FROM ROUTES TO EXCEPTIONS: AUTOMATING PLUNGER LIFT WELL MANAGEMENT

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INTRODUCTION

Traditional plunger lift is different than other forms of artificial lift in that it requires no external energy to operate (Lea, et al), yet still demands operational excellence and knowledge to maintain components and optimize setpoints. Any deficiencies in system operation could lead to costly well loading downtime, requiring additional personnel or third-party intervention. In the past, operators were typically assigned a specific set of wells, known as a “route”. Wells were reviewed manually in a supervisory control data acquisition (SCADA) system to maintain a plunger lift system’s mechanical integrity and its operating settings. As the routes grew, it became difficult for field operators to maintain their assigned wells. Incremental gains were made by improved surveillance screens, creation of exceptions and additional personnel focused on settings optimization. In 2021, Occidental (Oxy) created a closed loop plunger lift artificial intelligence application (PLAI) that helped serve as a catalyst for greater operational change of plunger lift well management. PLAI, along with preventive maintenance activities and more detailed exceptions, now serves as the main method for plunger lift well management within Oxy. This paper examines the transition, the systems built, the challenges overcome, and the measurable results achieved.

MANAGEMENT PHILOSOPHY

The current management philosophy for plunger lift focuses on operational efficiency. The key components mirror the success of previous operations methods but with greater emphasis on automation:

Mechanical Integrity

A preventive maintenance team was formed to take over the mechanical integrity duties that had previously been handled by the route operator. This team focuses on plunger changeouts, pressure transducer calibration, and control valve integrity. Failure data collected from plunger changeouts is used to automatically adjust the targeted changeout frequency for the well.

Exception Based Surveillance

In the prior route-based management model, surveillance relied on generalized trends and individual operator experience. These trends, while practical, relied heavily on the operator and proved difficult at scale. The PLAI model instead chose to formalize and automate field experience, with the SCADA team creating specific exception logic in collaboration with field operators. This logic automatically flags specific well criteria based on field-defined rules and is fully configurable, allowing for the continuous refinement of exceptions as PLAI continues to be implemented.

Setpoint Optimization

Setpoints are optimized by two main methods for wells on or off PLAI. Wells not on PLAI may require individual manual adjustment via SCADA, while wells on PLAI feature automatic logic to correct common plunger lift issues. In either case, if setpoint adjustment cannot resolve current issues, field staff is notified to handle the mechanical or automation problem at the wellsite.

<u>PLUNGER LIFT ARTIFICIAL INTELLIGENCE (PLAI)</u>

In 2021, PLAI development began to create an artificially intelligent closed-loop system to address challenges managing plunger lift operations. The primary objectives were to stabilize well performance and reduce well loading events. Reducing the need for manual setting changes and surveillance was also a key objective. A secondary objective was to increase production without risking stability. PLAI accomplishes this task by the process flowchart outlined in Figure 1.

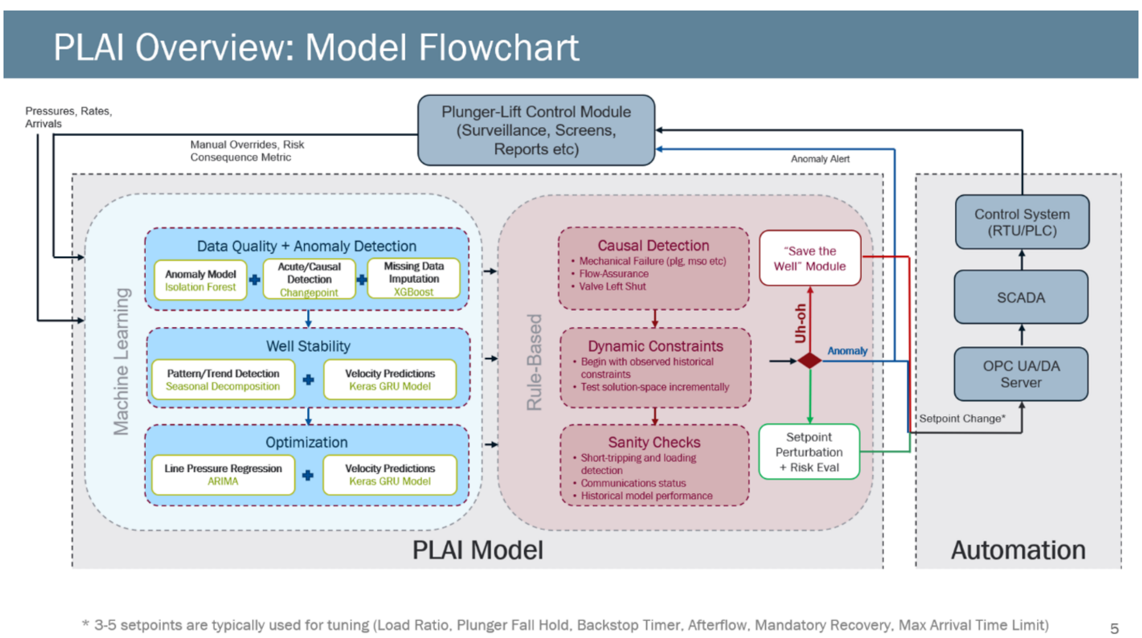

Figure 1: PLAI Model Flowchart.

SCADA data is ingested into machine-learning modules that assess data quality (including anomaly detection), operating stability, and optimization potential. Outputs are then evaluated through rule-based logic derived from operational feedback and historical observations. When PLAI identifies an opportunity for a setpoint update, the change is screened before being transmitted to the controller.

PLAI’s continuous development is supported by a JavaScript Object Notation (JSON) log generated for each well analysis. Figure 2 provides an example log for a representative well condition.


```json
{
  "well initialization": [
    "pfh: 4.0 lf: 0.27 ct: 9.83 af: 2.5 max: 23.5",
    "last analyzed cycle: 2025-10-31 19:09:36",
    "last real time cycle: 2025-10-31 19:22:52",
    "using data from caching workflow directly preceeding",
    "vector length (how many cycles are considered as recent): 19",
    "number of cycles in input data: 73",
    "pf_cycles: 19 nonpf_cycles: 0 lf_cycles: 0 ct_cycles: 0. missed_cycles: 0",
    "primary open setting used: close timer or fall hold",
    "number of recent flip-flops between fluctuating and stable modes: 3",
    "not flipping between stabilization and optimization (stuck)",
    "stuck_settings? False",
    "currently fluctuating well. load ratio fluctuation: 0.44. arrival duration fluctuation: 6.52.
      median arrival durations: 10.08",
    "load ratio fluctuation is weighted the highest, followed by median arrival duration",
    "fluctuation parameter value: 0.11. value exceeds the threshold of 0.06",
    "historical forecast uncertainty: high. 2.74",
    "fluctuating well, go into stabilization mode",
    "low sensitivity. reducing number of cycles required between optimization changes from 19 to 18"
  ],
```


Figure 2: Example JSON Log.

The JSON log captures key model outputs and rule-based decisions, allowing lift specialists to review PLAI’s rationale for operational changes when needed. The log also records which criteria triggered exceptions, enabling rapid troubleshooting and supporting ongoing logic refinement. Because each decision is traceable, staff can quickly recommend updates when performance gaps are identified.

<u>SCADA EXCEPTION MANAGEMENT</u>

SCADA development and integration were critical to automating the new plunger-management methodology. Over several years, the SCADA system evolved into a centralized interface for notes, plunger metadata, detailed trends, pending callouts, and enabling/disabling PLAI and exception logic. To eliminate full-trend review for every well, operators established two critical exceptions to prioritize wells requiring immediate attention. The first flags multiple fast trips, which may indicate suboptimal settings, post-downtime charge-up behavior, a plunger not reaching bottom, or a failed clutch plunger.

The second flags multiple missed trips, which may indicate suboptimal settings, a stuck plunger, or other mechanical issues. Figure 3 shows an example exception.

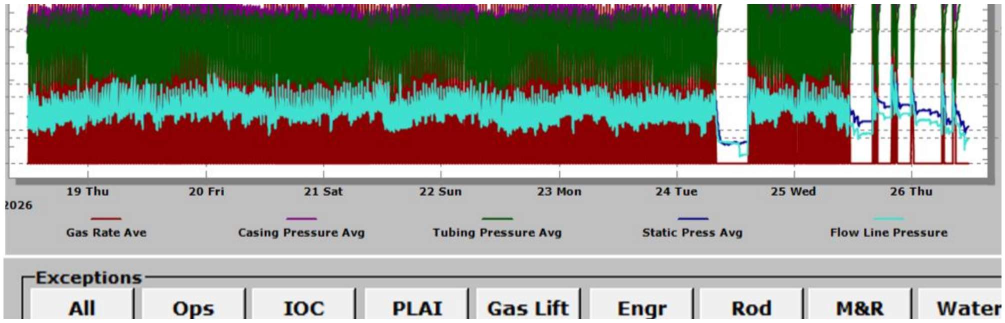

Figure 3: Example of SCADA system trend, plunger information and exception.

CALLOUTS

If automated (PLAI) or manual setpoint changes do not resolve an issue, operations are notified through an internal communication workflow referred to as a “callout.” Figure 4 shows typical callout content, including problem category, priority, and estimated barrel-of-oil-equivalent (BOE) impact.

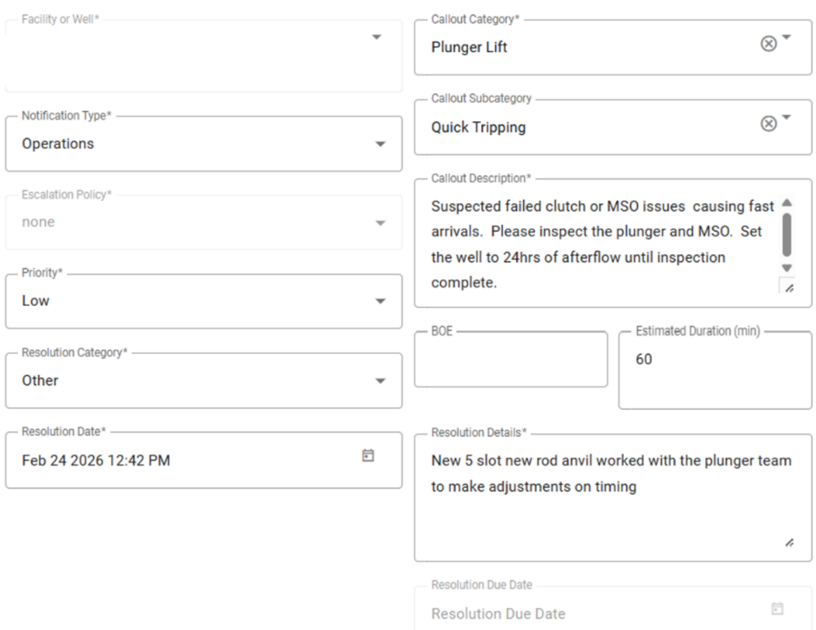

Figure 4: Callout example.

Callouts are routed to an operator (initiated by field or office staff) and closed with a resolution category and supporting details. This creates a documented maintenance history that supports troubleshooting, repeat-failure identification, and future design improvements.

CHALLENGES

Cultural Adoption of PLAI

Route-based operations were long established, so adoption of automation required a deliberate change-management effort. Early exception reporting (initiated in 2016) depended on SCADA data quality and well-defined logic; isolated data issues or overly narrow rules could reduce confidence in the system. Over time, the need to operate at higher well counts, combined with continued SCADA improvements, led to broader adoption of exception-based surveillance.

PLAI development and deployment began in 2021 and followed a phased rollout. The initial trial was supported by a developer with plunger-lift operational experience and included key stakeholders from the field. Regular review meetings with plunger-lift operators provided feedback on model performance and informed additional rule-based logic. After initial success, the process was replicated across other operating areas. As deployment expanded, lift specialists were added to troubleshoot issues and distinguish mechanical problems from program logic issues, improving operational confidence. Following a year of trials involving up to 300 wells and subsequent operational approval, PLAI was implemented on an additional 700 wells over the next three months.

Reliance on Sensors

Remote surveillance and closed-loop control depend on reliable wellsite instrumentation. Devices such as tubing-pressure transducers and magnetic shutoff (MSO) sensors provide critical inputs for automated setpoint changes and exception detection. PLAI includes logic to identify missing or suspect sensor inputs (e.g., values not updating for an extended period), prompting staff to review the issue and generate a callout if field intervention is required. While identification is rapid, each exception must be reviewed, and most sensor corrections require field response. Figures 5 and 6 illustrate a suspected tubing-pressure transducer issue and the associated callout.

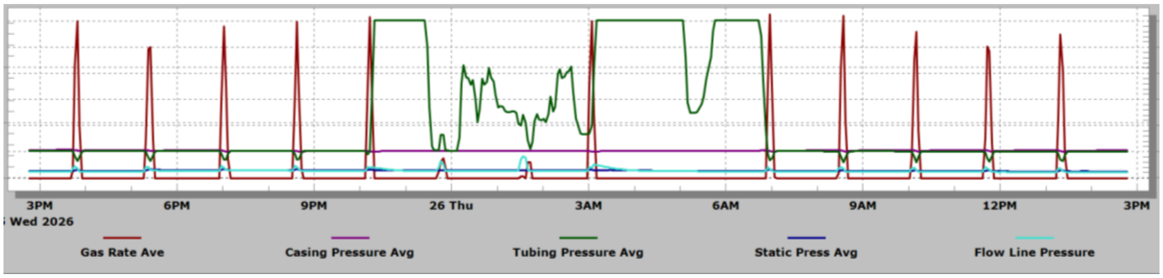

Figure 5: Sensor data displaying probable tubing pressure data issues.

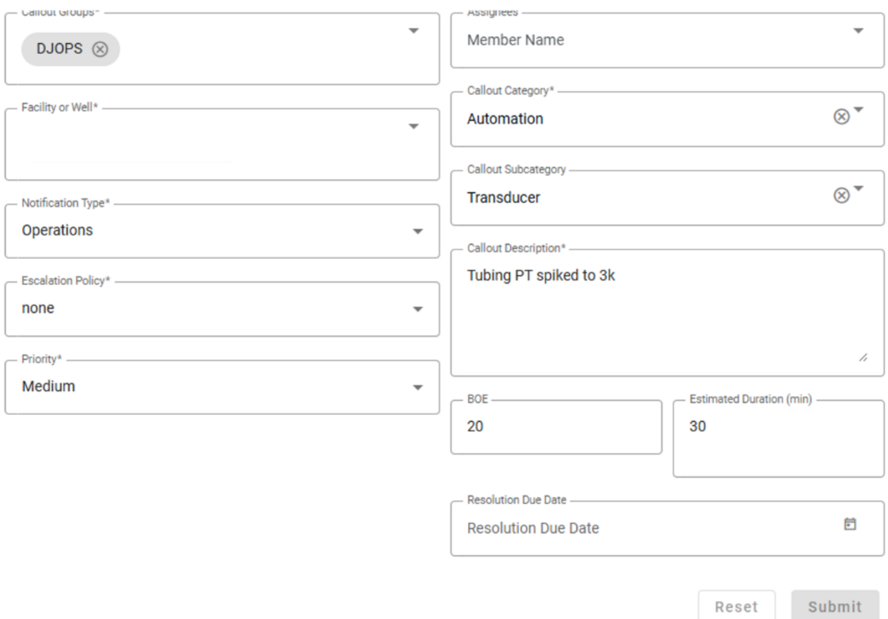

Figure 6: Tubing pressure transducer issue callout.

Changes to Operational Task Assignment

As the operator shifts away from route-based management, roles and task allocation continue to evolve. With automated surveillance, operators are less tied to fixed well lists and instead focus on responding to callouts, resolving automation and mechanical issues, and completing targeted projects. In parallel, lift specialists shift toward governing PLAI logic by reviewing performance, refining rules, and ensuring effective communication with the field through callouts and recommended updates. Clearly defining ownership for callout execution, logic oversight, and field response remains critical as the route-less model expands.

RESULTS

PLAI enables exception-based operations by stabilizing wells, automating optimization actions, and reducing the manual workload required to manage large plunger lift portfolios.

Well Stabilization and Emission Reduction

Operational upsets in plunger lift can lead to well-loading events. In 2021, these events were commonly resolved by unloading to a tank, swabbing, or using a trailer of compressed natural gas to add energy back into the well. In addition to downtime and labor costs, these interventions have emissions impacts. Figure 7 shows a pre-PLAI baseline of approximately 200 unloads per month. As PLAI adoption expanded from 2021 to 2023, unloading events decreased and the reduction was sustained. Relative to the pre-PLAI baseline, the program reduced unloading events by approximately 3,000 and avoided an estimated ~8,000 tons of CO2-equivalent emissions.

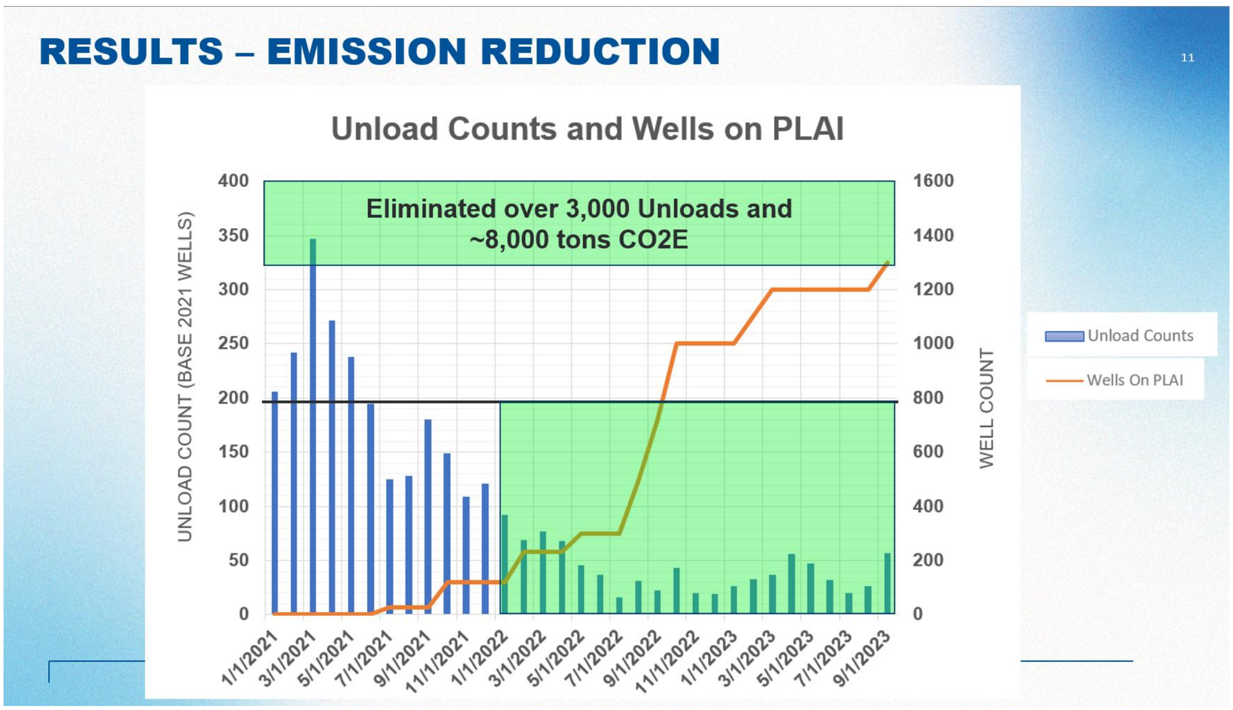

Figure 7: Emission reduction and unloads compared to PLAI count.

Automate the Field

A key objective for PLAI was to reduce manual setpoint changes and routine surveillance. Best practice is to adjust setpoints incrementally and allow sufficient time to observe response before making subsequent changes. At high well counts per operator, this approach is difficult to execute consistently. PLAI performs incremental changes autonomously and continuously. Figure 8 compares changes initiated by users versus by changes initiated by PLAI for September 2023 and highlights the scale and continuity of automated actions.

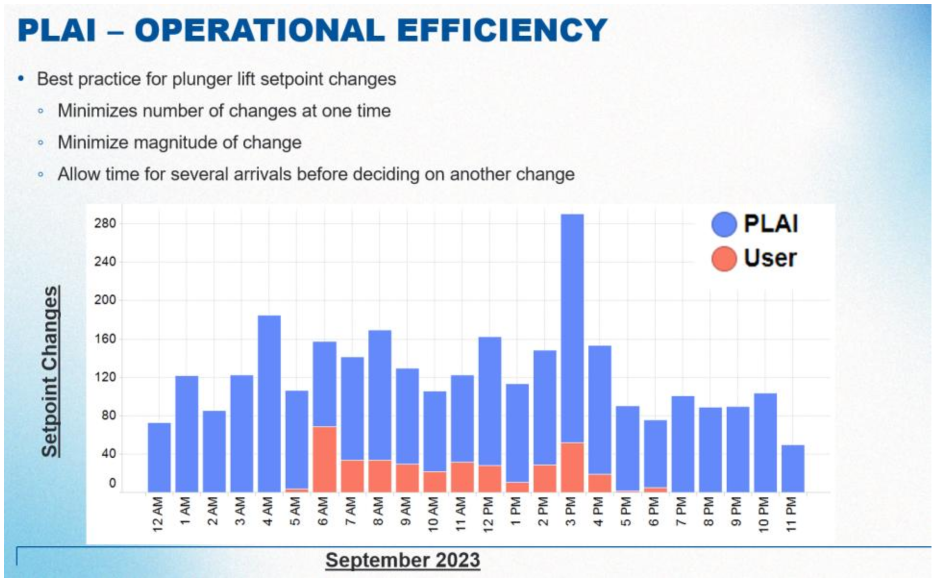

Figure 8:PLAI Operational Efficiency.

Production Impact

PLAI delivered measurable production impact in consecutive years. In 2022, during the largest scale-up to approximately 900 wells, incremental production uplift totaled 2.4 MBOED (million barrels of oil equivalent per day) on an annualized basis. In 2023, an additional ~300 wells were added, generating an incremental 1.3 MBOED. The reduction in wells added to PLAI from 2022 to 2023 reflects candidate high-grading and inclusion of the highest-producing wells during the 2022 rollout.

Table 1:Production impact due to PLAI.

Results		
Metric	Year	
	2022	2023
Production		
Annualized MBOED Impact	2.4	
Current MBOED Impact		1.3
Counts		
Total wells reviewed for PLAI	1,100	1,685
Wells on PLAI	900	1,230
PAGL wells on PLAI	0	50

CONCLUSION

The transition from route-based plunger operations to an exception-based model with automated setpoint changes represents a fundamental shift in plunger lift well management. While the operator continues to implement and further develop PLAI across its plunger lift portfolio, the following conclusions have been drawn so far:

1. Successful deployment relies heavily on field operator engagement, both their operational input to refine PLAI models and willingness to adopt the cultural shift from route-based management to a callout-driven model.

2. The route-based system for well management struggles to be effective at scale. The development of exception-based surveillance, supported by automation, provides a scalable alternative without sacrificing operational oversight.

3. PLAI is the AI application that makes scalable exception-based operations viable by autonomously stabilizing wells and adjusting setpoints at scale.

4. After PLAI was implemented, the number of unloading events was significantly reduced, demonstrating the significant operational, financial, and environmental benefits of automated well stabilization.

5. PLAI delivered consecutive years of measurable production uplift, validating the programs' ability to optimize at scale.

6. As routes are replaced with a callout system, the redistribution of stakeholder responsibilities is an ongoing process that must be continuously evaluated as the route-less model expands to ensure best efficiency.

7. Data collection requires dedicated monitoring strategies, employee input and regular reviews to maintain automation equipment and PLAI's algorithms to sustain program performance.

As PLAI expands across the operator's plunger lift portfolio, it continues to be shaped by ongoing operational feedback, data collection, and continuous refinement of its logic. The transition documented in this paper, from route-based management to an automation-driven exception-based model demonstrates that scalable operational excellence is achievable when technological development is paired with strong field engagement.

REFERENCES

Lea, J.F. and Rowlan, L. 2019. *Gas Well Deliquification*. Gulf Professional Publishing, Oxford, UK. ISBN: 978-0-12-815897-5.