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Case Histories of Life Cycle Well Integrity Management Using iWIT Software

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Abstract

The Intetech Well Integrity Toolkit (iWIT) is a web-based program which provides a comprehensive approach to well integrity management covering all potential integrity threats to the whole well. Using its own or existing client databases, this software carries out quantitative data analysis in real-time and provides feedback to the operator about the condition of individual wells and also overviews of the whole field integrity status to support timely, informed, decision-making.

Case histories are described of seven different operations introducing the software. The diverse reasons for introducing the software and the direct and indirect benefits ensuing are described. Each is a unique story, highlighting how flexible and comprehensive this successful software product has been. A common element is the management of data spread across multiple 3rd party datasystems which have been successfully integrated in each case, sometimes utilizing data entered in tablet PCs in the field directly linked to iWIT. More challenging is the vast range of data analysis and presentation which has been customized for each client to achieve their goal. This includes risk evaluation against complex criteria, determination of tubing condition based upon varying production conditions, calculating MAASP values per well per annulus, managing and generating well handover documentation from the software, tracking scaling issues, determining mean time to failure of equipment to establish risk-based inspection frequencies and many more detailed analyses,

The iWIT software has allowed these operators to prove their adherence to Well Integrity Management policies and provides numerous report formats including email alerts for engineers and managers. By ensuring well problems are proactively identified and responded to within guideline timeframes the software ensures that well integrity related shut-downs are reduced, thus providing improved productivity from the well stock and at the same time raising safety within the operations.

Key Benefits of the iWIT Software Identified from Case Histories

1) Reduction in number of wells shut in for well integrity reasons by about 80% over two years resulting in higher productivity and major cost saving.
2) Clear indication of wells' integrity status customised to meet company philosophy and local regulatory requirements.
3) Maximising value of all data about the well by making it available to all users in the company.
4) Integration of data from multiple sources by interfacing to existing 3rd party databases.
5) Real-time evaluation of environmental conditions which could result in failure of tubing in wells with variable production conditions.
6) Common system suitable for managing both brand-new field and mature field with aging wells.
7) Continuously updated risk status of all wells as data updates are made in real time.
8) Comprehensive scope capable of handling every type of data relevant to well integrity status; one-system covers all.
9) Common standards systematically applied throughout the company raising confidence in decision-making.
10) Reduction in data-gathering effort and report preparation by engineers, freeing them to carry out more detailed evaluation of workover options to resolve well issues; better utilization of skilled personnel.

Introduction

The essential function of an oil and gas production well and water or gas/injection well is to achieve the production of hydrocarbons in a cost effective and safe manner. The importance of well integrity total control has been recognized and accepted as a key part of safe operations for a long time. Significant improvements concerning both well design and operating procedures have been made. Nevertheless, the integrity of all well barrier components is continuously threatened and requires great vigilance to ensure continuous active control without the risk of unintentional leakage of well's fluid to the environment.

Recent regulations and standards demand that there is a need for a systematic control during the entire life cycle of a well. Whilst well integrity management system documentation provides the framework for decision-making and the organisational structure, total control of well integrity requires a *system* to be implemented with a sophisticated datahandling, analysis and communication capability. Such a system, the Intetech Well Integrity Toolkit (iWIT), has been in operation since 2006 with various operators internationally and is especially developed to meet the enormous challenge of providing total well integrity control. To date 15 operations have installed iWIT. Across all the iWIT deployments, interfaces have been made to 24 different 3rd party systems including SAP and Maximo (IBM). A number of case histories are described within this paper.

What Do We Mean By Well Integrity Problems?

The range of well integrity problems experienced internationally is widespread and different issues are more prevalent in different parts of the world. The most frequently reported operational well integrity problems are:

- o   Sustained annulus pressure,
- o   Completion string leaks,
- o   Wear/corrosion/erosion within the completion string,
- o   Casing corrosion,
- o   Scaling,
- o   Wellhead movement,
- o   Xmas tree and wellhead safety critical element (SCE) leaks.

Individual operators may be fortunate to face only some of these problems, but for many operators the range of problems to be managed is very widespread, either across the whole field of wells, or within individual wells. Any one of these issues is governed by many parameters: well design, well construction practice and the daily changes in operating conditions.

Hydrocarbon producing reservoirs contain acid gases (carbon dioxide and hydrogen sulfide) and high salinity formation water that are generally associated with increasing the severity of tubular material degradation. A great strength of the iWIT software, and a valuable feature for operations, is its capability to evaluate quantitatively the material degradation (corrosion & erosion) threats to the well integrity. The corrosion model used has been field-proven for over 14 years for both CO_2 corrosion and H_2S corrosion conditions. The tubular material degradation model takes into account the mass transport of the corrosive species to the surface and therefore has a flow dependency on the corrosion rate. This is a significant influence on the calculated corrosion rates compared to models which do not take flow effects into account. A sand erosion model, is also incorporated and safe operating envelopes for 13Cr and other alloy tubing. The output gives, on a per well basis, the wall thickness loss of individual well tubulars (Figure 1) and a cross-field review of the installed tubing identifying the percentage of wells having wall thickness loss in various fractions (Figure 2), indicating the potential future workover demand.

Annulus pressure records integrate automated readings with manually entered data giving a total overview in tabulated and graphical format. The data is automatically trended and communication of adjacent annuli is identified. Thermally imposed and sustained annulus pressure (SAP) cases are distinguished. All pressures are monitored relative to individual maximum allowed annulus surface pressure (MAASP) values, automatically calculated per annulus and per well, derating with time dependent on well component degradation and operating conditions (Figure 3). This allows the field to be operated safely but with minimum annuli bleed-off frequency. The transport of fluids within the annulus may result in accelerated corrosion of the casing strings and the resulting wall thickness loss impacts the load carrying capability of the tubulars. Reducing bleed-off frequency reduces the risks of annulus degradation resulting from replenishment of an aggressive annulus fluid.

No well that exhibits sustained annulus pressure is operated without problems. Managing operating risk means not letting small annulus integrity problems become big ones. What is often overlooked is the interaction of all the potential problems. Yet, it is often the case that when a well problem is investigated there are several factors which have contributed. It is really critical to take a holistic view to avoid overlooking combinations of problems which together can present a major threat. Integration of the tubular degradation model with the annulus pressure management, wellhead movement and SCE leak testing provides a uniquely powerful insight into the possible root causes of one of the most critical well integrity challenges.

Proactive well integrity management is the route to the maintenance of well integrity while maximizing field production. The methodology adopted here has proven to be an effective tool for well barrier control and well integrity management.

Case Histories

The following case histories highlight the range of issues which have been key problems for individual operators and show how the iWIT software has addressed those problems and opened up further benefits in each case.

CASE HISTORY 1

Background

The primary concern was control of annulus pressure across more than 300 wells, each with individually calculated maximum allowable annulus surface pressure limits for each of the annuli per well. All operational wells were surveyed manually each day by a variety of organizational groups. Data was sent by email to one engineer who visually surveyed the data, identifying wells with pressures above agreed limits. Those wells were identified for daily meeting discussions and appropriate action plans. All the daily manually collected data was subsequently re-typed into Excel spreadsheets for archive. From time to time individual wells' data was graphed for more detailed investigation and trending. The processes were labour intensive, open to error through manual data transfer, presented difficulty in the review and comparison of trends of adjacent annuli within individual wells and required weeks of effort to review for annual reporting to regulators.

Generally speaking the identification of well problems was not consistent and management demanded a system with greater visibility of data, faster analysis and response to problems and, overall, a reduction in the numbers of wells showing pressure problems.

Impact of iWIT Software Installation

Now all the wells data is entered directly into the software by the organizational group which gathers the data. Sources include:
-   About 20% of the wells are automated with annulus pressure readings directly into a SCADA (supervisory control and data acquisition) system which interfaces directly to iWIT in real time. As any additional new wells are automated, the set-up ensures their data is automatically transferred to iWIT.
-   The remaining 80% of the wells are visited daily by operators who collect the data out in the field using tablet PCs with software designed by Intetech (Figure 4). These identify the well as it is approached; data is entered into a user – friendly interface which validates data on entry. Data is transferred wirelessly to iWIT as it is entered (effectively at the time it is measured), or if communications fail, can be transferred by physical connection on return to the office.
-   Wells which have been identified for special investigation may be monitored more frequently by specialists either within the well integrity team or 3rd party company. Their data can be manually entered into the software using data entry forms which identify per well how many annuli exist and therefore require data to be entered.

For each well, individual MAASP (maximum allowable annulus surface pressure) values have been entered for each well and each annulus. MAASP values are updated with time and the history is maintained per well/annulus. All pressure data entered from all sources is accessible directly in tabular form for each well and graphed relative to the historical MAASP values. Bleed-off events are identified and communication from one annulus to another is indicated by correlation of pressure trends in adjacent annuli.

Individual wells with annuli pressures exceeding limits are immediately identified by traffic light indication, visibility on maps of the field and subsetting into automated daily report format. These requirements meet fully the fundamental concern of this client and give high and immediate visibility of key problem wells to managers and engineers.

Value-Added Benefits of the iWIT Software

Further reports were devised to provide the reporting of annuli pressures in the format demanded by the regulatory authorities, thus reducing the workload for the engineers and releasing more time for active problem analysis and workover planning. After 2 years of operations the numbers of problem wells closed in for well integrity reasons had dropped by about 80% as issues were being identified more quickly and appropriate repair solutions implemented.

In setting-up the software, all well design data was translated from various electronic and paper formats into an audited well design database accessible per well through iWIT. Later developments of the software capability enhanced the collection of routine and specialized leak testing of Safety Critical Elements (SCEs) such as valves and seals installed on the wellhead and Xmas tree.

CASE HISTORY 2

Background

The client was developing a new field and had concerns regarding the variation in production conditions being experienced as each well was drilled and tested. Specifically there were indications that the fluids might vary also with time in composition, depending upon the flow through individual wells across the reservoir. Since the integrity of the materials installed in the wells was a high priority concern in order to meet the full design life of the well it was considered necessary to install a well integrity system capable of evaluating in real time the agressiveness of the well fluids.

Impact of iWIT Software Installation

The iWIT software has highly advanced analytical capability to calculate the in-situ pH of the fluids in the well and evaluate the well fluid chemistry for compatibility with the materials installed in the completion string. Produced fluid sample analysis data is entered into the software per well. This chemical data, combined with the fluid flow rate data and pressures and temperatures provided from a 3rd party production data management system interfaced to iWIT, is used to identify any wells operating in, or close to, conditions which could cause pitting or cracking of the installed tubular materials (Figure 5). Reporting of the risks follows the format required by the company and wells are identified by traffic light colours and reporting in map-views and daily or other reports to management and engineers. New wells are entered into the software as drilled and all the required functionality automatically comes into operation as relevant well data is entered.

The initial aim of the software to allow the close management of a new field to within the safe operating envelope of the tubulars installed was achieved in full and the field continues successfully in operation with continued surveillance of this critical requirement.

Value-Added Benefits of the iWIT Software

Noting the much wider functionality available through the IWIT software, the company broadened its use to incorporate a second, mature field which had a typical cross-section of legacy Excel spreadsheets of data and history of past testing of installed SCEs. This much larger field was incorporated into their iWIT deployment and the legacy well design data and annulus pressure information and SCE test data was entered. The client makes extensive use of the reporting of the schedule of required tests to ensure compliance with Well Integrity Management schedules and the tracking of all wells operating under individually approved dispensations.

CASE HISTORY 3

Background

The overwhelming problem faced by this client was a need to integrate 5 existing 3rd party database systems to achieve an integrated solution, comprehensive data evaluation in a common platform and clear visibility of well problems across the whole organization. The existing databases were physically located on servers in different cities and the data within had never previously been directly accessible by personnel located outside the local offices.

The other key issues the client faced were related to corrosion of tubing and incidences of scaling in the wells. They were also tracking microbial sampling of various well fluids as part of a general reservoir and condition monitoring activity. All these diverse problems were dealt with by separate experts generating valuable data which was not readily available to others in the company.

Impact of iWIT Software Installation

Interfaces were created to all the databases to separately supply the iWIT software with:
-    Well design data (installed completion string and casings information and deviation surveys)

- Production data (T, P, flow rates of fluids) and Fluid sample analysis
- Annulus pressures from automated and manual sources
- Valve and seal leak testing results

The final 3rd party system was the Event Logging system which identified the opening and closing events of actuated valves. This was initially used to identify the Open/Closed condition of the wells.

iWIT customization was carried out to match the business process of scale identification offshore, its initial recording and subsequent laboratory analysis. Over time this has vastly improved the understanding of scale incidence, aiding in its treatment and prevention. Microbial analyses are also now tracked centrally, helping to identify the spread of species across different wells and reservoir regions.

Value-Added Benefits of the iWIT Software

With the interface to the Event Logging software in place, the closure of a SSSV was set up to trigger immediate high frequency collection of THP data. Effectively, this means that whenever the SSSV is closed (even if not related to well integrity issues) the pressure above it is monitored, and in some cases may generate a satisfactory SSSV leak test. Effectively this may then "save" having to carry out a deliberate SSSV closure on that well until a later test date. Deferment of even a couple of SSSV tests per year across all of the wells provides a significant enough production saving to justify the annual software costs.

CASE HISTORY 4

Background

With a large number of wells, this client had already made a major effort in entering the well design data, produced fluids chemical analyses and routine annulus pressure readings into a 3rd party database. The requirement for iWIT was to utilize the advances available in data analysis within iWIT to automate the risk – ranking of wells according to a wide variety of criteria:
- Annulus pressure values compared to individual annuli MAASP figures
- Failures of individual well component leak tests breaching a single well barrier
- Failures of combinations of well components, indicative of dual barrier failure
- Presence of high H2S in wells associated with high leak rates

Depending upon the combinations of issues arising in individual wells an Action Rank was applied, requiring a repair response within a defined timeframe.

Impact of iWIT Software Installation

Given the large number of wells involved, the data to be evaluated on a continuous basis was very substantial and the software provided a totally reliable way to carry out the risk ranking in real time. Data is drawn from the 3rd party database, from maintenance management software (Maximo) and from the manually entered data within the iWIT software database. An overview pie chart identifies the % and number of wells at each risk level (Figure 6); clicking on the pie segments produces a list of the actual well IDs in that segment.

The iWIT software also has a real-time evaluation of tubing corrosion rates which the client used to identify wells with higher corrosion rate which were then prioritized for batch inhibition. Once in the batch inhibition program wells enter the schedule for re-treatment within the required time-frame to ensure that this critical integrity treatment is maintained. Similarly, wells requiring scale treatment are identified and scale treatments are kept to the schedule of the optimum treatment.

Value-Added Benefits of the iWIT Software

Following successful use of the system for one year, the client realized the great potential of having all their historical data from the past 30 years of operations available within the single system. Intetech data managers entered all the historical change-out of wellhead and Xmas tree valves and seals since start up of every well. All integrity tests and diagnostic pressure blow down and build up tests have been entered resulting in what is probably the most comprehensive set of well integrity data available to any operator internationally.

CASE HISTORY 5

Background

This operator was looking for a well integrity software system suitable for controlling well integrity in all its worldwide assets with a common approach and reporting format but with the flexibility to accommodate a wide variety of production conditions, onshore and offshore, single and dual wells, conventional and coal-bed methane production wells.

Impact of iWIT Software Installation

The software was customized to reflect the overall company well integrity management philosophy for testing requirements, acceptance criteria, dispensation for deferred action, repair planning and prioritization of actions.

Rolled out across operations in 6 countries, the iWIT software links to existing database systems for accessing well design data, production data, chemical analysis of fluids and annulus pressure readings. A comprehensive iWIT database of all installed wellhead, Xmas tree and SSSV safety critical equipment provides the basis for defining the scope of routine testing. Further customizing of reports to provide a standardized format across the globe all contributed to better efficiency and clearer communication of well integrity issues within the group.

All the systems are linked to "iWIT International" software based at the head office which provides a snapshot overview of the well integrity status of the worldwide wells.

Value-Added Benefits of the iWIT Software

The key benefit identified by this operator in implementing the software was in reducing the number of wells shut-in because of integrity reasons, primarily through identifying well problems proactively before they reached a condition requiring shut-in. Gaining production in one typical producing well for even a few days through addressing problems in a timely way covers all the maintenance costs of the software.

Extra benefits in the more efficient use of personnel is enormous too; engineers are pleased to be relieved of tedious data gathering and report preparation tasks, freeing their time for the more in-depth evaluation of solutions to identified well barrier breaches and detailed risk analysis. A shift from the "fire-fighting" mode to "planning" greatly reduces stress and improves work quality for all. In a time of skill shortage, optimum use of skilled personnel across the globe is critical to business success.

CASE HISTORY 6

Background

This operator has about 500 onshore gas storage wells. Well integrity and control is critical to ensure that there are no losses of the valuable stored gas and to provide guaranteed protection to the environment and public living close to the storage fields.

Impact of iWIT Software Installation

The iWIT software automatically reads injected and produced gas volumes per well allowing tracking of productivity as well as managing all the safety critical SSSV testing and annulus pressure monitoring in real time. Interfacing to the existing production data management system and incorporating a comprehensive well design database within iWIT, the software is fulfilling a vital role for the company.

Value-Added Benefits of the iWIT Software

Having a history of more than 20 years of SCE test data available, the client has a vast statistical resource available which is sufficient to provide a viable calculation of the mean time to failure (MTTF) of SSSVs of varying sources and models. Based on the MTTF output, the basis of frequency of equipment testing can be adjusted on a risk-based inspection criteria, rather than on a fixed frequency. Carrying out tests in some cases in a shorter timeframe than in the past, to ensure failures are caught, will improve safety. However, in many cases, the test frequency will be *reduced* meaning that time between testing is increased, resulting in great savings whilst staying inside clear safety guidelines. The analysis of the vast amount of data involved, and its continuous update in real time as new test data is added, is a critical service which this advanced software can provide.

CASE HISTORY 7

Background

Working in a highly regulated environment with a large number of wells this client needed to greatly improve the ease of reporting the well integrity status in the format required by the regulator. Challenges included the existence of many in-house 3rd party data systems of various architectures, with multiple instances of each across the several fields. A key focus was on the handover of relevant documentation defining the safe operating envelope of each well at every well handover stage.

Impact of iWIT Software Installation

Interfaces were constructed to all the various systems and a new method of tracking the well handover events established; the iWIT software itself generating the safe operating envelope for handover from operations to drilling and the updated document being automatically re-read into the software when handed back from drilling. Specific reporting templates were created to meet the regulators requirements, thus reducing the tedious data collection and risk of errors associated with handling large volumes of data in spreadsheets. The reports are also more up to date as they are generated based on the real-time data.

Value-Added Benefits of the iWIT Software

Introducing the iWIT software has forced some review of the legacy data systems and has identified strong business cases for the update of some of those old systems ranging from data auditing through to establishing new schemas for data management in some cases. The integrity of data within the company has been strengthened as a consequence of introducing the iWIT software.

Conclusions

Total control of well integrity is a necessity. The iWIT software aims to address the full scope of possible well integrity problems and has provided its clients with specialized data analysis and reporting formats to cover a wide range of requirements.

With a strong track record of proven successful case histories this software has established itself as the leading product on the market.

Author Biographies

Dr Liane Smith, Director of Intetech Ltd, formed the company in 1991 after 10 years working for the Shell Group of Companies in the UK and Netherlands. She has been involved with solving well integrity problems, modelling field corrosion in downhole tubing and selecting materials for production tubing throughout her career. Elected in 2008 as a Fellow of NACE (USA) for her work in modeling corrosion and materials selection, she was honoured to be awarded a Fellowship of the Academy of Engineers (UK) in 2010. She can be contacted at liane@intetech.com.

Mr Ged Lunt is the manager of Intetech Wells Ltd and has been responsible for delivering the Intetech Well Integrity Toolkit (iWIT) software for well integrity management to clients including the BG Group worldwide operations, Statoil (2000 wells in Norway), Stogit (ENI gas storage company) and Hess Equitorial Guinea. He has extensive experience in analysis of customer well integrity management requirements, in interfacing database systems into the iWIT software and customising iWIT to match company requirements. He can be contacted at ged@intetech.com.
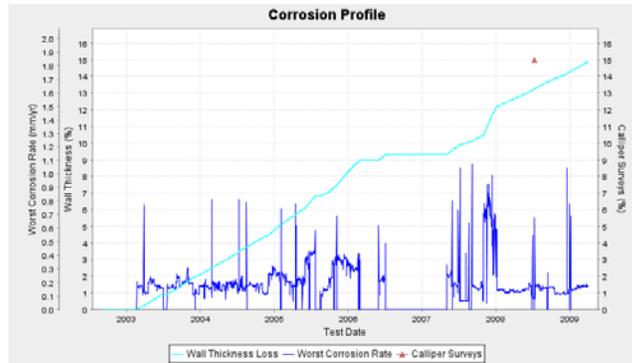
Figure 1 – Example corrosion rate estimate for an individual well as a function of time (dark line) and cumulative tubing wall thickness loss (light line). A caliper survey result is indicated by a triangle in mid 2008 confirming reasonable agreement with the corrosion model at that date.
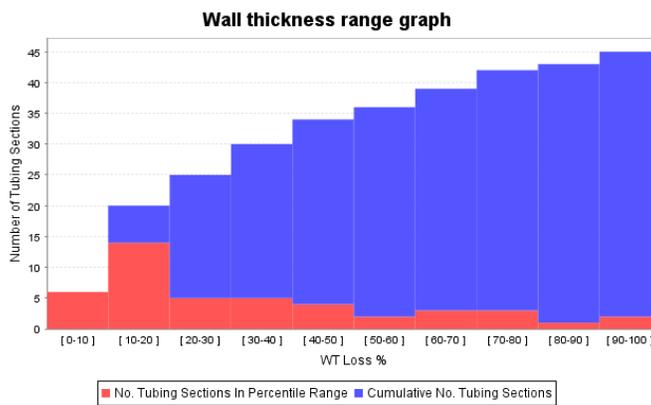

Figure 2 - Review of the installed tubing in one field identifying the percentage of wells having wall thickness loss in various fractions.
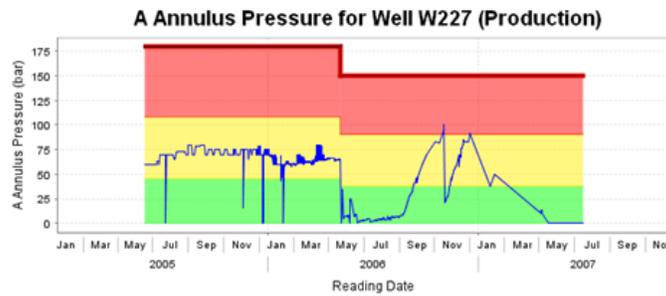

Figure 3 – Example annulus pressure monitoring graph showing (upper line) the annuli MAASP values derated with time.

Figure 4 – iWITNotePad touch screen handheld tablet PC for entry of data from the wellsite directly into iWIT.
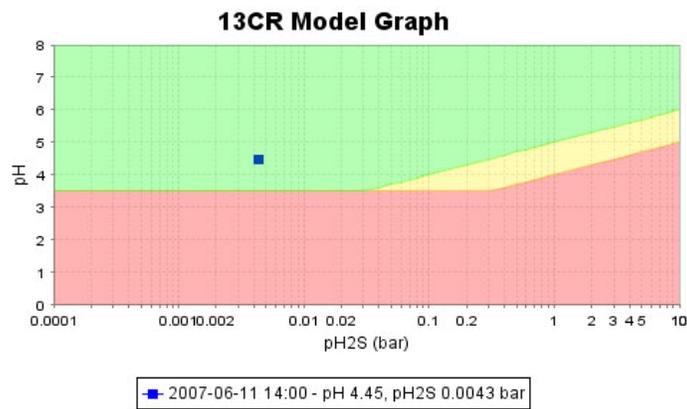

Figure 5 – Automatically estimated pH and partial pressure of H2S to define whether a well condition is safe for 13Cr tubing.
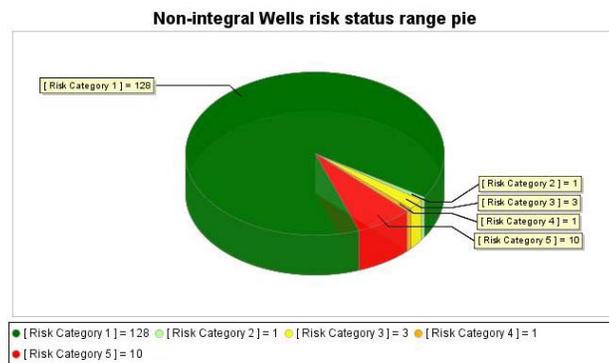

Figure 6 – Risk status pie chart indicating % and numbers of wells in each risk status level.