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Docket Number: 23-AFC-01

Morton Bay Geothermal Project Impact Screening Study

Regarding concerns about optimizing and sustainably using the geothermal resource

Additional submitted attachment is included below.

Geothermal Resource Group, Inc.
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Palm Desert, CA 92211
Phone: 760-341-0186

Date:	2/26/2024	
To:	Cyrq Energy	
From:	Richard Holt Geothermal Resource Group	William Rickard PE Geothermal Resource Group
Re:	**Morton Bay Geothermal Project Impact Screening Study**	

Executive Summary

Cyrq owns and operates the 60 MW (nominal) Hudson Ranch Power I (HRP I) geothermal project in the Salton Sea Geothermal Field (SSGF). The Morton Bay Geothermal Project (Morton Bay) proposes to install 157 MW of new generation capacity with new wells approximately ½ mile from the existing HRP I wellfield. Geothermal Resource Group (GRG) was engaged by Cyrq to provide a review of and make comments on Cyrq's internal report, "Morton Bay Geothermal Project Impact Screening Study", draft dated February 14, 2024 and updated February 22, 2024. GRG does not support or oppose the proposed Morton Bay development, nor does GRG have any financial interest in either Cyrq or Morton Bay. In the above referenced memo, Cyrq raises issues that strongly indicate the Morton Bay Geothermal Project, as proposed, will adversely impact the Salton Sea geothermal resource as well as generation at HRP I. GRG's purpose is to provide an independent third-party objective opinion of Cyrq's assertion. GRG concludes the following:

- The SSGF is currently underdeveloped, having 430 MW of installed capacity with total possible reserves estimated to be as high as 2900 MW.
- For these additional reserves to be developed sustainably the density of development should not exceed current levels.
- The SSGF has been operating in a sustainable manner for 40 years at a density of development of 25 to 35 MW/km^2 (65 to 90 MW/mile^2), which is consistent with expectations in comparison to other resources of similar temperature.
- The Morton Bay project proposes a development density of 217 MW/mile^2, which is far exceeds what GRG would recommend and is likely to have unsustainable decline rates for both Morton Bay and HRP.

GRG's Experience at Salton Sea

GRG personnel have worked in the Salton Sea field since the 1980's and have become leading experts in well targeting, drilling, well testing, reservoir engineering, numerical simulation and more recently lithium recovery. Several GRG personnel were involved with the highly referenced publication on SSGF's conceptual model and reserves (Kaspereit, et al, 2016) which included a refined model of the field. This is in addition to voluminous confidential reports and projects completed by GRG for numerous clients over the past decades. Due to this body of experience, GRG is well-positioned to provide insight into successful development plans.

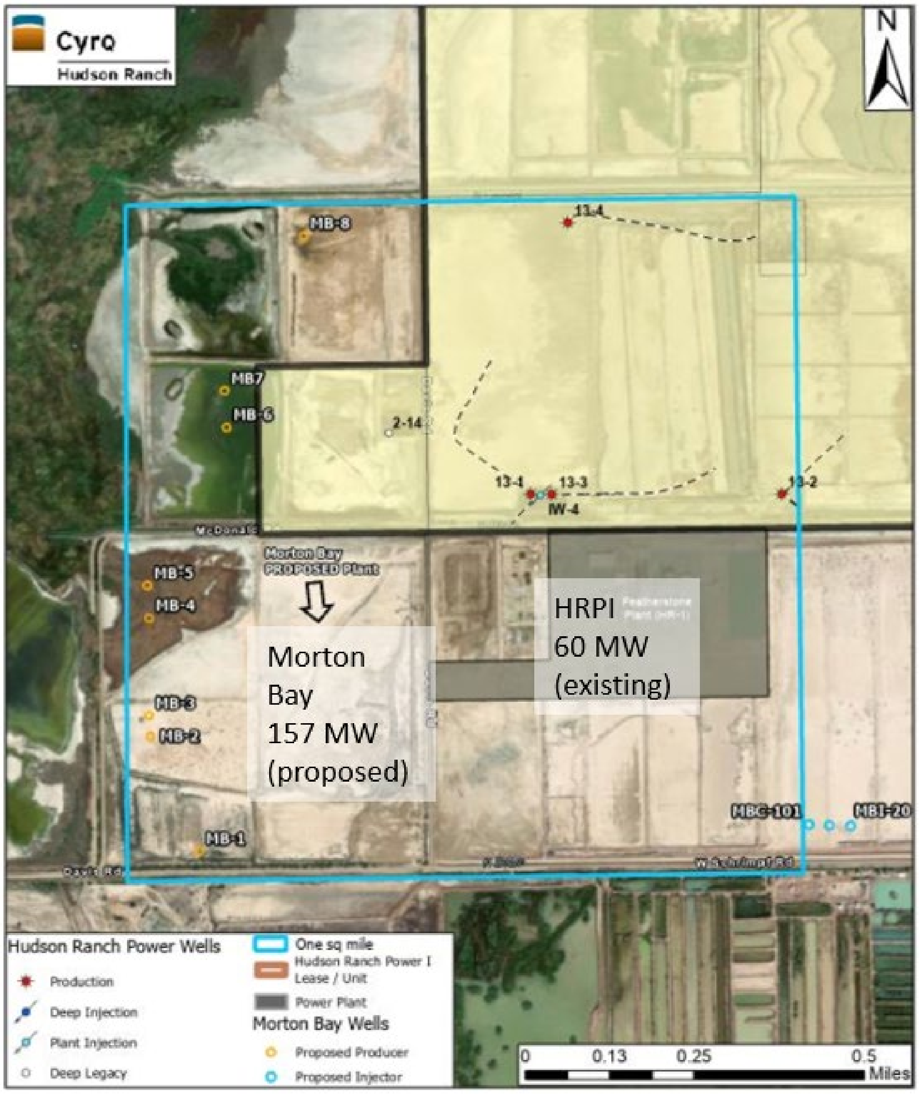

Figure 1: One square mile encompassing Morton Bay (proposed) and HPRI (existing) production well fields totaling approximately 217 MW.

Development Density and Sustainability

The existing developed Salton Sea geothermal field has shown long-term sustainable production dating back to the 1980s. The field is currently not overdeveloped and the industry consensus, supported by GRG, is that the SSGF has very significant undeveloped reserves. While the SSGF currently has 430MW of online development, the total reserves are estimated as high as 2900MW (Kaspereit, et al, 2016). A useful measure and guideline for the level of sustainable development potential is the field's "power density", which is the MW per unit area (MW/km^2 or MW/mile^2) of the resource. Well regarded publications by several authors have concluded that sustainable power density increases with resource temperature in developed fields. Grant (2000) notes that while reservoir simulation is the superior approach to predicting sustainable resource capacity, power density analysis is the next best approach.

Because a fieldwide reservoir simulation of the SSGF is not available, GRG relied on the power density approach. Both Grant (2000) and Wilmarth (2015) show that a power density of 30 MW/km^2 (78 $MW/mile^2$) is a reasonable expectation for the SSGF when compared to other fields with similar reservoir temperatures, 300 to 320 ^oC (570 to 610 ^oF) as shown in Figure 2.

The power density of the developed part of the SSGF is in the range of 25 to 35 MW/km^2 (65 to 90 $MW/mile^2$), depending on how the developed area is defined. The mid-range value for the power density at SSGF is 30 MW/km^2 (78 $MW/mile^2$), which is in accordance with the estimates from both Grant (2000) and Wilmarth (2015). In other work, which is confidential, GRG has advised its clients to use the guideline of 30 MW/km^2 (78 $MW/mile^2$) because this level of development is proven sustainable and is consistent with global analogues.

While GRG understands this guideline is approximate and not absolute, Morton Bay as proposed reaches 85 MW/km^2 (217 $MW/mile^2$) in that area of the reservoir (see Figure 1). This is nearly three times the known sustainable power density of the overall SSGF. Further, as shown in Figure 2, the highest reported power densities in the world are less than 45 MW/km^2 (116 $MW/mile^2$). In GRG's opinion Morton Bay's proposed power density of 85 MW/km^2 (217 $MW/mile^2$) will cause accelerated decline for both Morton Bay and HRP I. GRG recommends a lower power density of development for the benefit and long-term sustainability of both Morton Bay and HRP I.

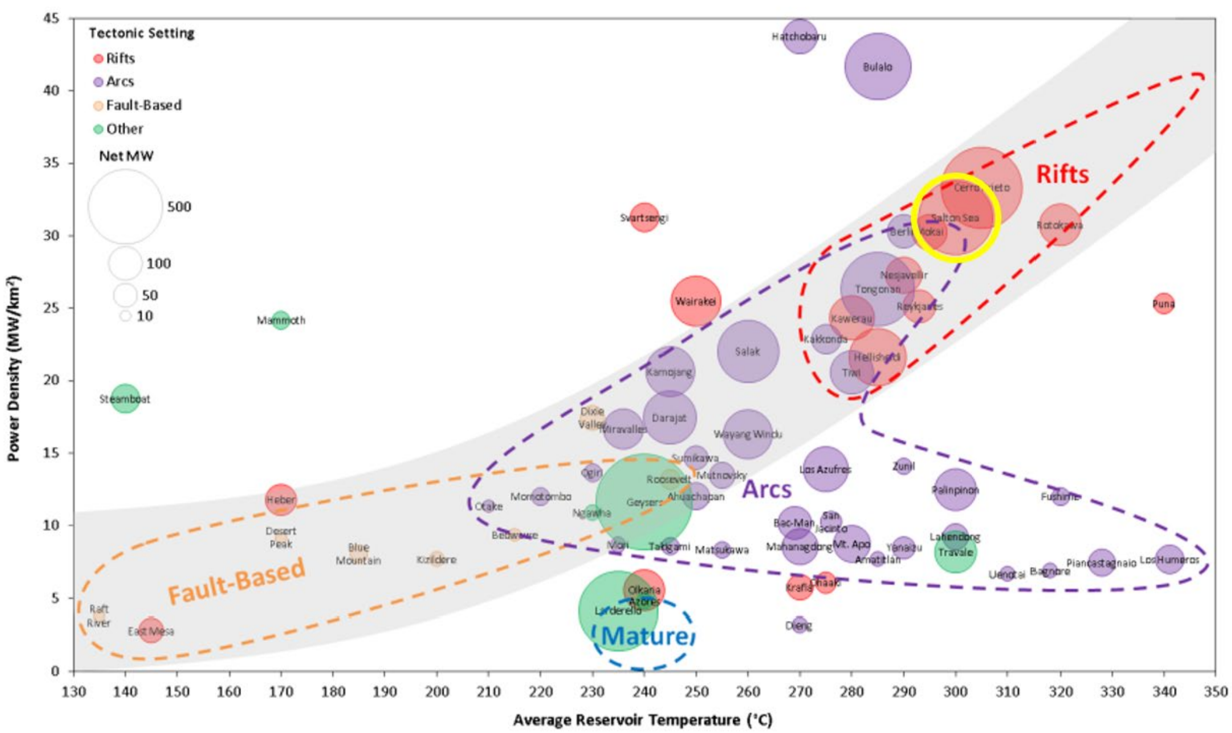

Figure 2: From Wilmarth(2015) showing Salton Sea power density of 30 MW/km^2 (78 $MW/mile^2$)

References

Kaspereit, D et al, “Updated Conceptual Model and Reserve Estimate for the Salton Sea Geothermal Field, Imperial Valley, California” GRC Transactions, Vol. 40, 2016

Grant, M: “Geothermal Resource Proving Criteria”, Proceedings World Geothermal Congress 2000, Kyushu – Tohoku Japan, May 28 – June 10, 2000

Wilmarth, M., and Stimac, J.: “Power Density in Geothermal Fields”, Proceedings World Geothermal Congress 2015, Melbourne, Australia, 19-25 April 2015

Cyrq
Hudson Ranch

Morton Bay Geothermal Project Impact Screening Study

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Final Review Date:

February 22, 2024

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Executive Summary

The Morton Bay Geothermal Project (Morton Bay) proposes to install 157 MW of generation capacity from 8 production wells within approximately ½ mile of the existing Hudson Ranch Power I (HRPI) Geothermal Project. This screening study evaluates the Morton Bay proposal against numerical simulation, empirical data sets, and global analogues to assess the impact of the project on the Salton Sea Geothermal Field's (SSGF) sustainable producibility. Through all lenses of evaluation, the proposed project is expected to exceed the sustainable capacity of the SSGF. Proceeding with this project as designed is likely to result in rapid and material degradation of the SSGF resource, which will negatively impact renewable power generation.

Key findings from this screening study include:

- Morton Bay will need to produce and inject approximately 11,200 kilo pounds per hour (kph) of deeply sourced SSGF brine to achieve its 157 MW target.

- Third-party numerical simulations demonstrate that even a fraction of this produced flow (3,150 kph) when produced at ½ mile spacing in the SSGF will result in material enthalpy (total energy) reductions in the geothermal resource. As a result, neither the 157 MW targeted by Morton Bay nor the current 60 MW generated by HRPI will be sustained, even beyond the first year of full production.

- Pressure transient analysis suggests that Morton Bay's needed production rate of ~11,200 KPH and proposed well spacing of ~½ mile or less will result in a reservoir pressure decline at HRPI on the order of 75 PSI, or roughly 18.5 MW generation in 5 years. If the total mass production of the project is reduced to ~3,500 kph, the impact at the same distance is reduced to 27 PSI, or roughly 5.5 MW generation in 5 years. While this analysis has many caveats, it should motivate a more rigorous, collaborative study of the likely interference between existing and proposed wells that results in a sustainable development plan for the SSGF for existing and future projects.

- A power density screening demonstrates that the Morton Bay proposal and existing HRPI production would combine for 217 MW produced in 1 square mile, or 83.5 MW per square kilometer. These values are nearly double the highest recognized power density of a geothermal field in global analogues, and more than doubles the established power density for the SSGF. The inconsistency of the project design with global analogues should significantly raise the bar of scrutiny to ensure the results are feasible and not detrimental to the resource overall.

These analyses strongly indicate the Morton Bay Geothermal Project, as proposed, will adversely impact the SSGF as well as generation at HRPI. The project should be re-sized, relocated, or both to preserve the ability for long term utilization of this shared geothermal resource. HRPI proposes a collaborative, field wide reservoir model for the SSGF to inform future development, prevent long term degradation of the resource to the detriment of all vested geothermal stakeholders, and optimize the ability to produce renewable electricity from this resource.

Introduction

The Morton Bay Geothermal Project (Morton Bay) proposes a continuous rating of approximately 157 megawatts (MW) gross from the Salton Sea Geothermal Field (SSGF).[1] The project plans to drill and complete eight production wells and eleven injection wells in order to achieve this targeted amount of power generation. Three of the proposed producers sit less than 2,200 ft west from the current HRPI Unit boundary, while five of the proposed injectors sit less than 2,500 ft south from the current HRPI production wells (Figure 1). The proposed density and high flow rates of these wells raise significant concerns for the long-term management of the SSGF.

Hudson Ranch Power I (HRPI) is in possession of a numerical simulation provided by a third-party consultant, GeothermEx, Inc., designed to assess the sensitivity of the SSGF resource to production and injection flows and spacing. This model was used to inform the sustainable development of HRPI. Estimates of the flow required to achieve the goals of the Morton Bay project are very likely to have a detrimental effect on the long term producibility of the SSGF, not only for HRPI, but also for Morton Bay, in light of the results of this model.

HRPI is also in possession of a significant production history data set that can be used to empirically demonstrate the tendency of wells in the SSGF to interfere with each other. This data set demonstrates hydrologic communication between wells completed in the same zones, as well as communication between wells completed in different zones which implies, importantly, that unsustainable degradation to the SSGF cannot confidently be mitigated through strategies that inject brine in shallower parts of the reservoir, compared to the primary deeper zones.

Finally, a simple comparison of the Morton Bay project goals to other global geothermal analogs shows the scale of production resulting from the combined Morton Bay and HRPI projects would double the power density requirements from the highest end-member global analogue. A simple pressure transient model (PTA) suggests that this level of overproduction may result in rapid impacts to existing generation, on the scale of 0 to 5 years.

The analyses in this study suggest the proposed Morton Bay project is over-sized for the SSGF and will result in degradation of the resource. HRPI is willing to share data and collaborate with all stakeholders to build a detailed and informed field wide numerical simulation that informs the sustainable development of the SSGF. To avoid material impacts on the SSGF, HRPI recommends Morton Bay development be paused until such a study can be completed, and the project can be properly sized for sustainability.

[1] https://www.energy.ca.gov/powerplant/steam-turbine/morton-bay-geothermal-project-mbgp

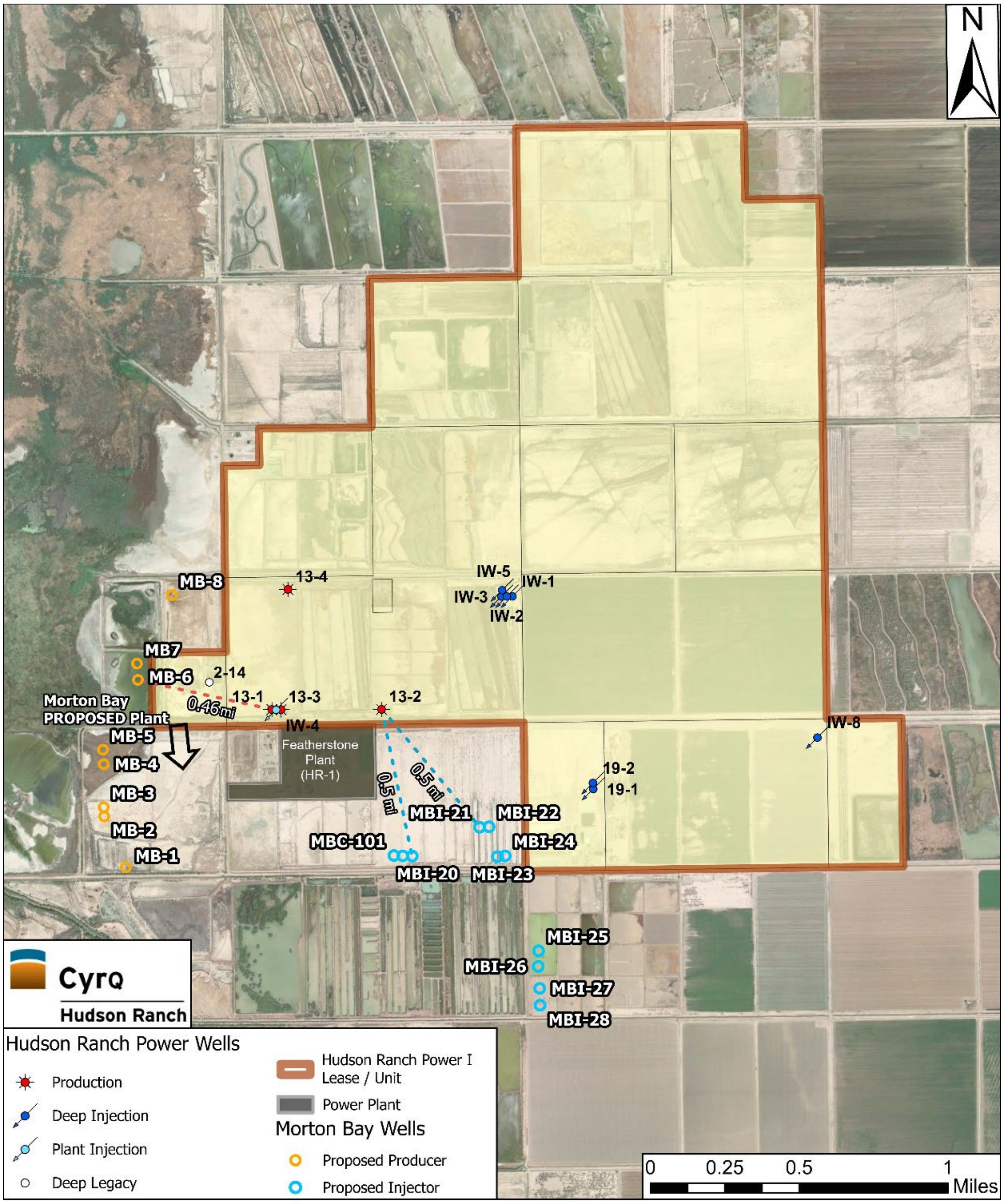

Figure 1. Hudson Ranch Power I Wellfield and Morton Bay Project Wellfield.

Numerical Simulation

GeothermEx Numerical Simulation

During the development of the HRPI project, GeothermEx developed a model and wrote a Resource Due-Diligence Report[2] that analyzed various scenarios of offsetting (adjacent) development. Relevant to this analysis are Case 5 and Case 6 from that report, which investigate the impact of a hypothetical third party's three offset injection wells located directly south of the HRPI lease/Unit boundary, similar to the location of the injection wells proposed by Morton Bay. The key distinction between these scenarios is the spacing of the offsetting injectors, ¼ mile vs. ½ mile from the HRPI wells. The setup of the model is described in the excerpts below and illustrated in Figures 2 and 3.

> ***Case 5:*** "… assumes injection immediately south of the three Hudson Ranch producers and at the same level in the reservoir. Case 5 also includes three additional production locations still further south (again at corresponding levels in the reservoir), on the premise that a competing plant would require production as well as injection."[6] Refer to Figure 2 where the offsetting wells are located at ¼ mile (or 1,320 ft) away from the HRPI producers. Each injector assumes a mass flow rate of 1,046 kph.
>
> ***Case 6:*** "is a modification of Case 5, such that the offsetting injection wells are moved one grid block (i.e., ¼ mile) further south and are assumed to inject at greater depth (into Level 3), while the production further south is assumed to remain the same."[6] Refer to Figure 3 where the offsetting wells are located at ½ mile (or 2,640 ft) away from the HRPI producers. Each injector assumes a mass flow rate of 1,046 kph.

Case 5 exhibited an immediate and material impact on the HRPI wellfield, resulting in a forecasted enthalpy decrease of more than 50 British thermal units (BTU)/lb in less than 10 years. Case 6 showed a smaller impact, with enthalpy decreasing by approximately 13 BTU/lb over the same period (Figure 4). There are at least two caveats that imply these cases grossly underestimate the impact a project like Morton Bay will have on the SSGF and HRPI production:

- The simulation assumed total injection rates near 3,150 kph. A new Morton Bay plant targeting 157 MW gross would need approximately 11,200 kph of production, and similar quantities of injection assuming similar brine enthalpies and plant efficiencies to HRPI. This is 3.5 times greater than envisioned in the simulation and is expected to significantly increase the negative impact on fluid enthalpy compared to this reference model.

- The simulation assumed a homogeneous, single-porosity reservoir layer with 500 millidarcy permeability. In reality, the SSGF hosts both stratigraphic and fracture permeability that could be significantly greater than this assumption, further multiplying the negative impact of offset wells on each other.

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[2] GeothermEx, Inc, (2010). Resource Due-Diligence Report for Hudson Ranch Unit 1 Geothermal Project on Char Leasehold, Salton Sea Field, Imperial Valley, California [Internal Report]. Société Générale – New York

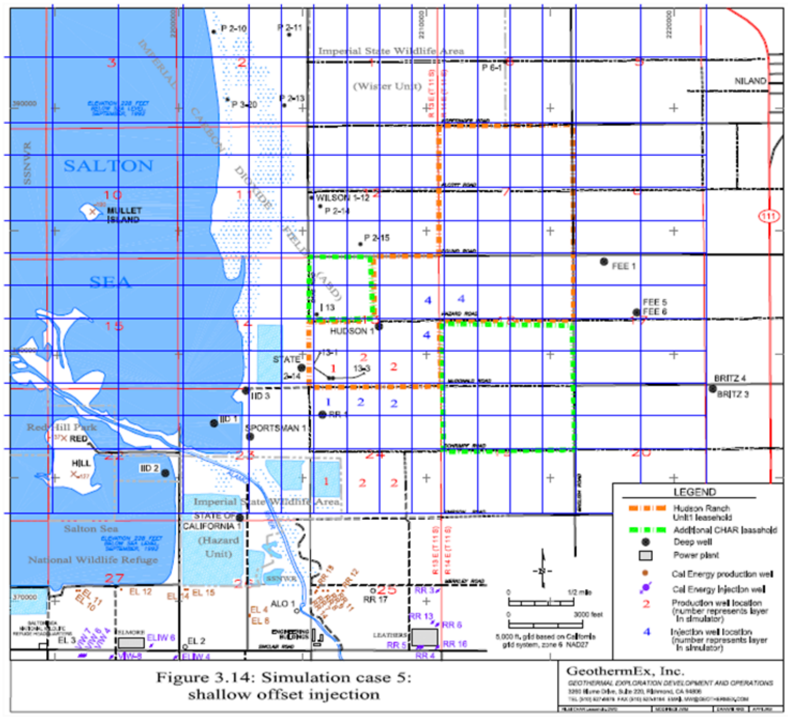

Figure 2. Simulation Case 5 with injection immediately south of the three Hudson Ranch producers (taken from GeothermEx, 2010)

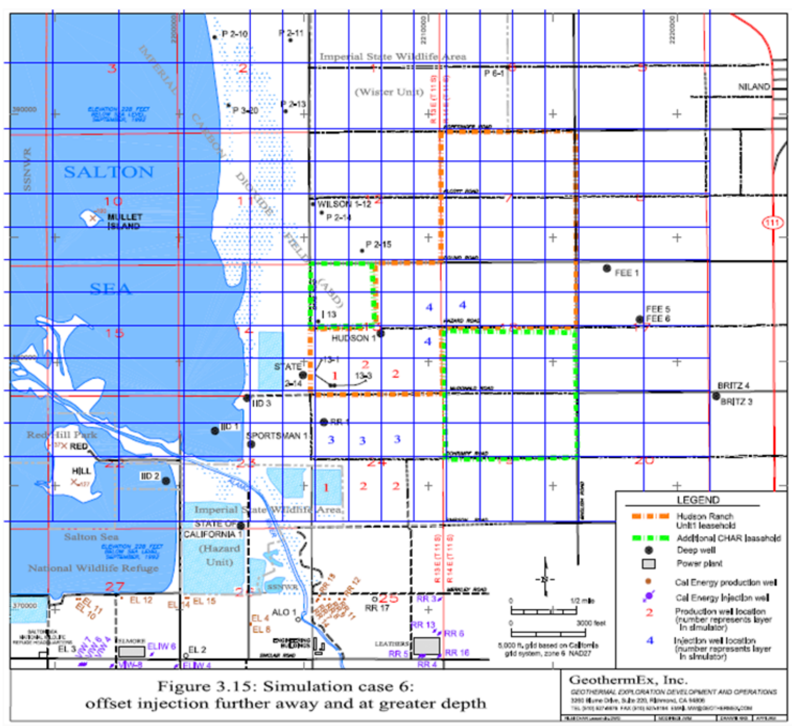

Figure 3. Simulation Case 6 with injection wells ¼ mile further south (taken from GeothermEx, 2010)

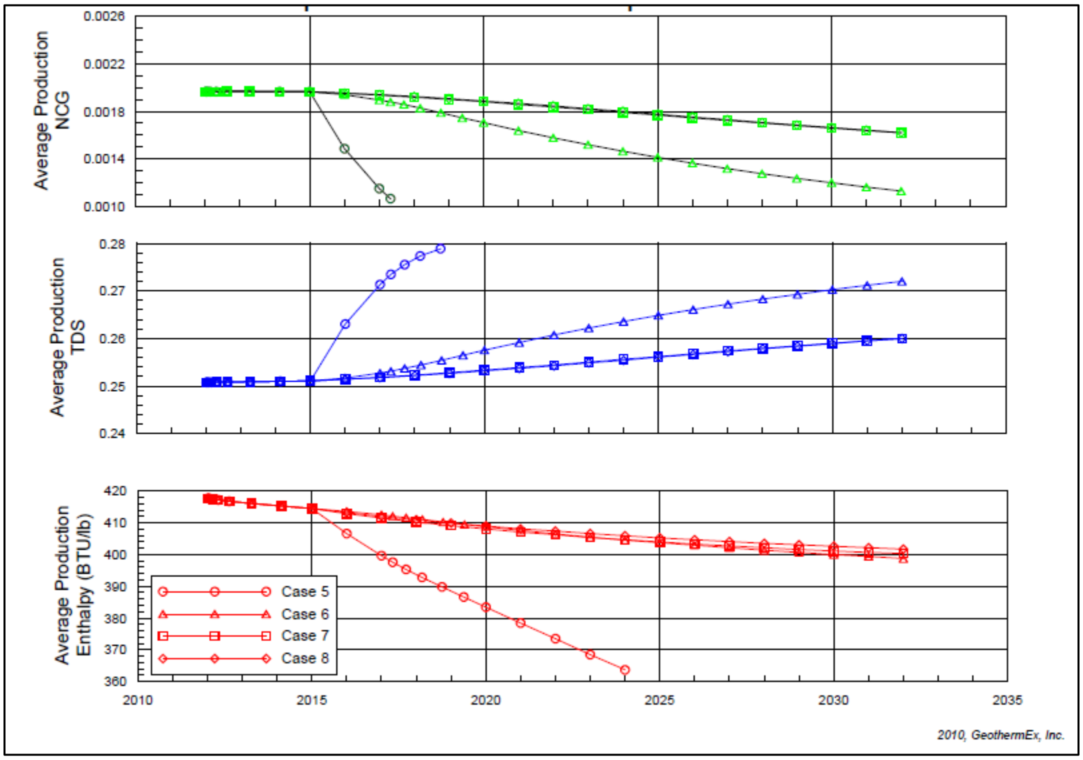

Figure 4. Comparison of Cases 5-8 for production well 13-2 (taken from GeothermEx, 2010)

Potential Resource Impacts of the Morton Bay Development, Pressure Interference Models

GeothermEx provided a resource adequacy report demonstrating the potential effects of the proposed Berkshire Hathaway Energy Renewables LLC (BHER) development of the SSGF, including the Morton Bay project[3]. The report noted the robustness of the Salton Sea resource and provided “representative” pressure decline curves for various project areas under the proposed development scenario. These curves demonstrate roughly 20 pounds per square inch (PSI) drawdown in the reservoir by 2030, and greater than 100 PSI of drawdown through 2065 (refer to GeothermEx, Figure 3.1). These declines would yield 4 megawatts (MW) to 25 MW decline in generation, respectively, assuming production well behavior similar to HRPI. Many of the assumptions and calibrations underpinning this model are not auditable by the public. The specific impact on existing wells and generation is also not captured in the report.

To our knowledge, no numerical simulation of the reservoir exists that benefits from collaboration and sharing of data amongst operators. As a result, no effort has been undertaken to quantitatively define a development path that optimizes the long-term benefit of the SSGF for all vested geothermal stakeholders, the state of California and the general public. It is the position of HRPI that a collaborative study amongst operators must be undertaken, that seeks to maximize the long-term benefits of the SSGF, including minimizing the degradation of existing projects by new development.

[3] “Numerical Reservoir Simulation of the Salton Sea Geothermal Resource for Power Generation” GeothermEx, May 2023, Docket Number: 23-AFC-01

Pending a comprehensive and collaborative study, HRPI has developed analytical models to explore the potential impact of the Morton Bay project on the existing Hudson Ranch project. These "radial flow models"[4] make several simplifying assumptions but are useful for demonstrating the sensitivity of the SSGF in specific areas to adjacent production. The results presented here use characteristics from the SSGF measured using conventional testing methods at the HRPI wells. The analyses also simplify the geometry of the well field, assuming the Morton Bay production is essentially consolidated at a single point, while varying the separation distance of that point from HRP1 and the magnitude of the flow extracted from the Morton Bay Project. The model omits the impact of Morton Bay injection, thus the precise pressure drawdowns predicted by this model will likely differ from reality. Nevertheless, the relative impact of spacing and flow magnitude decisions made during Morton Bay development are reasonably explored. As no directional plans are available, all Morton Bay wells are assumed to be drilled vertically (not directionally) to -8,227 ft above sea level (ASL), similar to the HRPI wells.

The initial analytical model (Figure 5) studied the production impact on the HRPI wellfield given different spacing setbacks for the Morton Bay producers at the flow rates needed to achieve 157 MW gross generation: roughly 11,200 kph total. Spacing setbacks between 500 ft and 15,000 ft were tested, yielding pressure drawdown in the reservoir between 102 and 35 PSI after 5 years of production. At 2,500 ft of separation (roughly the distance proposed between HRPI and Morton Bay of ~½ mile), and assuming a constant operating wellhead pressure of 400 PSI, the anticipated reservoir pressure drawdown approaches 75 PSI, resulting in a 350 KPH reduction of production on each HRPI producer, i.e., 1,400 kph of total mass reduction, equal to a loss of roughly 18.5 MW net in winter conditions (Figure 5). Even if the setback distances were expanded to 15,000 ft (nearly 3 miles away), a reservoir drawdown of 35 PSI is expected, which translates into a reduction in HRP1's generation of 600 kph or 8 MW net in winter conditions.

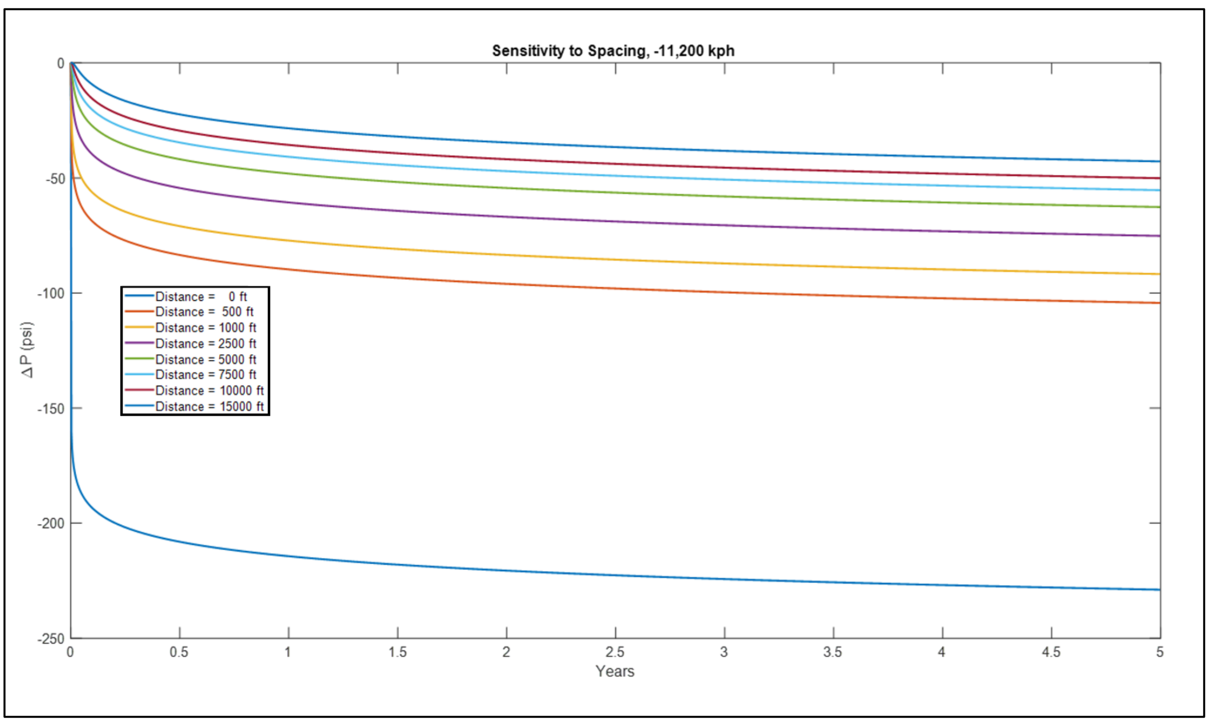

Figure 5. Pressure 2interference from the Morton Bay production (11,200 kph of total production)

[4] Horne, Roland N. "Modern well test analysis." *Petroway Inc* 926 (1995): 985.

An alternative Pressure Transient Analysis was proposed, reducing the total mass produced to 3,500 kph, or a roughly 50 MW project. All other parameters remained constant. At this lower generation target, with consistent spacing setbacks ranging from 500 ft to 15,000 ft, the estimated pressure drawdown in the reservoir varied between 39 and 16 PSI after 5 years of production. At a separation of 2,500 ft, and assuming a constant operating wellhead pressure of 400 PSI, the expected reservoir pressure drawdown approaches 27 PSI, resulting in a reduction of 105 KPH in production for each HRPI producer, totaling a reduction of 420 kph in total mass, equivalent to a net loss of 5.5 MW in winter conditions even if a proposed project is scaled back to 50 MW (Figure 6).

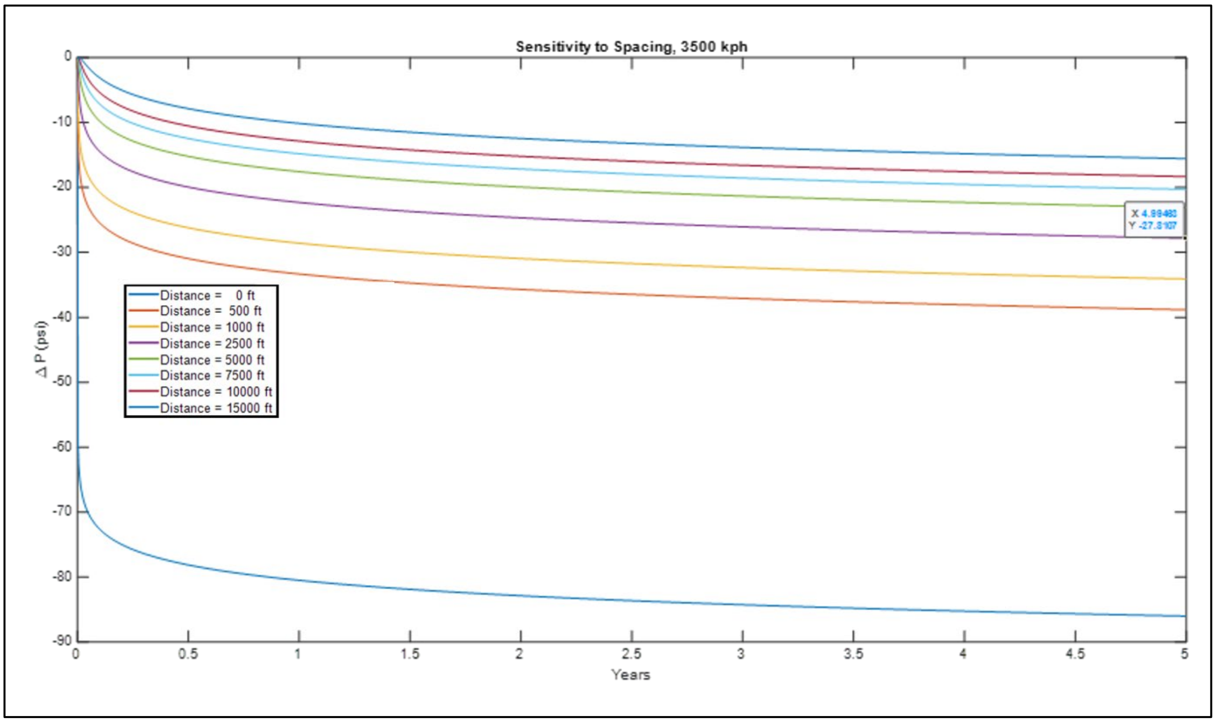

Figure 6. Pressure interference3 from the Morton Bay production (3,500 kph of total production)

These models illustrate the concept that well spacing and well flow are key design parameters that can be optimized to ensure long-term sustainable production from both new, and existing wells. Conversely, they can be ignored, significantly threatening the value of existing developments, and portending unsustainable results from new developments. The initial model, which approximates the needed flow from the proposed Morton Bay development, clearly suggests the size of the Morton Bay project as proposed is too large and spaced too closely to not have a material detrimental effect on the geothermal resource and the HRPI project.

Empirical Evidence of Reservoir Interference

Hudson Ranch has been generating electricity for over 10 years. The long run time of HRPI wells provides a robust data set to demonstrate real hydrologic communication between offset production and injection wells to complement the theoretical connections described in the previous section.

In 2018, a tracer test analysis was conducted on the sole shallow injection well (IW-4) for the HRPI project at the time. This test utilized ethylenediaminetetraacetic acid (EDTA) added to the IW-4 injectate which was injecting at a relatively low flow rate of ~390 KPH. Subsequently the produced brine was sampled in the high-pressure separator, where all produced fluid enters the HRPI power plant. During the test, the tracer was initially detected in HRPI's production wells 23 days after injection, reaching its peak after 43 days (Figure 7). Well IW-4 is completed at -2,967 ft ASL, meanwhile, all production wells at HRPI are completed at -7,122 ASL or deeper. The test demonstrates the important result that shallow and deep reservoirs in the Salton Sea geothermal area are in hydrologic communication.

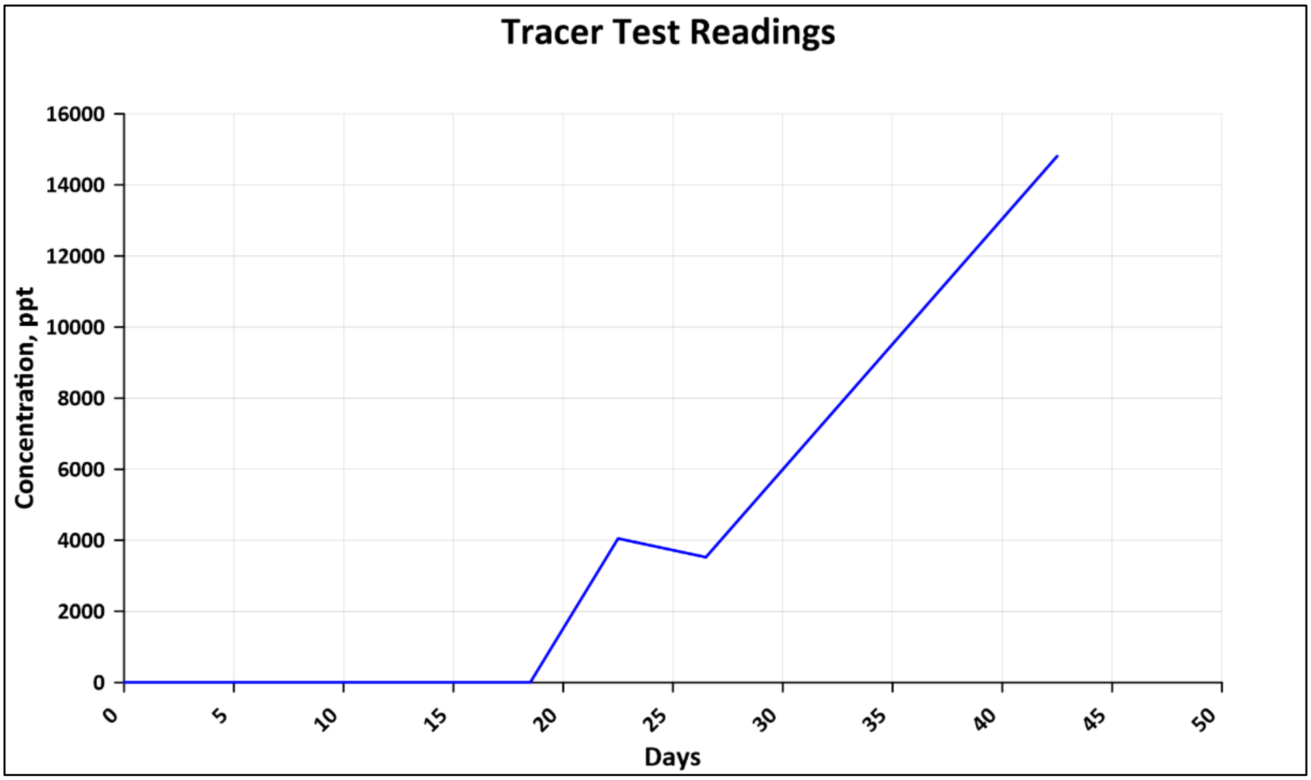

Figure 7. 2018 Tracer test injecting on IW-4 and reading on the HP Separator

The production contribution of each of HRPI's wells is monitored via pressure, temperature, flow rate, and salinity. Salinity is also a proxy for the relative contribution of the deep SSGF resource, around 7,000 ft below surface, compared to shallower, less saline and lower enthalpy fluids. HRPI has developed a model to estimate the zonal contribution[5] from each of the production wells. The analysis uses a multi-component mixing model where the contribution from each zone can be estimated using the salinities observed at surface. The model suggests that the deeper zones on HRPI's production wells 13-2 and 13-3 are in communication, as demonstrated in Figure 8: When well 13-2 is producing higher flowrates, the correlative zone in well 13-3 produces at lower rates and vice versa. For this specific case, the linear distance between the points where the zone intersects the wells is 1,084 ft. The analysis demonstrates that the tight spacing

[5] Siddique, A., Faulder, D.D., Rocha, S.: Inferring Zonal Contributions and Productivity from a High-temperature High-salinity Reservoir, Proceedings, 49th Workshop on Geothermal Reservoir Engineering, Stanford University, Stanford, CA (2024). *To be published in February 2024

of the Morton Bay wells to each other may not sustainably produce the flow needed, and also supports the concern that drawdown effects from the large amount of flow will reduce the productivity of the HRPI wells.

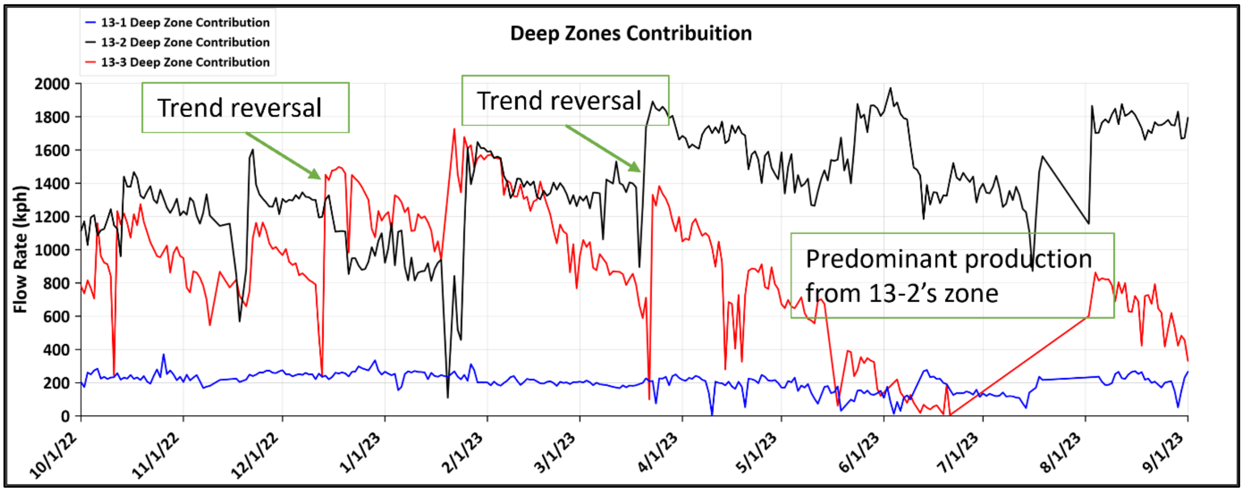

Figure 8. 13-2 and 13-3 deep zonal contribution with time

Power Density Considerations

As an initial check on project feasibility, the power density needed to support the Morton Bay project, as proposed, was compared to global analogues. A 1 square mile (2.6 square km) grid cell is shown over the combined Hudson Ranch and Morton Bay wellfield (Figure 9). Combined, the two projects are proposed to produce 217 MW in this 1 square mile, or 83.5 MW per square kilometer (60 MW existing from HRPI, 157 proposed from Morton Bay). This number is double the upper end member of power densities found in global analogues of 45 MW per square km at the Hatchobaru geothermal field in Japan (refer to Wilmarth and Stimac, 2015, Figure 6). Wilmarth and Stimac list the power density of the SSGF between 30 and 35 MW per square kilometer (*id*., Figure 3). Stated differently, of all producing geothermal fields in the world, 45 MW per square km is the far upper extreme of power density. The 83.5 MW per square km requirement from the SSGF is so far outside the distribution of established power densities in natural systems, that it is unlikely to be achievable for long.

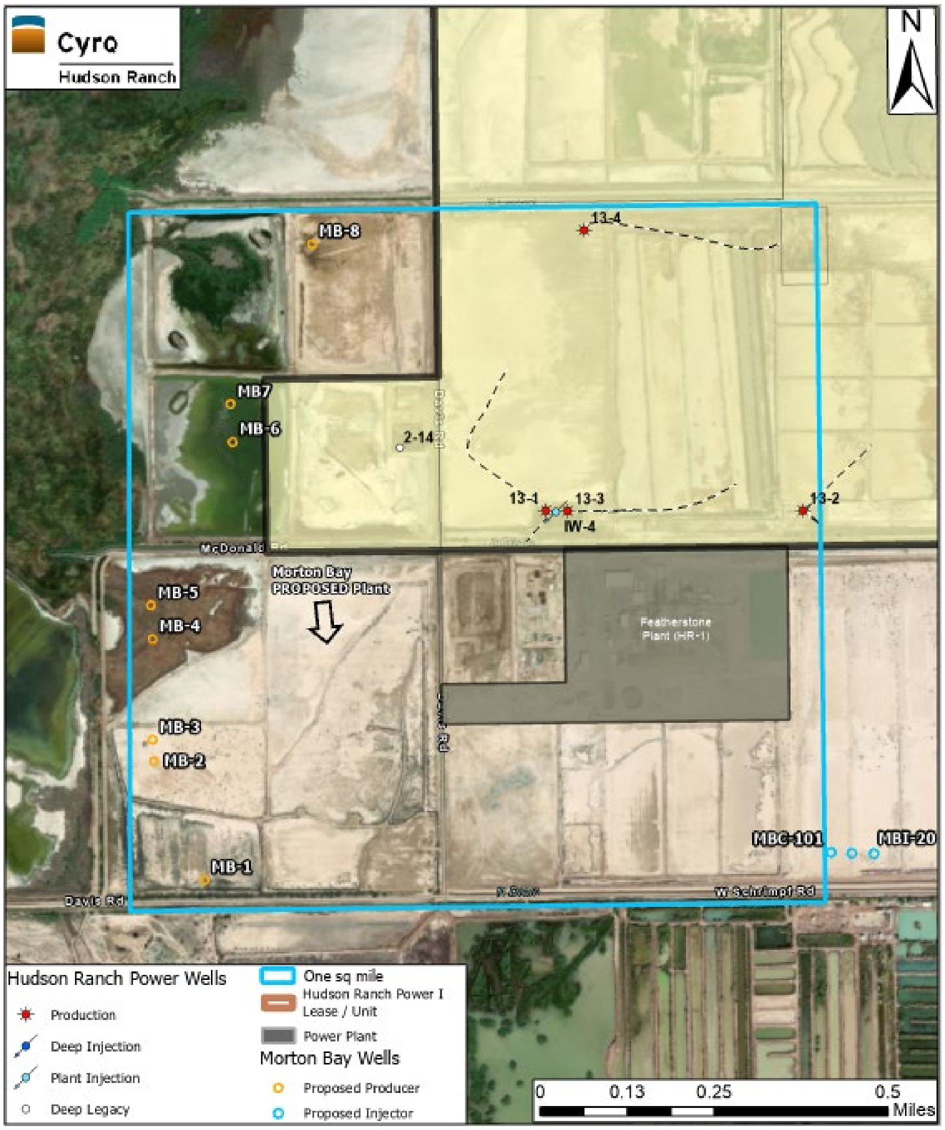

Figure 9: 1 square mile encompassing the Morton Bay and HRPI production well field

Likely Harm Resulting from the Morton Bay Geothermal Project as Proposed

As proposed, the Morton Bay Geothermal Project is predicted to result in reservoir pressure drawdown in the area of HRPI's production wells. This means lower well head pressure and consequently lower flow for the production wells. HRPI cannot compensate for the loss of pressure by flowing more fluid as the power plant design is fixed and relies on high pressure steam (320 pounds per square inch absolute [PSIA]). Since the power plant design is fixed, following a pressure drawdown, the existing wells will have to be operated at a lower flow rate in order to hold pressure constant. This lower flower rate is the basis of our estimated 18 MW reduction in generation, which has a financial impact on the order of tens of millions of dollars per year. Thus, in order to maintain the amount of electricity currently generated by HRPI and sold to its customer pursuant to a long term Power Purchase Agreement, HRPI will need to drill new wells that operate at the higher, necessary pressure—a costly proposition, particularly in the SSGF, and one that will likely exacerbate the resource depletion issue by again reducing overall well spacing.

Conclusions

This study reflects a range of analyses from broad global analogue comparison to detailed numerical simulation. In all outcomes, significant challenges to the long-term sustainable development of the SSGF arise raising risk of overdevelopment and degradation. It is the request of HRPI to pause the development of the Morton Bay Geothermal Project so that a joint study of the field may be undertaken, and a right-sized Morton Bay project may resume that ensures long-term sustainable development of this shared renewable energy source.