final design alignment at El -45.7 to El -49.7 meter, shallow enough to be keyed into with CSM equipment equipped with a Kelly bar (i.e., a rigid, controlled structural element allowing better vertical control).

The Feasibility Report extended the perimeter slurry wall alignment around the Turbine Building, in part to facilitate the removal of deep foundation piles. The Turbine Building cutoff elevations range from El – 0.91 to El + 3.05 meter. CB&I recognized that the cutoff elevations of the Turbine Building piles were all within the First Bay clay layer close to the Upper Hookton sand interface allowing removal without water problems. CB&I developed a shallow dewatering plan using surface sumps to control groundwater, in lieu of the perimeter slurry wall. To date, the Unit 3 foundation support piles have all been successfully removed using the shallow dewatering system.

Slurry walls, like the wall identified in the Feasibility Report, are start to finish construction operations along an alignment. CSM walls are constructed as individual overlapping panels allowing the process to move from one area to another around other demolition activities like the demolition of the Re-Fueling Building. Increasing the inside diameter of the deep shoring system to 33.5-meter inside diameter allowed for the majority of the panels to be constructed before the Unit 3 Refueling Building was demolished. By increasing the inside diameter of the system to 33.5-meter a majority of the Unit 3 Refuel Building fell inside the deep shoring and cutoff wall footprint unlike the Project baseline approach which required the Unit 3 Refueling Building be demolished before construction of the baseline deep shoring could begin.

PG&E Vetting of the CB&I Final Design

PG&E provided oversight to vet seismic criteria and design integration of the water cutoff wall with the support of excavation deep shoring system. Early in the design phase project teams from PG&E and the CBI visited two sites to benchmark the project and to evaluate appropriate means and methods for similar work to be performed at HBPP. CB&I led and coordinated these site visits and PG&E focused its desired outcome on better design margins and reduced risks.

Appropriate independent oversight was implemented by PG&E through their Engineer of Record for Caisson Feasibility Removal Study, Parsons Brinkerhoff, and Akana (formerly Cooper Zietz) providing Subject Matter Expertise consultation on water cutoff and support of excavation. The primary focus with preparer of the Feasibility Study was to keep continuity of the Engineer of Record for the feasibility study used in the bids.

PG&E made use of its Technical Evaluation-Decommissioning (TE-D) tool developed to assess, evaluate and document positions on significant technical issues. This document explains the issue being addressed and if alternate approaches exist to address the issue, describe those, explain the method of evaluation and summarize the results of the evaluation. This approach was used to evaluate the Slurry

Wall/Water Cut-off design options. A description/explanation of the various options was provided as well as the evaluation method.

During the development of the design, HBPP invited the General Office risk analyst for Energy Supply to HBPP to meet the CBI project team and to provide an overview of the PG&E risk initiative program, its importance and specifics to the caisson removal project.

The safety of its workers and contractors is the top priority for PG&E and the original plan's installation of a slurry wall were environmental, safety and line of business concerns. So too was the idea of doing all of this work adjacent to the Humboldt Bay Generating Station (HBGS), a conventionally operating power plant. For these reasons, the original feasibility study design was not selected because it combined a slurry wall with a nail wall down to minus-9 meter elevation and then added sheet piles with concrete support beams down to minus-24 meter. This required substantial work within the deep excavation in a tsunami zone and earthquake-prone region.

The selected approach of combining the SOE and cutoff wall, both utilizing CSM technology, reduced risk and increased safety. Fewer people in the excavation and for shorter periods of time – primary equipment operators – greatly reduced the industrial risk and improved safety of the workers. Design features accounted for quick excavation and separation of people and source terms within the excavation, yielding all around improvements in safety.

Description of Work

The CB&I final design includes a deep shoring and cutoff wall that is composed of five concentric CSM rings installed to various depths allowing for excavation to a depth of 29.3-meter. The inside ring will have an inside diameter of 33.5-meter centered near the Unit 3 foundation support caisson. The inside ring will extend to a depth of 32.3-meter deep. The depths of the following three rings will increase by 1.22-meter for each progressive ring. The outside ring will also serve as a deep shoring and a groundwater cutoff ring keyed a minimum 0.3-meter into the Unit F clay at a final depth of 53-meter.

Four dewatering wells located inside the deep shoring system allow for dry excavation of deep structures and the wells will extend to a depth of 38.4-meter. Four (4) open tube piezometers will be installed inside the CSM deep shoring and cutoff wall and seven (7) vibrating wire piezometers installed outside to monitor groundwater during excavation and backfill operations. Additionally, four (4) inclinometers will be installed outside the CSM deep shoring and cutoff wall system to monitor mass ground movement. However, no movement is expected.

Each CSM ring will consist of individual panels approximately 1.0-meter thick and approximately 2.8-meter in length and each panel overlaps with the next. The panel overlapping techniques shall ensure that the overlap extends the full depth of the wall, with the depth being measured at the center of the cutting wheels. The total thickness of the compression ring will be a minimum 3.96-meter. There are a total of 255 CSM panels in the deep shoring and cutoff wall system distributed as shown in Table 1 below.

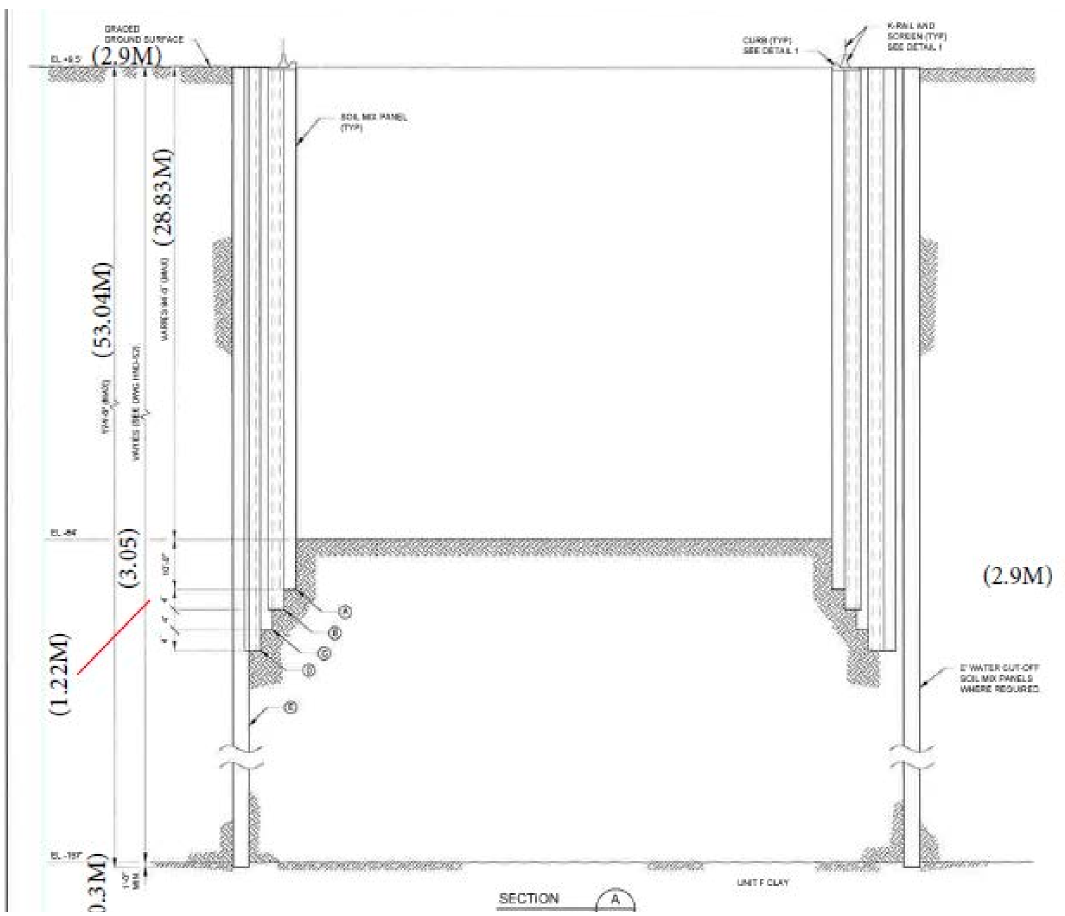


Figure 5 - CB&I Final Design Profile View

Each CSM ring will consist of individual panels approximately 1.0-meter thick and approximately 2.8-meter in length and each panel overlaps with the next. The panel overlapping techniques shall ensure that the overlap extends the full depth of the wall, with the depth being measured at the center of the cutting wheels. The total

thickness of the compression ring will be a minimum 3.96-meter. There are a total of 255 CSM panels in the deep shoring and cutoff wall system distributed as shown in Table 1 below.

Table 1 - CSM Panels per Ring

Ring	Number of Panels
A	47
B	49
C	51
D	53
E	55

CSM Shoring System and Cutoff Wall Installation

Drill Tech initiated the installation of the deep shoring panels in Rows A through D on July 13, 2015. A one of a kind Bauer BG-50 with a 52.7-meter Kelly bar system and tracks are almost 1.52-meter tall, and 2.74-meter wide initiated was mobilized on September 18, 2015. This combination specs make the BG-50 onsite a one of a kind piece of equipment specifically intended to install the deep cutoff wall panels in Ring E. The BG-50 allow**s** the CSM Cut-Off wall (Ring E) to tie into the Unit F clay to effectively control water that will allow the Caisson excavation and demolition work face to be dewatered.

As of February 1, 2016 half of the panels or total of 127 CSM panels have been installed.

Figure 6 – CMS Operations at HBPP

CSM Shoring System prerequisites – RFB Open Air Demolition

In order for the CSM wall construction to complete, and the project critical path to proceed, the RFB and all of its internal and external radiological work had to be complete to meet OAD status, as well as demolish a portion of the RFB to allow the CSM wall to complete. This included the completion of the RPV Segmentation, RFB characterization and remediation activities, environmental remediation of hazardous substances to meet the OAD criteria, decommissioning the Main Plant Exhaust system, and the demolition of approximately 12.2-meter of the RFB on its East side.

RPV Project Completion:

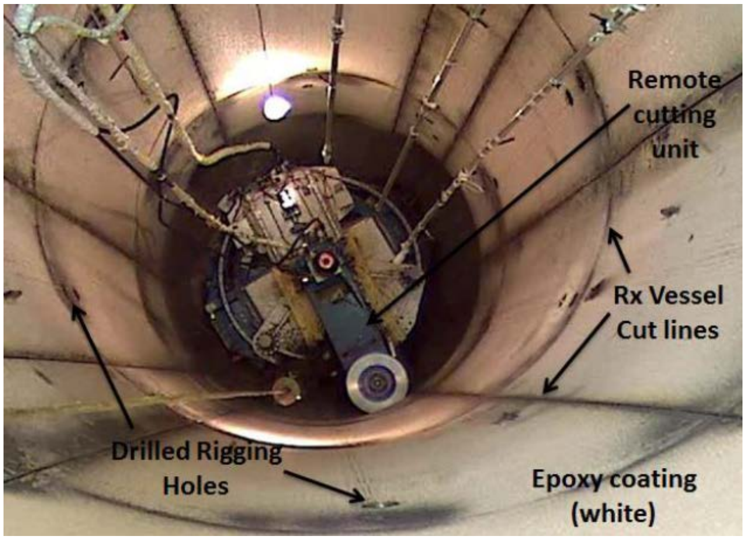
The view looking up from inside the reactor vessel post panel cut and removal. Lead Shielding was added to reduce dose from the activated core region during asbestos abatement. Shown below insulation panels being removed.

The RPV project was awarded to CB&I in December of 2014, after PG&E had released the previous segmentation contractor. The RPV itself had the horizontal and vertical segmentation mostly complete. The CB&I project team had the remaining scope to physically remove the RPV sections, and complete the removal process using the FOAK equipment. A project team was developed utilizing the already experienced Project Manager, Project Engineer, and Project Superintendent, as well as a skilled craft team that had current knowledge of the FOAK segmentation equipment.

The new RPV team was able to successfully remove the first RPV window in February of 2015. These sections were then packaged in waste packages and then ultimately into standard intermodals for shipment to the disposal site. The project team successfully removed all of the sections ahead of the original scheduled 3 day/section to 1 window per day, and in most cases 2 sections per day.

The project included the removal of asbestos and mirror fiberglass insulation that surrounded the RPV. This was performed by a specialty contractor. This phase of the project posed its own unique set of challenges. These challenges included limited egress, and highly contaminated materials. Once the insulation was removed, the project team successfully completed the removal of the last components of the RPV comprising of the top and bottom sections. These sections weighed in at over 27,000 kilo grams each. With the phases of project removal including removal of the insulation, the RPV project successfully completed in June of 2015.

Because the PRV was tightly placed within the bio-shield walls, had high contamination levels, and was supported from the top, the project team was faced with many safety challenges. Some of the most difficult were: confined space with multiple obstructions; the presence of hazardous materials such as asbestos and alpha radiation; limited egress; non-ergonomically friendly environment; high radiation area; and high seismic concerns.



View inside of the reactor vessel and remote horizontal cutting tool. The specialty epoxy coated (white) surface minimized generation of airborne contamination. Shown below the Tendon Window Cutter removing a severed reactor tendon piece.

In summary, vessel segmentation provided challenges and constraints that required a very refined approach. This segmentation project was a FOAK in the industry. Its challenges included working within the limited space constraints of the HBPP drywell and the vessel segmentation containment structure, operating the segmentation equipment to meet ALARA goals, and removing vessel pieces in sizes that met shipping and disposal limitations.

PG&E developed a segmentation plan that overcame these challenges and translated this plan into bid specifications. Numerous dry runs and practice minimized personnel risks. Use of Run Up Testing full scale models to test production rates and safety practices, along with remote monitoring and control of equipment, all yielded outstanding results. Development of a plan to support the vessel during cutting and how to rig and remove very large and heavy pieces, along with how to package and dispose of them, attests to the team's success in developing this approach to the RPV removal.

RFB OAD Preparation:

Once the RPV was completed, it allowed for the remainder of the RFB and Caisson to be prepared for OAD. This project scope included: Complete removal of all accessible hazardous materials such as Lead, PCB's, Asbestos and other materials. This also included a complete radiological characterization of the RFB and Caisson in an effort to bring the RFB to OAD radiological limits.

The process of preparing the RFB and Caisson included an in depth review of the legacy structures, systems and components that were left in the RFB and Caisson structure. This review was performed by the CB&I project team which included the RPV Project Manager (PM), RPV Project Engineer (PE), Industry Experts in Radiological decontamination and Characterization (from several other US and England Decommissioning's), and experienced Radiation Protection Technicians. The choice of the RPV PM and PE was for the legacy information that this team brought to the group. These two individuals were part of the PG&E Self Perform project and knowledgeable of the left behind SSC's.

The physical work of characterization was performed in a systematic level by level examination of all rooms and areas within the RFB and Caisson proper. This included all remaining piping, penetrations, embedded pipes, and all concrete surfaces. Radiological data such as surface contamination, gamma and beta dose rate analyses were reviewed and assessed. These values where documented, and submitted to the project team to determine what course of removal or remediation was needed, if any. The bounding limits for OAD were governed by PG&E Procedures for OAD. This procedure included the calculations based on the site specific radionuclide distribution, and bounding that with the NRC regulations for site boundary dose rates. These values were used in the determination of removal, remediation, or no action.

The project team using the above mentioned data and criteria were able to develop a list of SSC's that had to be removed, and or remediated to meet the OAD criteria. Many systems, like embedded floor drains could not be removed, as it would affect the structural stability of the RFB and Caisson. A unique mixture of remediation techniques involving paints, epoxies, glues, and foams was successfully executed to remediate the non-removable SSC's, and bring the RFB and Caisson to OAD status. The project team also utilized specialty subcontractors to effectively abate and remove any accessible hazardous materials that were discovered during the characterization process. All materials that were removed were packaged and properly disposed of by the CB&I Waste team.

While the physical work was being performed, the CB&I Waste team was also evaluating the data that was collected by the characterization team. This data was analyzed to ensure that the Waste Acceptance Criteria (WAC) of the planned disposal locations could be met, without risk of a non-compliant shipment. The Project Team, Waste Team, and the PG&E team all worked together to ensure that the end result of OAD would be within acceptable risk limits for Personnel and Radiological Safety, and for Regulatory Compliance. The project team developed a demolition guidance document that would be used to develop the detailed demolition work plans of the Caisson. This document included the areas of high risk, both radiological and environmental, for the demolition process. This document also defined how the remaining radiological waste would be segregated and packaged during the caisson demolition. Part of the RFB OAD approval to proceed from PG&E included a Readiness Review Board approval of the work that had been completed and of the guidance document for RFB and Caisson OAD.

Demolition of the East end of RFB:

Once the RFB was approved for OAD, the physical work for preparing the path way for CSM installation had to continue. As the RFB is not centered in the CSM, the East 12.2-meter of the building had to be demolished to allow the CSM to continue on its circular path. Also in the way of the CSM was the Main Plant Exhaust System.

The RFB East 12.2-meter would be one of the first sections of the RFB and Caisson to utilize the data gathered during the preparation phase above. The Project Work Plans were updated to include the required characterization data, and turned over to the demolition contractor. CB&I contracted with a demolition contractor who was familiar with radiological contaminated structures. The contractor was able to employ all of the necessary practices governed by the demolition guidance document mentioned above, and successfully demolish this portion of the RFB in October of 2015. This demolition work was executed without personnel injury, or uptake of any radiological material. All waste was downsized and packaged within the guidelines of the demolition guidance document above as well.

East end of the Refueling Building being demolished

Pulling the 75 Ton bridge crane from the building

The Main Plant Exhaust System (MPES) was also removed. This system was original plant equipment that provided the negative ventilation during plant operation and throughout the decommissioning of the SSC's within the RFB and Caisson. The same process was applied to the MPES work plans as the RFB work plans. The Project Work Plan was updated to include the required characterization data, and turned over to the demolition contractor. This system was successfully removed from service in October of 2015 by the same demolition contractor who removed the East 12.2-meter of the RFB.

The above mentioned areas of preparation are only a portion of all the site work that took place to successfully install the CSM wall. As the CSM wall is on the project critical path, the entire CB&I Site team along with the PG&E team worked together to successfully implement the project using industry expertise, and benchmarking techniques.

Conclusion

What we learned with the CSM wall and the project as a whole is that feasibility studies are just that - concepts. Execution may be completely different when competitive bids are awarded and when the field execution team is mobilized on-site. This was proven three times on our project. (1) a six month $1M study recommended to removing the reactor vessel whole in lieu of segmentation that ultimately became the chosen path once worker safety weighed in when removing insulation around the shell of the vessel; and (2) removal of the spent fuel pool liner wet in lieu of dry (another CBI initiative) and successfully completing the work with no injuries; and (3) a better integrated design of the water cut-off wall with the SOE (excavation shoring system) using CSM technology (CBI initiative).

Key take away – PG&E hires contractors to do work that PG&E is not in the line of business of performing and expects contractors to be innovative, think outside the box, make the project safer and deliver on budget and on schedule (Leadership affordability expectation). Integration of these initiatives (RPV Segmentation, SFP wet, RFB OAD, water cut-off and SOE integration) by CBI has brought the project completion date in from May 2019 to December 2018 through these innovative ways to better execute the project.

The key takeaway demonstrated by the CSM and other high risk projects completed to date is to do feasibility studies, benchmarking, and risk assessments but do not become locked in on a chosen path. As conditions change, allow innovation and expertise by team members to determine the path forward and do not be afraid to change when consensus drives it. Risk drivers change in weight depending on ownership, values, priorities and numerous factors that need continual reassessment. The CSM wall offered some cost and schedule advantages but the overriding factors were safety and environmental stewardship supported by executable design.

Strong field oversight, contract management and business oversight by PG&E raised the appropriate expectations for CBI to deliver on excellence.

Below are several technical benefits, including risk reduction, to the project with regard to the combined cutoff wall and caisson SOE shoring system:

1. The integration of the water cutoff wall with SOE validates the final design configuration of the two-wall system.
    - A single Specialty Contractor (CSM versus CSM and Slurry) offers one learning curve when it comes to embracing work safety while working on-site.
2. The five-meter-thick CSM wall design does not rely on steel or concrete ring beams for appropriate structural support.
    - Although more man-hours are spent installing the CSM, fewer man-hours are spent inside the excavation reducing risk to personnel.
3. The combined circular cutoff wall and caisson SOE shaft system greatly reduces the quantity of deep drilling work as compared to the full perimeter wall alignment.
    - Approximately 131-meter of wall length would extend down to Unit F versus 209-meter length of slurry wall.
    - The reduced perimeter reduces spoils from 19,000 cubic meters to 12,000 cubic meters, a 36 percent reduction in spoil requiring stabilization, resulting in a significant savings in material handling.

4. Groundwater isolation is limited to the confines of the circular shaft geometry, and focuses on only dewatering the caisson for removal; not unnecessarily dewatering other shallow structures.