

11966 SENATE RESOURCES

These meetings will be targeted for April and October of each year, although this timing can be adjusted upon the mutual agreement of BP, PAI, and ADEC. The location of the meetings will alternate between the parties.

2. BP and PAI will submit annual reports to ADEC, which will provide the status of current and projected monitoring activities. These reports will be issued on or before March 31<sup>st</sup> of each year, and reflect the prior calendar year. The following information will be provided:
  - A. Annual bullet item reporting the progress of the Charter Agreement corrosion related commitment.
  - B. A general overview of the previous year's monitoring activities.
  - C. Metrics that depict coupon and probe corrosion rates.
  - D. Metrics that characterize chemical optimization activities.
  - E. Metrics that depict the number and type of internal/external inspections done, and, as applicable, the corrosion increases/rates and corresponding inspection intervals.
  - F. Metrics that characterize the quantity and type of repairs made in response to the internal/external inspections done per the above paragraph.
  - G. Metrics that depict the numbers and types of corrosion and structural related spills and incidents.
  - H. A forecast of the next year's monitoring activities in terms of focus areas and inspection goals. These forecasts cannot be viewed as binding, as corrosion strategies are dynamic and priorities will change over the course of the year. However, changes in focus will be communicated to ADEC during the semi-annual meetings described above.

Note: These reports will be presented in, and be part of, a comprehensive North Slope Charter Agreement status report.

3. In addition to the semi-annual "meet and confer" working sessions referenced above, BP and PAI will remain accessible to provide "ongoing consultation" to ADEC regarding environmental control technologies and management practices

'Environmental Control Technologies' refer to those technologies specifically related to corrosion monitoring and mitigation of the subject pipelines.

'Management practices' refer to corrosion monitoring and related practices as defined above.

4. During the semi-annual 'Meet and Confer' working meetings with BP and/or PAI, ADEC may use the services of a corrosion expert(s) (contracted from funds under Charter Commitment paragraph II.A.7) to assist in a review of performance trends and corrosion program features.
5. BP has assigned CIC Manager, R. Woollam/564-4437, and Phillips has assigned Kuperuk Engineering and Corrosion Supervisor M. Cherry and J. Huber/659-7384, to be the contacts responsible for ensuring these commitments are met, including ADEC notification of scheduled times for the semiannual presentations. The ADEC contact for this effort is (Pipeline Integrity Section Manager/S. Colberg/269-3078) who will notify interested personnel of the presentation times, maintain the reports for distribution to the public when requested and coordinate other issues relating to this commitment.

#### **Annual Timetable**

- March 31<sup>st</sup> Annual Report
- April 30<sup>th</sup> 1H Semi-Annual Review (Meet and Confer)
- October 31<sup>st</sup> 2H Semi-Annual Review (Meet and Confer)

## Guide for Performance Metric Reporting

### General

- Different metrics show and reveal different aspects of the business and as a consequence there are rarely any 'right' or 'wrong' measures only 'right' or 'wrong' application and usage
- Summary statistics described below may be provided as a data appendix to the annual reports with the more pertinent tables and graphics being contained in the text as appropriate. The intent is not to clutter and interrupt the flow of the text with extraneous data
- Format of data, the order in which it is presented, etc. of each company's annual report may differ from the order presented below, depending on key messages and data context. For example, one company may choose to imbed Leak/Save data into an inspection graph as opposed to presenting the Leak/Save data in standalone tabular format.
- This is an initial document for implementation in the 2001 annual report to ADEC, it should be noted, that the guidelines provided below can and will be adjusted to improve the efficacy of the annual report and reporting mechanism

### Timescale

- Data to be presented on an aggregate annualized basis
- Base year 1995 providing 5 year history before the start of the Charter Agreement and each year's annual report will add to time series starting in 1995

### Equipment Classification

- **Well Line** Pipe work from the well head to the Well Pad Manifold Building, generally, the flow from a single well prior to commingling before transportation to the separation plant
- **Flow Line** Pipe work from the Well Pad Manifold Building to the Separation plant, generally, cross country and off pad pipe work which carries commingled flow to/from a well pad. Also, straight run flow from the wellhead to separation plant, without commingling, is classified as Flow Line pipe work
- **Exceptions** Pipe work not conforming to these basic definitions will be reported by exception

### Service Definitions

- **Three Phase Production(3ø or O/WG)** Basic reservoir fluids (O/W/G – oil, water and gas) produced from down hole through to the main separation plants that typically see only see changes in temperature and pressure from reservoir conditions and are therefore essentially un-separated

- **Seawater (SW)** Water sourced typically from the Beaufort Sea that has undergone primary treatment at the Seawater Treatment Plant. Note, that the seawater treatment plants differ across the slope in the primary treatment methods, most importantly oxygen removal, with both production gas and vacuum stripping being employed
- **Produced Water (PW)** The water produced with the primary reservoir 3 phase production after passing through the separation and treatment
- **Commingled Water (CW) or Mixed Water (MW)** Water which has been commingled and is therefore multi-sourced, this is typically a mix of SW and PW although other combinations exist in the operations on the North Slope
- **Gas (G)** Generic term for a number of different gas systems which transport essentially dry gas between facilities including fuel gas, lift gas and miscible injectant
- **Processed Oil (PO)** The oil/hydrocarbon produced with the primary reservoir 3 phase production after separation and treatment, this is primarily black oil but could include black oil plus NGL's

#### Basic Summary Statistics

- **Distribution** The data is fundamentally of log-normal distribution, with a lower limit of zero or no-change and potentially unlimited upper extent
- **Count** A count of the number of activities completed i.e. coupons pulled in a given year
- **Average** The average or mean for the criteria being summarized i.e. average corrosion rate
- **Target Value** The target value against which non-conformance, see below, is reported
- **Number Non-conformant** The number of items not conforming to the control criteria i.e. the number of coupons exceeding the control value
- **Percentage Non-conformance** The percentage not conforming to the control value as a percentage of the total

#### Weight Loss Coupon Data

Table below summarizes the reporting of weight loss coupon data for the major fields on the North Slope

	Well Lines	CCL/FL
<b>3 <math>\phi</math> Production</b>	All	All
<b>Seawater</b>	GPB	All
<b>Prod. Water</b>	GPB	GPB
<b>Commingled Water</b>	All	All

The data sets to be provided for both general corrosion rates and pitting rates are,

- Count of coupons
- Average corrosion rate
- Number non-conformant

- % Conformant i.e. 1 minus the % non-conformant
- A corrective action list for non-conformant flow lines (FL/LDF/CCL/CLs) will also be provided.

### Internal Inspection Data

Table below summarizes the reporting of internal corrosion inspection data for the major fields on the North Slope

	Well Lines	CCL/FL
3 ø Production	All	All
Commingled Water	All	All

Note that no distinction will be made between water services across the North Slope since in many cases the service is variable making meaningful analysis and aggregation difficult.

The data sets to be provided for internal inspection are,

- Count of inspections
- Number of increases on repeat inspection locations
- Percentage of increases on repeat inspections

A corrective action list for flow lines (FL/LDF/CCL/CLs) with inspection increases will also be provided.

### Corrosion Inhibition

The corrosion inhibition program is to be reported as the target and actual total annual gallons and gallons per day, and as concentration, ppm, based on a field wide average.

### External Corrosion Inspection

External corrosion inspection program is to be reported as an aggregate of all piping systems without distinction or differentiation of service and equipment type with a summary of the overall program status.

The data sets to be provided for external inspection are,

- Count of inspected location
- Number of corroded locations
- Percentage of inspection locations corroded

### Repair and Leak Statistics

The repair and leak/spill statistics to be reported for each year plus the historical trend back to 1995 consistent with other performance metrics. The basic definitions,

- **Leak/Spill** An agency reportable leak/spill for the pipelines covered under the Charter Agreement which was caused by corrosion and/or erosion

- **Save** A location which required repair action as a result of corrosion and/or erosion damage but which was found through inspection prior to causing a leak/spill

The data sets to be provided for Repair/Leak statistics,

- Count of Leaks/Saves by flow line and well lines
- Summary of leak/spill causes

#### **Below Grade Piping**

The data sets to be provided for Below Grade Piping (BGP) program,

- Number of segments/crossings inspected broken out by inspection method
- Number with anomalies and severity of anomaly

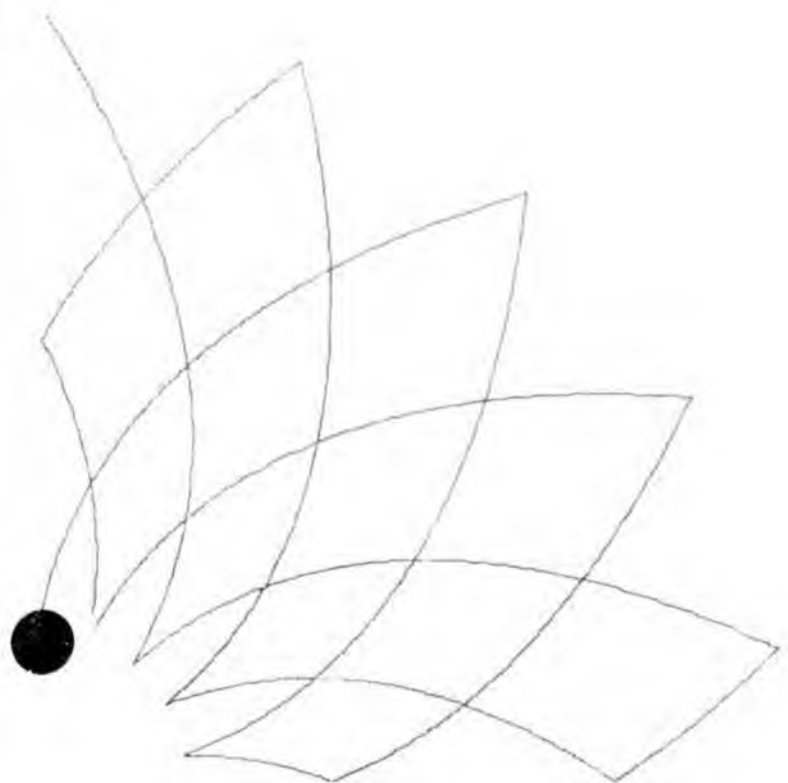
Results of casing digs, visual casing inspections and casing clean-out to be reported as appropriate.

#### **Other Programs**

Reporting of ER probe, smart pigging, maintenance pigging, structural issues, and details of individual spill incidents to be reported as dictated by the current year's program activity.

**Appendix 3**

- (a) Map of the North Slope
- (b) North Slope Oil Field Facility and Piping Summary



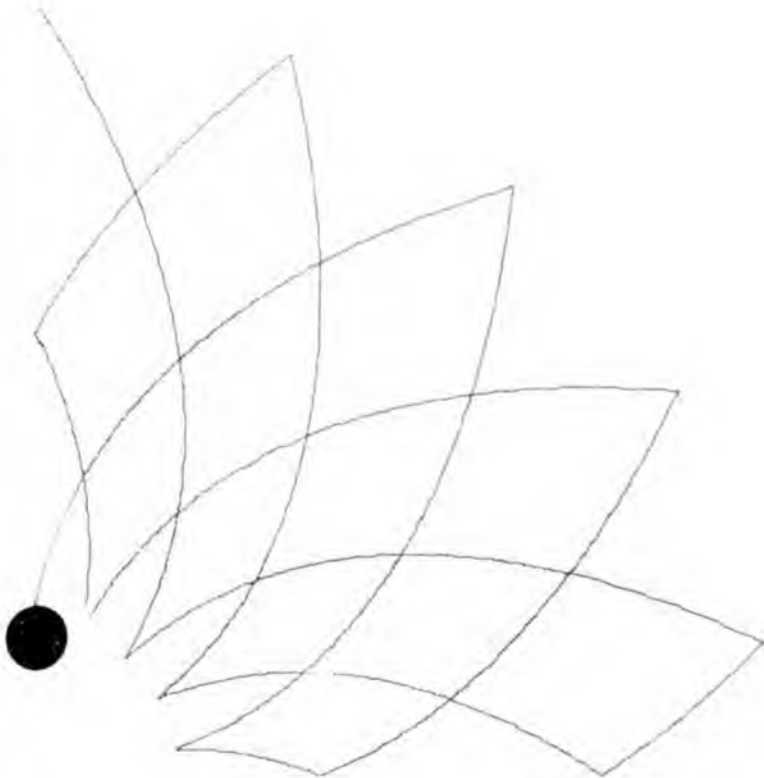


<b>BP North Slope Operations</b>	<b>Field Data (current 1/01)</b>	
Greater Prudhoe Bay	Field Area	150,000 acres
	Original Oil in Place (Gross)	25 billion barrels
	Original Gas in Place (Gross)	47 trillion Std. Cu Ft
	Oil Production Wells	1,080
	Gas Injection Wells	36
	Water Injection Wells	174
	Major Separation Plants	6
	Major Gas Handling Plants	2
	Major Water Handling Plants	3
	Miles of Pipelines (approximate)	1,300
Midnight Sun	Field Area	3,000 acres
	Original Oil in Place (Gross)	0.06 billion barrels
	Original Gas in Place (Gross)	0.1 trillion Std Cu Ft
	Oil Production Wells	2
	Water Injection Wells	1
	Miles of Pipelines (approximate)	4
Aurora	Field Area	10,000 acres
	Original Oil in Place (Gross)	0.1 billion barrels
	Original Gas in Place (Gross)	0.1 trillion Std Cu Ft
	Oil Production Wells	5
	Miles of Pipelines (approximate)	1
Pt. McIntyre	Field Area	8,000 acres
	Original Oil in Place (Gross)	0.8 billion barrels
	Original Gas in Place (Gross)	0.9 trillion Std Cu Ft
	Oil Production Wells	59
	Gas Injection Wells	1
	Water Injection Wells	15
	Miles of Pipelines (approximate)	6
Lisburne	Field Area	30,000 acres
	Original Oil in Place (Gross)	1.8 billion barrels
	Original Gas in Place (Gross)	0.3 trillion Std Cu ft
	Oil Production Wells	74
	Gas Injection Wells	4
	Major Separation Plants	1
	Miles of Pipelines (approximate)	27
Niakuk & Western Niakuk	Field Area	1,900 acres
	Original Oil in Place (Gross)	0.2 billion barrels
	Original Gas in Place (Gross)	0.1 trillion Std Cu Ft
	Oil Production Wells	18
	Water Injection Wells	7
	Miles of Pipelines (approximate)	6

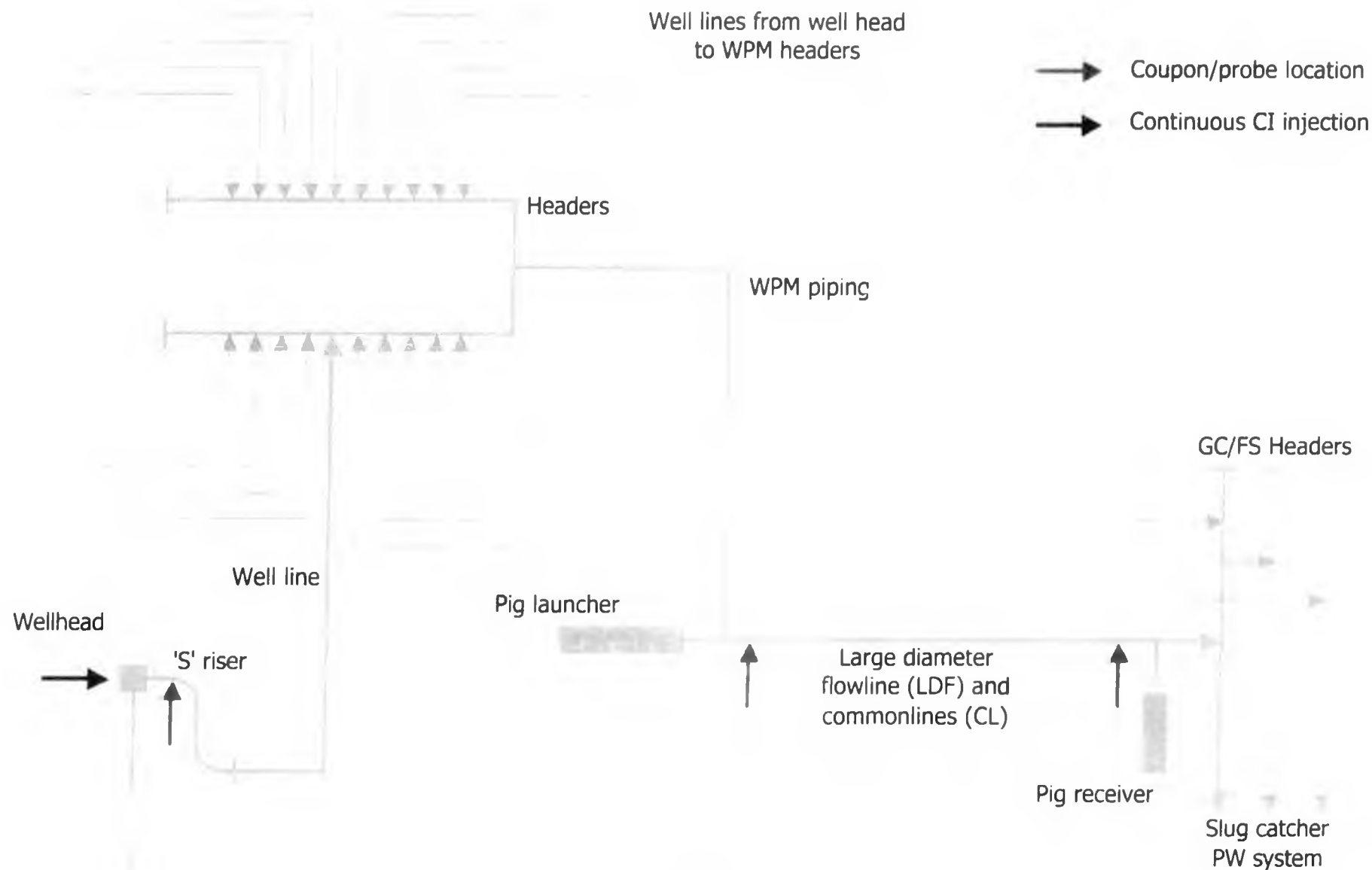
<b>BP North Slope Operations</b>	<b>Field Data (current 1/01)</b>	
Milne Point	Field Area	36,454 acres
	Original Oil in Place (Gross)	0.92 billion barrels
	Oil Production Wells	107
	Gas/Water Injection Wells	59
	Source Water Wells	8
	Major Separation Plants	1
	Miles of Pipelines (approximate)	55
Schrader Bluff	Field Area	28,000 acres
	Original Oil in Place (Gross)	1.97 billion barrels
	Oil Production Wells	49
	Gas\Water Injection Wells	14
	Source Water Wells	3
	Miles of Pipelines (approximate)	15
Eider	Field Area	300 acres
	Original Oil in Place (Gross)	0.01 <sup>3</sup> billion barrels
	Original Gas in Place (Gross)	0.052 trillion Std Cu Ft
	Oil Production Wells	1
	Gas Injection Wells	1
	Miles of Pipelines (approximate)	.5
Endicott	Field Area	8,800 acres
	Original Oil in Place (Gross)	1.1 billion barrels
	Original Gas in Place (Gross)	1.4 trillion Std Cu Ft
	Oil Production Wells	47
	Gas Injection Wells	5
	Water Injection Wells	21
	Major Separation Plants	1
	Miles of Pipelines (approximate)	52
Sag Delta North	Field Area	380 acres
	Original Oil in Place (Gross)	0.014 billion barrels
	Oil Production Wells	2
	Gas Injection Wells	2
	Miles of Pipelines (approximate)	.5
Badami	Original Oil in Place (Gross)	0.160 billion barrels
	Oil Production Wells	6
	Gas Injection Wells	2
	Major Separation Plants	1
	Miles of Pipelines (approximate)	50
Northstar (current 3/02)	Field Area	38,000 acres
	Original Oil in Place (Gross)	.176 billion barrels
	Oil Production Wells	4
	Disposal Injection Wells	1
	Gas Injection Wells	2
	Major Separation Plants	1
	Miles of Pipelines (approximate)	30

## Appendix 4

### Facilities Schematic

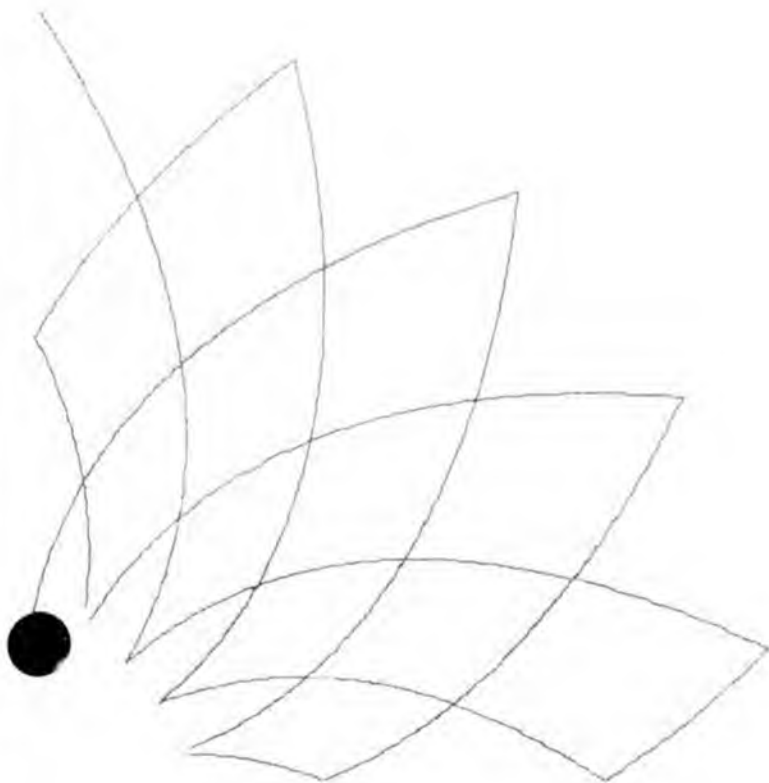


# Facility Schematic



## Appendix 5

### Data Tables



## Appendix 5 – Data Tables

### Introduction

With the introduction of single-operatorship at Greater Prudhoe Bay one of the major problems faced by the Corrosion Inspection and Chemical (CIC) Group was the integration of two historical data sets for inspection, corrosion monitoring and corrosion mitigation information.

There has been a significant investment in resources in order to bring together these two different histories from incompatible databases based on early 1990's technology.

As of the end of 2002, the inspection program and corrosion-monitoring program have largely been integrated into a single database on an Oracle platform with a user interface in VisualBasic.

The database development effort has involved a dedicated team of software developers and database administration but also significant resources from within the CIC Group. The program is currently a "work in progress" and in 2003 BP/CIC will continue work on the development of chemical management, electronic data recording, tank and vessel, and standard reporting modules.

The data is continuously monitored for integrity, quality and consistency, as a consequence any errors detected are corrected as they are found. In addition, as better analysis tools become available through further integration then records are amended to reflect the improved level of analysis.

As a result of the ongoing quality effort and the tracking of production/service changes, this is a 'live' database and therefore as the system changes then the records returned will change. The following are some of reasons why returned values change through time,

**Quality Control and Audit** A fundamental design philosophy for the database was that errors should be corrected through time as they are discovered. Therefore as the database is used and the quality control rules and procedures applied, data-entry, translation and record-keeping errors are eliminated.

**Equipment Service Changes** The database tracks active, in or out-of-use equipment, and equipment service changes. As a piece of equipment moves through different services and different status, then the data in the database tracks the equipment status.

**Transition Issues** As noted above, the two historical databases, heritage East and heritage West, were incompatible with very different structures and data fields. Therefore these have had to be translated to the new system. As the quality control and audit tools are applied to the translated data, error and mistranslations are removed.

**Time** The database is in active use with data being added everyday, given that there is sometimes a time delay between the reporting date and entry date then the data totals can and do change.

BU	Equip	Service	Metric	1995	1996	1997	1998	1999	2000	2001	2002
GPB	FL	OIL	WLC	1432	1558	1602	1494	1526	1409	1302	1323
GPB	FL	OIL	Ave CR	1.38	0.84	0.49	0.49	0.51	0.42	0.34	0.33
GPB	FL	OIL	SD CR	6.94	3.93	2.07	3.76	0.57	0.84	0.90	0.68
GPB	FL	OIL	WLC < 2	1371	1476	1558	1464	1512	1409	1282	1310
GPB	FL	OIL	% < 2 mpy	91%	95%	97%	98%	99%	97%	99%	99%
GPB	FL	PW/SW	WLC	122	105	113	90	100	81	60	59
GPB	FL	PW/SW	Ave CR	4.82	3.04	0.65	0.60	0.72	0.54	0.56	0.86
GPB	FL	PW/SW	SD CR	11.87	7.49	1.62	0.99	1.55	1.30	1.52	2.48
GPB	FL	PW/SW	WLC < 2	94	87	105	84	91	74	56	53
GPB	FL	PW/SW	% < 2 mpy	77%	83%	93%	93%	91%	91%	93%	90%
GPB	FL	PO	WLC	24	34	44	32	34	36	22	26
GPB	FL	PO	Ave CR	0.13	0.23	0.13	0.16	0.14	0.17	0.08	0.09
GPB	FL	PO	SD CR	0.17	0.21	0.19	0.11	0.05	0.07	0.06	0.03
GPB	FL	PO	WLC < 2	24	34	44	32	34	36	22	26
GPB	FL	PO	% < 2 mpy	100%	100%	100%	100%	100%	100%	100%	100%
GPB	WL	OIL	WLC	5265	6472	6536	6075	5729	5856	4472	4127
GPB	WL	OIL	Ave CR	2.76	2.27	0.97	0.73	0.57	0.78	0.69	0.63
GPB	WL	OIL	SD CR	6.96	6.08	2.32	3.74	1.31	1.55	1.74	1.20
GPB	WL	OIL	WLC < 2	3713	4864	5754	5703	5489	5374	4141	3819
GPB	WL	OIL	% < 2 mpy	71%	75%	88%	94%	96%	92%	93%	93%
GPB	WL	Majority PW	WLC	829	976	1073	959	733	699	651	398
GPB	WL	Majority PW	Ave Rate	0.80	0.86	0.35	2.46	0.47	0.27	1.44	0.33
GPB	WL	Majority PW	SD Rate	1.19	8.68	2.26	12.09	1.65	0.43	8.61	0.95
GPB	WL	Majority PW	WLC < 2 mpy	760	947	1047	879	709	690	592	383
GPB	WL	Majority PW	% < 2 mpy	92%	97%	98%	92%	97%	99%	91%	96%
GPB	WL	100% PW	WLC	485	604	717	718	521	459	472	288
GPB	WL	100% PW	Ave Rate	0.81	1.10	0.35	2.91	0.41	0.30	1.92	0.32
GPB	WL	100% PW	SD Rate	1.19	10.98	2.62	13.67	1.51	0.51	10.07	1.04
GPB	WL	100% PW	WLC < 2 mpy	447	589	703	655	509	450	415	279
GPB	WL	100% PW	% < 2 mpy	92%	98%	98%	91%	98%	98%	98%	97%
GPB	WL	Majority SW	WLC	311	162	56	44	82	98	44	25
GPB	WL	Majority SW	Ave Rate	2.67	3.25	0.65	0.96	1.82	1.78	6.01	6.58
GPB	WL	Majority SW	SD Rate	3.89	5.26	1.20	1.14	2.36	2.77	6.88	5.27
GPB	WL	Majority SW	WLC < 2 mpy	197	110	53	38	61	78	16	7
GPB	WL	Majority SW	% < 2 mpy	63%	68%	95%	86%	74%	80%	36%	28%
GPB	WL	100% SW	WLC	183	78	52	44	70	86	16	21
GPB	WL	100% SW	Ave Rate	2.88	2.86	0.68	0.96	1.82	1.89	1.92	7.46
GPB	WL	100% SW	SD Rate	4.48	5.39	1.24	1.14	2.50	2.93	1.07	5.28
GPB	WL	100% SW	WLC < 2 mpy	124	54	49	38	52	68	12	5
GPB	WL	100% SW	% < 2 mpy	68%	69%	94%	86%	74%	79%	75%	24%

Table 5.1 GPB Flow and Well Line General Corrosion Rate Data Summary

BU	Equip	Service	Metric	1995	1996	1997	1998	1999	2000	2001	2002
GPB	FL	OIL	P WLC	1432	1558	1600	1494	1526	1449	1302	1323
GPB	FL	OIL	Ave P CR	9.3	7.7	6.8	2.9	1.6	1.9	1.3	0.7
GPB	FL	OIL	SD P CR	24.3	15.0	14.1	6.7	6.1	7.7	10.5	3.9
GPB	FL	OIL	P WLC < 20	1308	1465	1543	1468	1503	1416	1290	1310
GPB	FL	OIL	% P WLC < 20mpy	91%	94%	96%	98%	99%	98%	99%	99%
GPB	FL	PW/SW	P WLC	127	105	113	90	100	81	60	59
GPB	FL	PW/SW	Ave P CR	23.1	17.8	12.2	8.5	5.0	7.5	8.8	5.1
GPB	FL	PW/SW	SD P CR	31.3	28.4	17.0	16.5	12.1	20.5	33.1	13.8
GPB	FL	PW/SW	P WLC < 20	83	83	103	83	92	73	55	54
GPB	FL	PW/SW	% P WLC < 20mpy	68%	79%	91%	92%	92%	90%	92%	92%
GPB	FL	PO	P WLC	24	34	44	32	34	36	22	26
GPB	FL	PO	Ave P CR	1.9	2.6	3.7	2.2	1.3	1.4	1.1	0.8
GPB	FL	PO	SD P CR	3.4	4.6	4.3	5.7	2.4	3.5	3.5	3.9
GPB	FL	PO	P WLC < 20	24	34	44	31	34	36	22	26
GPB	FL	PO	% P WLC < 20mpy	100%	100%	100%	97%	100%	100%	100%	100%
GPB	WL	OIL	P WLC	5258	6469	6536	6075	5722	5850	4460	4105
GPB	WL	OIL	Ave P CR	11.5	11.9	5.4	3.2	2.9	3.2	2.1	1.9
GPB	WL	OIL	SD P CR	32.3	29.1	14.9	9.2	8.1	8.4	6.6	6.0
GPB	WL	OIL	P WLC < 20	4592	5582	6257	5923	5600	5678	4365	4052
GPB	WL	OIL	% P WLC < 20mpy	87%	86%	96%	97%	98%	97%	98%	99%
GPB	WL	Majority PW	P WLC	829	976	1073	959	733	699	651	398
GPB	WL	Majority PW	Ave P CR	20.2	15.0	9.6	20.8	8.9	4.7	6.8	3.2
GPB	WL	Majority PW	SD P CR	29.1	29.6	29.0	58.7	26.2	9.7	17.6	9.6
GPB	WL	Majority PW	P WLC < 20	574	802	968	800	667	670	571	387
GPB	WL	Majority PW	% P WLC < 20mpy	69%	82%	90%	83%	91%	96%	88%	97%
GPB	WL	100% PW	P WLC	485	604	717	718	521	459	472	288
GPB	WL	100% PW	Ave P CR	20.7	15.1	7.6	22.3	7.1	4.7	8.2	3.0
GPB	WL	100% PW	SD P CR	31.0	30.2	19.3	64.3	25.6	11.1	20.0	10.3
GPB	WL	100% PW	P WLC < 20	331	500	659	600	486	438	399	279
GPB	WL	100% PW	% P WLC < 20mpy	68%	83%	92%	84%	93%	95%	85%	97%
GPB	WL	Majority SW	P WLC	311	162	56	44	82	98	44	25
GPB	WL	Majority SW	Ave P CR	11.6	16.9	1.5	1.5	5.6	6.6	18.8	30.5
GPB	WL	Majority SW	SD P CR	15.5	23.1	4.5	2.3	8.2	10.4	18.6	28.1
GPB	WL	Majority SW	P WLC < 20	257	115	55	44	80	92	24	14
GPB	WL	Majority SW	% P WLC < 20mpy	83%	71%	98%	100%	98%	94%	55%	56%
GPB	WL	100% SW	P WLC	183	78	52	44	70	86	16	21
GPB	WL	100% SW	Ave P CR	9.4	10.1	0.5	1.5	5.2	5.6	9.1	31.6
GPB	WL	100% SW	SD P CR	13.5	19.9	2.2	2.3	8.5	6.4	7.3	29.5
GPB	WL	100% SW	P WLC < 20	156	62	52	44	68	82	14	12
GPB	WL	100% SW	% P WLC < 20mpy	85%	79%	100%	100%	97%	95%	88%	57%

Table 5.2 GPB Flow and Well Line Pitting Rate Data Summary

<b>BU</b>	<b>Type</b>	<b>Service</b>	<b>Result</b>	<b>1995</b>	<b>1996</b>	<b>1997</b>	<b>1998</b>	<b>1999</b>	<b>2000</b>	<b>2001</b>	<b>2002</b>
GPB	FL	OIL	I	370	934	1176	411	239	66	60	103
GPB	FL	OIL	NC	15271	15813	16603	14891	12052	8239	7145	8829
GPB	FL	OIL	NL	3644	2122	1979	444	367	148	1767	1867
<b>GPB</b>	<b>FL</b>	<b>OIL</b>	<b>Total</b>	<b>19285</b>	<b>18869</b>	<b>19758</b>	<b>15746</b>	<b>12658</b>	<b>8453</b>	<b>8972</b>	<b>10799</b>
GPB	FL	WTR	I	171	124	154	192	72	17	43	137
GPB	FL	WTR	NC	1164	1076	1125	1561	1560	720	1092	1174
GPB	FL	WTR	NL	422	116	141	88	77	61	354	390
<b>GPB</b>	<b>FL</b>	<b>WTR</b>	<b>Total</b>	<b>1757</b>	<b>1316</b>	<b>1420</b>	<b>1841</b>	<b>1709</b>	<b>798</b>	<b>1489</b>	<b>1701</b>
<b>GPB</b>	<b>FL</b>	<b>Total</b>	<b>Total</b>	<b>21042</b>	<b>20185</b>	<b>21178</b>	<b>17587</b>	<b>14367</b>	<b>9251</b>	<b>10461</b>	<b>12500</b>
GPB	WL	OIL	I	641	918	877	605	311	263	214	276
GPB	WL	OIL	NC	2459	3507	3401	4092	3616	4134	5494	7154
GPB	WL	OIL	NL	975	1799	1987	725	574	530	2498	3504
<b>GPB</b>	<b>WL</b>	<b>OIL</b>	<b>Total</b>	<b>4075</b>	<b>6224</b>	<b>6265</b>	<b>5422</b>	<b>4501</b>	<b>4927</b>	<b>8206</b>	<b>10934</b>
GPB	WL	WTR	I	224	262	201	216	74	128	77	125
GPB	WL	WTR	NC	987	1500	1049	1607	1430	1718	1270	1117
GPB	WL	WTR	NL	620	360	635	223	176	260	490	523
<b>GPB</b>	<b>WL</b>	<b>WTR</b>	<b>Total</b>	<b>1831</b>	<b>2122</b>	<b>1885</b>	<b>2046</b>	<b>1680</b>	<b>2106</b>	<b>1837</b>	<b>1765</b>
<b>GPB</b>	<b>WL</b>	<b>Total</b>	<b>Total</b>	<b>5906</b>	<b>8346</b>	<b>8150</b>	<b>7468</b>	<b>6181</b>	<b>7033</b>	<b>10043</b>	<b>12699</b>
<b>GPB</b>	<b>Total</b>	<b>Total</b>	<b>Total</b>	<b>26948</b>	<b>28531</b>	<b>29328</b>	<b>25055</b>	<b>20548</b>	<b>16284</b>	<b>20504</b>	<b>25199</b>

Table 5.3 GPB Flow and Well Line Inspection Data



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Anchorage  
Alaska

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**BP Exploration Alaska  
Commitment to Corrosion Monitoring  
Annual Reports 2000 – 2005**

**Charter for Development of the Alaskan North Slope  
Section II.A.6**

**Volume 2 of 2**

2003



**Annual Report to Alaska Department of Environmental Conservation**

**Commitment to Corrosion Monitoring  
Year 2003**

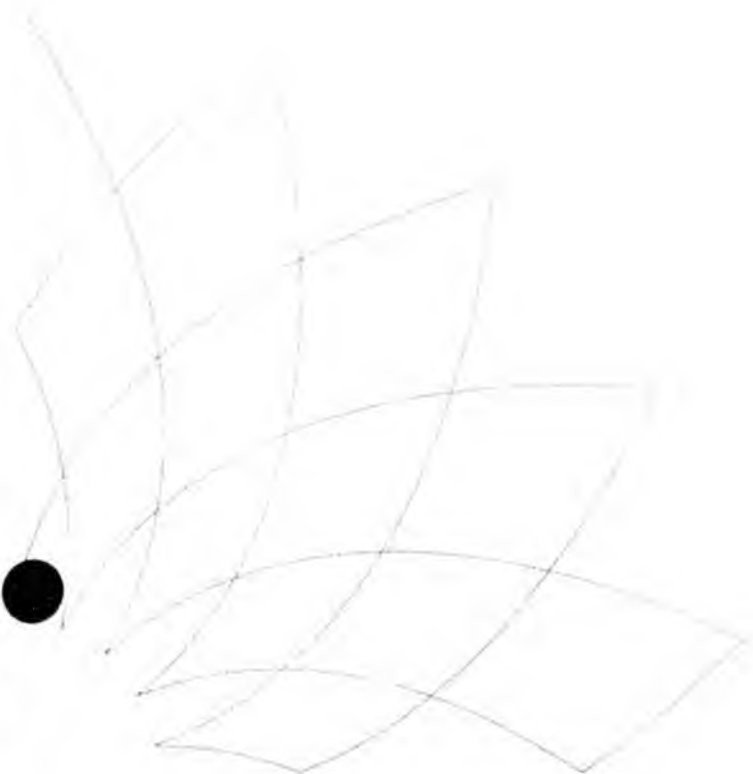
Prepared by

Corrosion, Inspection and Chemicals (CIC) Group  
BP Exploration (Alaska), Inc.

March 2004

# **Commitment to Corrosion Monitoring**

**Year 2003**



## Foreword

This is the fourth annual report that meets the commitment made by BPXA to the State of Alaska to provide a regular review of BPXA's corrosion monitoring and management practices for non-common carrier pipelines on the North Slope. The contents of this report reflect the Work Plan<sup>1</sup> agreed jointly between BPXA, Phillips and ADEC, the Guide for Performance Metric Reporting<sup>2</sup>, and feedback from previous ADEC reports. The report is divided into 2 main parts.

**Part 1** contains information regarding the BPXA operated fields within the Greater Prudhoe Bay (GPB) Performance Unit. This consists principally of fluids produced from Prudhoe Bay, Lisburne, Point McIntyre and Niakuk field areas but also includes smaller volumes of fluids from satellite accumulations.

**Part 2** contains information regarding the BPXA operated fields within the Alaska Consolidated Team (ACT) Performance Unit. This consists principally of fluids from Endicott, Badami, Milne Point and Northstar field areas. As with GPB, several smaller satellite accumulations are also produced through ACT facilities.

The report provides an overview of the corrosion management process, and provides data and discussion of the corrosion control, monitoring, inspection and fitness-for-service programs. These individual programs, in concert, form the core of the integrity/corrosion management system designed to deliver our corporate goal of no accidents, no harm to people and no damage to the environment<sup>3</sup>. The program also reflects the core values of BP: innovation, performance driven, environmental leadership and progressive.

**Innovation** is evident in several areas, from the development of more effective corrosion inhibitors and corrosion inhibition programs, to the application of new inspection technologies. These innovations are only made possible by working closely with partners, major suppliers and the regulatory community, to bring the best available technology to Alaskan oilfields.

**Performance** management and the drive for improved performance are central to all aspects of the corrosion management program. This report demonstrates an on-going effort to improve corrosion management. Over the last decade corrosion rates have been reduced by almost a factor of 10 in the cross-country pipelines that transport a mixture of oil, water and gas. Consistent with the pledge to report openly both good and bad performance, the report highlights areas for improvement and the plans in-place to deliver performance improvement.

---

<sup>1</sup> Appendix 2 (a) 2000 Work Plan

<sup>2</sup> Appendix 2 (b) Guide for Performance Metric Reporting

<sup>3</sup> BP HSE Policy Statement, EJP Browne, Group CEO, January, 1999, <http://www.bp.com/>

**Environmental** protection and corrosion management are closely linked. The improvements in corrosion management have resulted in lower corrosion rates and a lower risk of loss of containment. Opportunities to improve environmental performance still exist and the investment in continuous corrosion inhibitor injection at Drill Site Niakuk as well as the continued effort on our external corrosion inspection program is evidence of this on-going commitment.

**Progressive** evolution of the corrosion management programs is an on-going activity driven by changing field conditions and the desire to improve performance. Progress involves the continued refinement of the existing programs, but also, the development and implementation of new programs and corrosion management technologies.

The current corrosion management process has delivered a significantly improved level of corrosion control that has reduced corrosion rates in the cross-country flow lines by a factor of 10 in the last 10 years. Notwithstanding the successes of the last 10 years the corrosion management program must remain focused on the future in order to maintain the current level of control and, where necessary, implement the actions necessary to improve performance.

The continuous improvement of the corrosion management programs delivered over the last 10 years has enabled BPXA to deliver the programs strategic objectives of:

- Minimizing the health, safety and environmental impacts of loss of containment due to corrosion
- Providing a fit-for-service infrastructure for the remainder of field life
- Producing satellite accumulations through existing equipment and pipe-work
- Providing an infrastructure capable of supporting gas sales in the future

In addition, with the information in this report, BPXA intends to build a healthy relationship with the North Slope stakeholders through consultation, open reporting and striving to raise the standards of the industry.

BP Exploration (Alaska) Inc.  
March 2004

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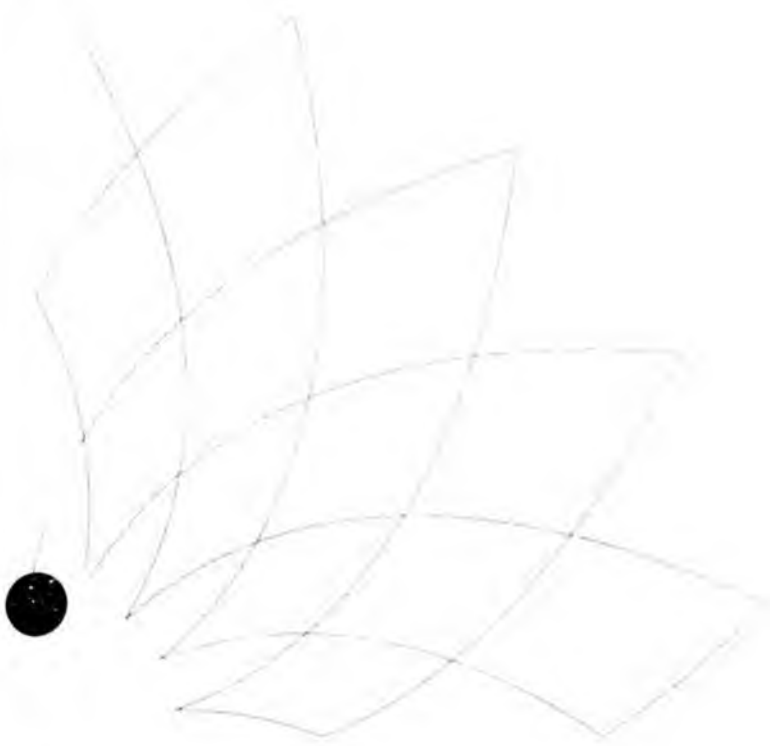
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**Section A**

**Charter Agreement – Corrosion Related Commitments**



## **Section A Charter Agreement – Corrosion Related Commitments**

The BPXA contact for all corrosion matters relating to the Charter Agreement is,

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Phone: (907) 564-4437

### **Section A.1 Project Achievements**

Oct-Nov 2000	Work Plan agreed between BPXA/PAI and ADEC (Appendix 1)
March 2001	1 <sup>st</sup> Annual Report submitted to ADEC
April 2001	1 <sup>st</sup> 2001 Meet and Confer session held
Oct-Dec 2001	Consultations with ADEC and ADEC's consultant
November 2001	2 <sup>nd</sup> 2001 Meet and Confer session held
Dec 01-Jan 02	Developed and agreed corrosion management metrics
February 2002	BPXA/PAI and ADEC agreed on performance metrics (Appendix 2)
March 2002	2 <sup>nd</sup> Annual Report submitted to ADEC
April 2002	1 <sup>st</sup> 2002 Meet and Confer session held
November 2002	2 <sup>nd</sup> 2002 Meet and Confer session held
March 2003	3 <sup>rd</sup> Annual Report submitted to ADEC
May 2003	1 <sup>st</sup> 2003 Meet and Confer session held
October 2003	2 <sup>nd</sup> 2003 Meet and Confer session held
March 2004	4 <sup>th</sup> Annual Report submitted to ADEC

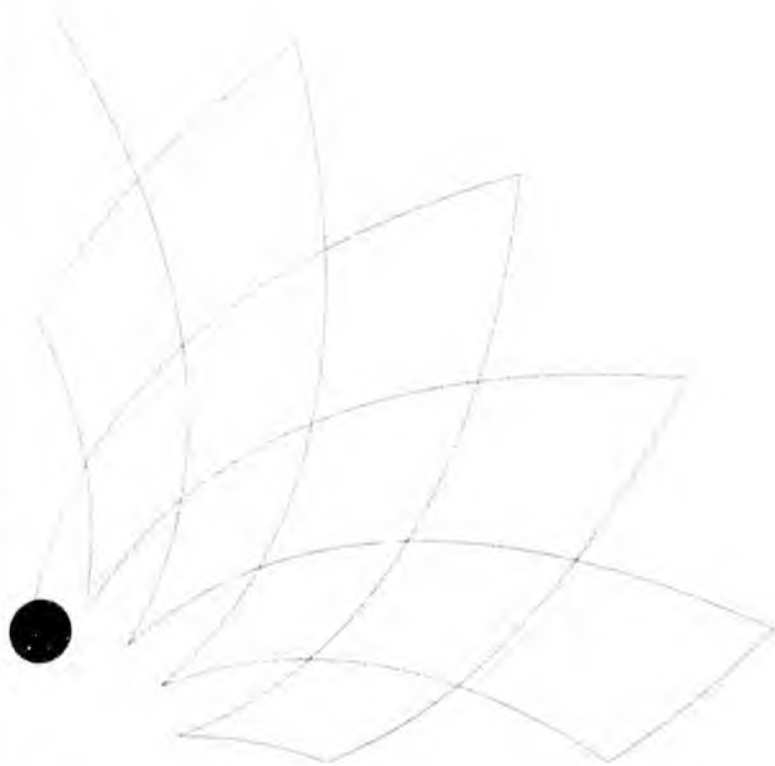
### **Section A.2 Annual Charter Timetable**

March 31 <sup>st</sup>	Annual Report submitted
April 30 <sup>th</sup>	1 <sup>st</sup> Semi-Annual Review/Meet and Confer
October 31 <sup>st</sup>	2 <sup>nd</sup> Semi-Annual Review/Meet and Confer

**Part 1 – Greater Prudhoe Bay Performance Unit**

**Section B**

**Corrosion Monitoring Activities**



## Section B Corrosion Monitoring Activities

This section summarizes the Corrosion Management System (CMS) in use at Greater Prudhoe Bay (GPB) Performance Unit, which incorporates Prudhoe Bay, Point McIntyre, Lisburne and Niakuk oilfields plus a number of smaller satellite accumulations all of which are produced through the main separation facilities. A map and brief description of each field and the associated production facilities can be found in Appendix 3. Appendix 4 contains a schematic of a typical production facility configuration.

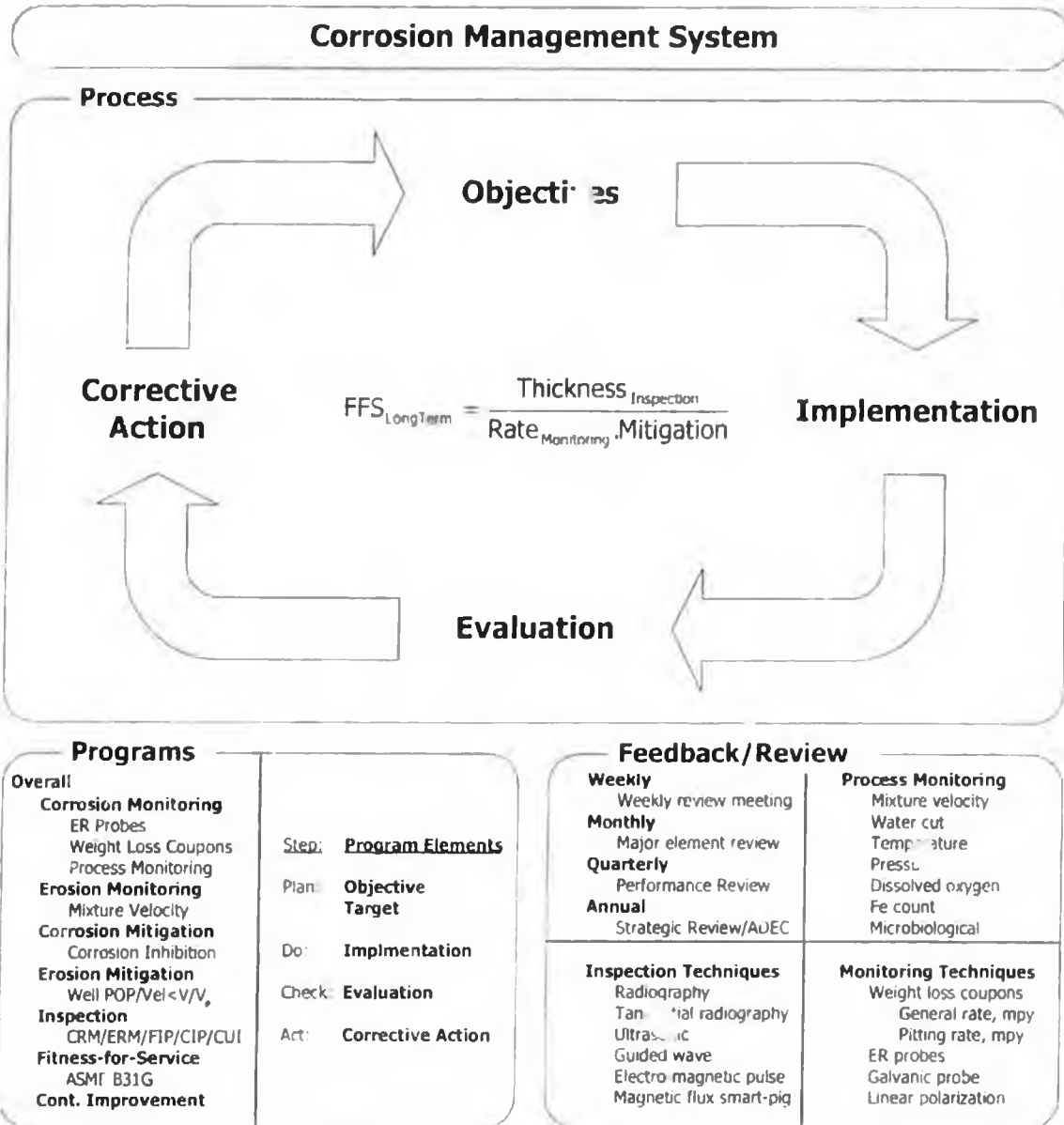
### Section B.1 Corrosion Management System

The Corrosion Management System consists of a number of major program elements: Corrosion Monitoring, Erosion Monitoring, Corrosion Mitigation, Inspection and Fitness-For-Service assessment, which follow a simple management process, represented in GPB Figure B.1. The CMS elements are summarized in GPB Table B.9, GPB Table B.10, and GPB Table B.11, at the end of this section. The Corrosion, Inspection and Chemical (CIC) Group utilizes data summarized in the remainder of this report as part of the overall Corrosion Management System.

The overall objective of the CMS is to meet the corporate objectives of 'no accidents, no harm to people and no damage to the environment' which translates for corrosion management within BPXA to delivering a mechanical integrity program which,

- Minimizes health, safety, and environmental impacts of corrosion resulting from a loss of containment
- Provides an infrastructure fit-for-service for the remainder of the life of the oilfield
- Provides infrastructure of sufficient mechanical integrity capable of producing satellite fields/accumulations through existing main production facilities and infrastructure
- Provides an infrastructure to support future major gas production and sales through current North Slope facilities

These overall goals and objectives are achieved through a comprehensive Corrosion Management System that consists of an integrated system of strategy, processes and programs.



GPB Figure B.1 Overview of the Corrosion Management Process

**Section B.1.1 Process**

Within the overall Corrosion Management System, each specific program element, i.e. Corrosion Monitoring, Mitigation, Inspection and Fitness-For-Service, follows the classic TQM (Total Quality Management) process of 'plan-do-check-act' and consists of,

Step	Activity	Description
Plan	<b>Objective</b>	The program objective and purpose
	<b>Target</b>	The metric against which performance is assessed
Do	<b>Implementation</b>	Implementation plan to achieve objective
Check	<b>Evaluation</b>	Method to evaluate performance of plan against target
Act	<b>Corrective Action</b>	The action required to correct deviation from target

GPB Table B.1 Corrosion Management Process

### Section B.1.2 Objectives and Targets

The objectives<sup>4</sup> for the CMS are set in order to support the delivery of the corporate objective and BPXA objectives described in the introduction to Section B. For the purposes of the CMS these can be translated into the corrosion management objectives of,

- Eliminate corrosion and erosion related failures
- Provide Fit-For-Service infrastructure to the end of field life

Based on these objectives, individual targets are set for the corrosion, erosion, mitigation and inspection programs, which in combination are designed to deliver the objectives. The overall business objectives and individual program objectives and targets are described in detail in GPB Table B.9, GPB Table B.10, and GPB Table B.11.

For example, the weight loss coupons (WLC) in the 3-phase production system have a corrosion rate target of 2 mils per year (mpy). The monitoring program objective is to meet or beat this target, which means an actual WLC corrosion rate of 2 mpy or less ( $WLC \leq 2$  mpy).

### Section B.1.3 Implementation

There are a number of different corrosion monitoring and inspection techniques, each of which has both advantages and disadvantages. The advantages and disadvantages, or strengths and weaknesses, make the results from an individual technique more or less applicable depending on the application circumstances.

GPB Table B.12, GPB Table B.13, and GPB Table B.14 summarize the main categories of corrosion monitoring, process monitoring, inspection techniques and briefly summarize relative strengths and weaknesses for different applications.

<sup>4</sup> In addition to Charter Work Plan, some information is supplied to provide additional context and help in understanding BPXA corrosion management activities

### Section B.1.4 Evaluation

The elements of the CMS have to be applied to each system at GPB to reflect their applicability and efficacy. The corrosion and erosion monitoring, inspection and mitigation practices for the major services and equipment type are summarized in GPB Table B.15.

The results from each of the corrosion management programs are reviewed on a regular basis to provide feedback and to take any necessary corrective action based on deviation from target performance. In general, the major review cycles within the CMS are presented in GPB Table B.2.

Review	Description
Weekly	A weekly internal review meeting at which the latest corrosion monitoring, mitigation, inspection and process data are analyzed and reviewed, and any tactical changes implemented
Monthly	Monthly summary of the major elements of the program are reviewed for the need for longer term corrective action
Quarterly	Quarterly strategic performance review held in order to ensure that the implementation plan is delivering the strategic objectives
Annual	Annual program and strategy review designed to review the strategic direction of the program and review effectiveness of the current programs in delivering the strategic direction, e.g. Annual Report to ADEC

GPB Table B.2 Corrosion Management Feedback Cycles

Based on the results of the evaluation process, corrective action plans are developed and the overall management program and strategic direction are reviewed

### Section B.1.5 Corrective Action

Corrective actions provide feedback to the adjustment and setting of Objectives and Targets. Corrective actions can be broken down into five basic categories,

- 1) Chemical Mitigation
- 2) Operational Intervention
- 3) Reduce Maximum Operating Pressure (Derate)
- 4) Repair/Replacement
- 5) Abandon or Remove from Service

Chemical mitigation is discussed in detail in Section D. Operational intervention centers on the GPB Velocity Management Program that is designed to control internal mixture velocity below target values dependent on equipment type, water cut and line size. Repair/replacement programs are driven by the inspection findings and include mechanical sleeves, pipe work refurbishment, and pipeline replacement.

## **Section B.2 Corrosion and Inspection Data Management**

### **Section B.2.1 MIMIR Database**

In order to deliver a comprehensive corrosion management program and manage the extensive corrosion monitoring and inspection activity, it is necessary to have an active and structured electronic database.

Single-operatorship at GPB necessitated the integration of the two aging data systems into a single unified database. This process has been an on-going effort for the last several years. The weight loss coupon, inspection, ER probe and production data are held and accessed through a single database supported by Oracle<sup>®</sup> technology.

Users of the system are provided two primary methods for accessing data stored in the database. The first is a custom user interface written in Microsoft Visual Basic<sup>®</sup>, and the second is through ad-hoc data query tools such as BrioQuery<sup>®</sup> and BusinessObjects<sup>®</sup> which allow free-form SQL<sup>®</sup> access to the data.

Checks for data integrity are provided at a number of different levels including error checking at the point of data capture and data entry, regular reviews of data quality, and data entry rules within the database.

The data are continuously monitored for integrity and quality, and any errors are corrected as they are found. In addition, as better analysis tools become available through further integration then records are amended to reflect the improved level of analysis.

GPB Table B.3 gives an illustration of the number of records and the rate at which those records are accumulated on an annual basis in the database. The table clearly shows the level of complexity and volume of data involved in managing the corrosion programs at GPB.

In addition, the table also shows that the range and types of information being gathered is being improved through time to enable better overall corrosion management at the GPB. The most notable examples of this increasing range of coverage of the corrosion and inspection database is the inclusion of the production and injection data, the introduction of chemical usage data and the long term storage of ER probe data.

Data Record	Unit	Records	#/year	History
Weight loss coupons	10 <sup>6</sup>	0.2	0.01	~20 years
ER probes readings	10 <sup>6</sup>	1.3	0.4	1½ years
Equipment	10 <sup>3</sup>	28	-	-
Inspection locations	10 <sup>6</sup>	0.4	.07	-
Inspection records	10 <sup>6</sup>	1.1	0.1	~12 years
Chemical injection	10 <sup>3</sup>	30	22	1½ years
Production rates	10 <sup>6</sup>	7.8	0.5	~14 years
Injection rates	10 <sup>6</sup>	1.8	0.2	~11 years

GPB Table B.3 Database Record Accumulation Rate

### Section B.2.2 Historical Data

The small differences in data between Annual Reports reflect the movement of lines into and out of service, the addition or abandonment of equipment, and the addition or removal of corrosion access fittings to the program. The historical data for prior years has been updated to reflect the current equipment inventory.

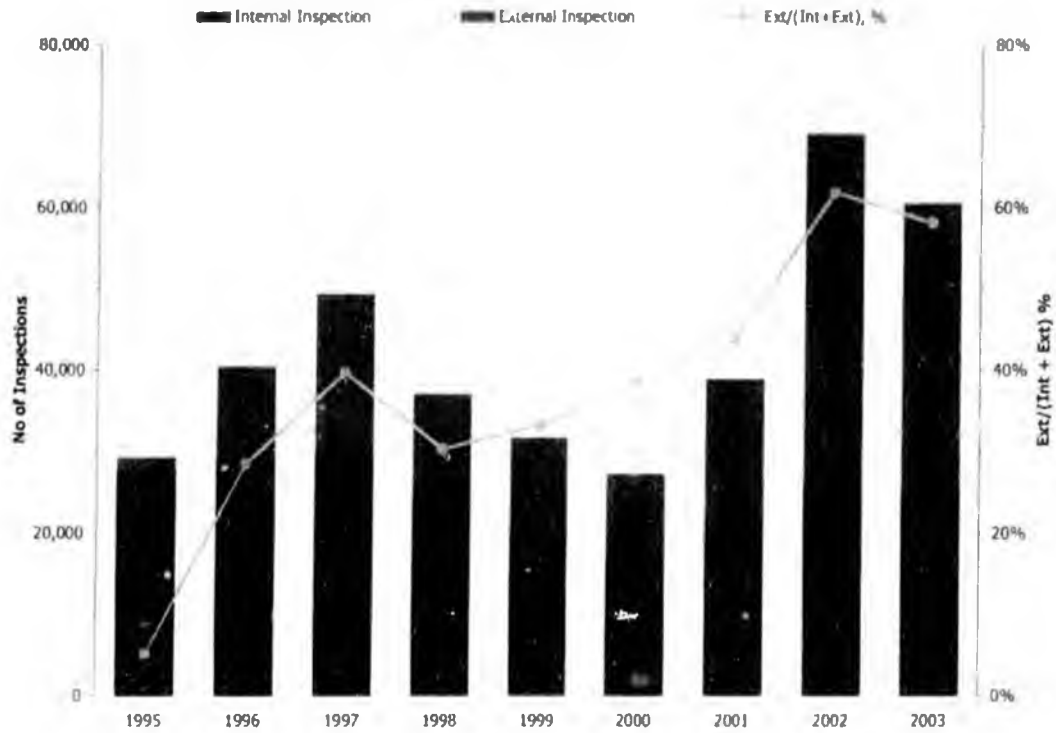
### Section B.3 Inspection and Corrosion Monitoring Activity Level

#### Section B.3.1 Inspection Activity

GPB Figure B.3 summarizes the level of internal and external inspection activity across GPB since 1995 for both cross-country flow lines and well lines. The 2003 internal inspection activity of ~25,000 inspections was consistent with historical levels of activity. From the figure it can be seen that the percentage,  $\frac{\text{Ext}}{(\text{Ext} + \text{Int})}$  %, of the overall inspection effort dedicated to external corrosion inspection in 2003 was consistent with the 2002 forecast of 55%.

GPB Table B.4 illustrates the increased level of external corrosion inspection activity established in 2002 was maintained through 2003. This level is up from the 6-year average (1996 to 2001) of ~13,000 inspections to the 2002/03 target of 35,000 inspections. This is discussed in detail in Section E.1.

Section B Corrosion Monitoring Activities



GPB Figure B.2 Internal and External Inspection Activity for Flow and Well Lines

Year	1995	1996	1997	1998	1999	2000	2001	2002	2003
External	1,508	11,498	19,546	11,235	10,512	10,437	17,037	42,676	35,079
Internal	27,804	28,997	29,860	25,934	21,304	16,861	21,929	26,410	25,382
<b>Total</b>	<b>29,312</b>	<b>40,495</b>	<b>49,406</b>	<b>37,169</b>	<b>31,816</b>	<b>27,298</b>	<b>38,966</b>	<b>69,086</b>	<b>60,461</b>
$\frac{\text{Ext}}{\text{Ext} + \text{Int}} \%$	5%	28%	40%	30%	33%	38%	44%	62%	58%

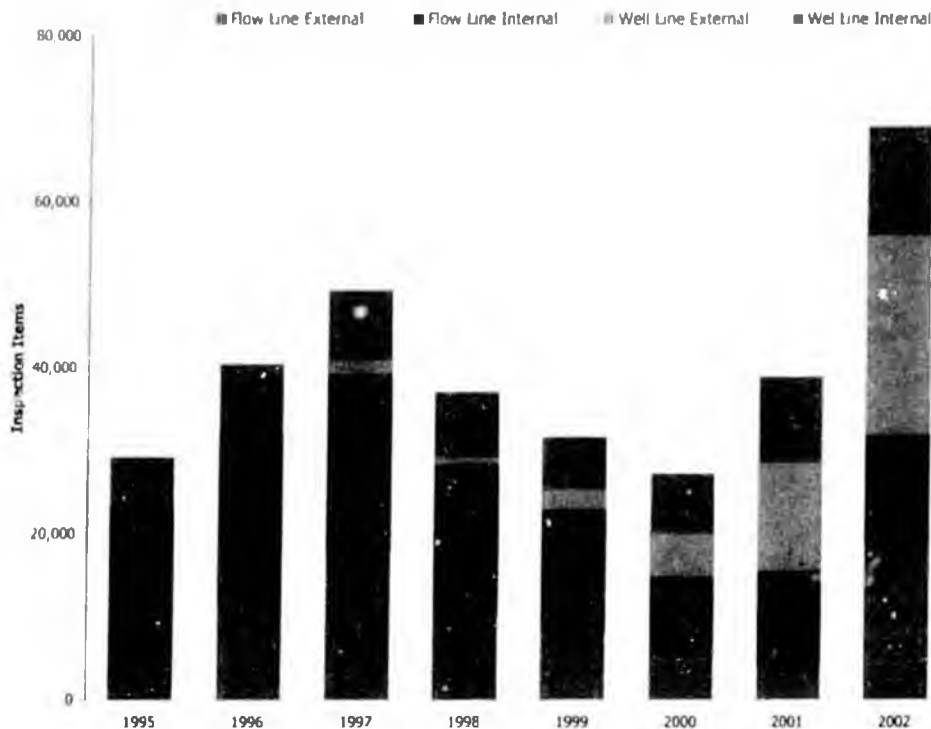
GPB Table B.4 Internal and External Inspection Activity Breakdown

GPB Table B.5 and GPB Figure B.3 show the split between flow line and well line inspections for both the internal and external programs. The data show an increase in the number of external flow line inspections and this reflects the difference in focus between 2002 and 2003. The overall inspection activity is running at or above 60,000 inspections per year, in line with the 2002 increased emphasis on external corrosion detection.

Part 1 – Greater Prudhoe Bay Performance Unit

Year		1995	1996	1997	1998	1999	2000	2001	2002	2003
Flow Line	External	1,508	11,462	17,866	10,289	8,136	5,180	3,966	18,727	24,258
	Internal	21,733	20,509	21,329	18,180	14,965	9,612	11,618	13,234	14,131
<b>Total</b>		<b>23,241</b>	<b>31,971</b>	<b>39,195</b>	<b>28,469</b>	<b>23,101</b>	<b>14,792</b>	<b>15,584</b>	<b>31,961</b>	<b>38,389</b>
$\frac{\text{Ext}}{\text{(Ext + Int)}}\%$		6%	36%	46%	36%	35%	35%	25%	59%	63%
Well Line	External	-	36	1,680	946	2,376	5,257	13,071	23,949	10,821
	Internal	6,071	8,488	8,531	7,754	6,339	7,249	10,311	13,176	11,251
<b>Total</b>		<b>6,071</b>	<b>8,524</b>	<b>10,211</b>	<b>8,700</b>	<b>8,715</b>	<b>12,506</b>	<b>23,382</b>	<b>37,125</b>	<b>22,072</b>
$\frac{\text{Ext}}{\text{(Ext + Int)}}\%$		0%	0%	16%	11%	27%	42%	56%	65%	49%
Grand Total		29,312	40,495	49,406	37,169	31,816	27,298	38,966	69,086	60,461
$\frac{\text{FL}}{\text{(FL + WL)}}\%$		79%	79%	79%	77%	73%	54%	40%	46%	63%

GPB Table B.5 Internal and External Inspection Activity Summary by Flow/Well Line



GPB Figure B.3 Internal and External Inspection Activity Summary by Flow/Well Line

The 2003 in-line inspection (ILI) program consisted of three 24-inch cross-country 3-phase flow lines: S, Y and Pt. McIntyre. Due to the limitations of the magnetic flux leakage (MFL) technique, see GPB Table B.14, the ILI data are used as a guide to the depth and location of damage in the pipeline inspected. This assessment of pipeline condition is then incorporated into the routine ultrasonic and radiographic inspection program. The inspection program verifies the depth of damage, and the location is scheduled for repair and/or re-inspection as necessary.

### Section B.3.2 Corrosion Monitoring Activity

The number of weight loss coupon (WLC) monitoring locations by equipment type and service, is summarized in GPB Table B.6. The relatively small number of differences between years reflects the movement of lines into and out of service, the addition or abandonment of equipment, and the addition or removal of corrosion access fittings to the program.

Service	1995	1996	1997	1998	1999	2000	2001	2002	2003
Flow Line									
3 Phase	220	317	270	276	269	257	260	261	252
Export/PO	3	7	7	5	5	6	4	6	5
Gas	5	5	3	3	3	2	2	2	1
Other	2	2	1	1	1				2
Water	27	28	36	34	37	36	35	38	39
<b>Total</b>	<b>257</b>	<b>359</b>	<b>317</b>	<b>319</b>	<b>315</b>	<b>303</b>	<b>301</b>	<b>307</b>	<b>299</b>
Well Line									
3 Phase	1,057	1,180	1,225	1,210	1,179	1,174	1,089	1,104	1,091
Export/PO		3	6	5	5	5	5	2	2
Gas	6	7	6	6	5	5	6	5	4
Other	1	1	1	1	1	1		3	7
Water	196	206	208	201	186	180	182	185	153
<b>Total</b>	<b>1,260</b>	<b>1,397</b>	<b>1,446</b>	<b>1,423</b>	<b>1,376</b>	<b>1,365</b>	<b>1,282</b>	<b>1,299</b>	<b>1,257</b>
<b>Grand Total</b>	<b>1,517</b>	<b>1,756</b>	<b>1,763</b>	<b>1,742</b>	<b>1,691</b>	<b>1,666</b>	<b>1,583</b>	<b>1,606</b>	<b>1,556</b>

GPB Table B.6 Corrosion Monitoring Locations by Equipment and Service

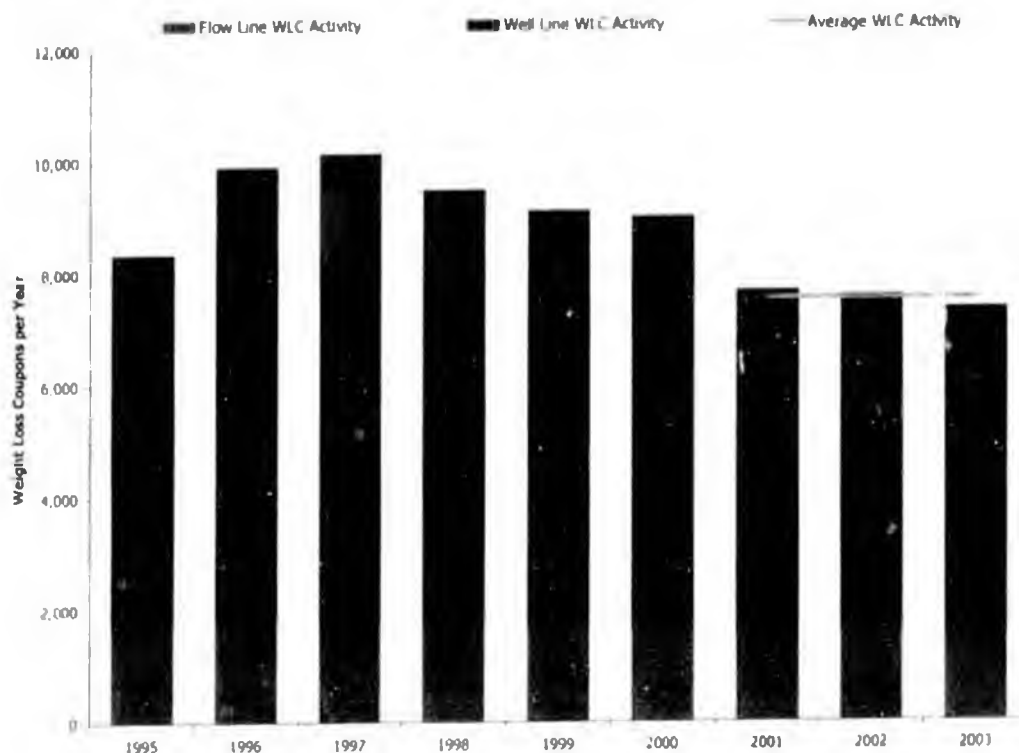
The corrosion-monitoring program is further detailed in GPB Table B.7 and GPB Figure B.4, which shows the number of coupon pulls and number of coupons retrieved, on average, for each active location identified in GPB Table B.6. Two corrosion coupons are typically recovered for each WLC pull with the exception of those lines that are regularly maintenance pigged where single flush mounted coupons are installed. The number of coupons, coupons per pull, and pull frequency has been optimized through time to gain greater value from the data obtained by the program.

As discussed in prior reports, there has been a gradual reduction in the number of weight loss coupons being evaluated, which reflects the on-going effort to optimize the program. Following the rationalization in 2000/01, the level of WLC activity has stabilized at ~7,500 coupons per year (refer to GPB Figure B.4).

<b>Statistic</b>	<b>1995</b>	<b>1996</b>	<b>1997</b>	<b>1998</b>	<b>1999</b>	<b>2000</b>	<b>2001</b>	<b>2002</b>	<b>2003</b>
Flow Line									
# of Equip	196	201	194	192	193	190	187	193	193
Locations	257	359	317	319	315	301	301	307	299
Pulls	926	1,012	1,203	1,110	1,146	1,079	984	1,034	976
FL WLC	1,668	1,788	1,833	1,690	1,738	1,642	1,534	1,551	1,507
WLC/Pull	1.80	1.77	1.52	1.52	1.52	1.52	1.56	1.50	1.54
Pull/Year	3.6	2.8	3.8	3.5	3.6	3.6	3.3	3.4	3.3
Well Line									
# of Equip.	1,128	1,262	1,314	1,325	1,278	1,275	1,193	1,264	1,233
Locations	1,260	1,397	1,446	1,423	1,376	1,365	1,282	1,299	1,257
Pulls	3,373	4,080	4,171	3,922	3,699	3,694	3,099	3,028	2,927
WL WLC	6,684	8,128	8,313	7,806	7,384	7,370	6,152	6,045	5,855
WLC/Pull	1.98	1.99	1.99	1.99	2.00	2.00	1.99	2.00	2.00
Pull/Year	2.7	2.9	2.9	2.8	2.7	2.7	2.4	2.3	2.3
<b>Total Pulls</b>	<b>4,299</b>	<b>5,092</b>	<b>5,374</b>	<b>5,032</b>	<b>4,845</b>	<b>4,773</b>	<b>4,083</b>	<b>4,062</b>	<b>3,903</b>
<b>Total WLCs</b>	<b>8,352</b>	<b>9,916</b>	<b>10,146</b>	<b>9,496</b>	<b>9,122</b>	<b>9,012</b>	<b>7,686</b>	<b>7,596</b>	<b>7,362</b>

GPB Table B.7 Corrosion Monitoring Activity Statistics by Equipment Type

The number of weight loss coupons reported for 2003 reflects the inventory of coupons that are installed in the system at year-end that are still to be 'processed.' The reduction in 2003 coupon numbers therefore represents a timing effect and not a reduction in the program scope or activity level.



**GPB Figure B.4 Corrosion Monitoring Activity Statistics by Equipment**

For the electrical resistance (ER) probes, the number of active locations in the flow lines is given in GPB Table B.8. 2003 had the greatest number of ER probes in service which reflects an ongoing effort to utilize ER probe monitoring equipment on all large diameter oil service flow lines.

Year	Total Probe Locations
2001	83
2002	82
2003	85

**GPB Table B.8 Active ER Probe Locations**

Optimization of the corrosion-monitoring program is a continuous effort and any future changes will be reported as part of the Annual Report.

**Section B.4 Corrosion Monitoring Activity Summary**

The CMS at GPB provides a framework where individual elements are managed against BPXA's performance targets established by CIC. The overall activity level has remained stable for the last two years at 60,000 inspection locations (35,000 external and 25,000 internal), 85 active ER probe locations, and 7,500 WLC per year.

<b>Program</b>	<b>Plan/Objectives</b>	<b>Target</b>	<b>Implementation</b>	<b>Evaluation</b>	<b>Corrective Action</b>
1.0 Overall program goals	Eliminate corrosion/erosion related failures	No harm to people No accidents No damage to environment Regulatory compliance Compliance with industry standards	Integrated program with monitoring, inspection, operational controls, and corrosion inhibitor	Key performance indicators Leading and lagging indicators	Adjust mitigation, monitoring, and operational targets to meet objective Defect elimination - repair/replace/abandon
	Provide equipment availability to end of Field life	2050	Integrated Program with Monitoring, Inspection, Operational Controls, and Corrosion Inhibition	Key Performance Indicators Leading and Lagging Indicators	Adjust Mitigation, Monitoring, and Operational Targets to Meet Objective
	Cost effective Corrosion Management	Budget	Alliance Partnerships Technical Incentive Contracts Continuous Improvement	Key Performance Indicators Leading and Lagging Indicators	Develop more Cost Effective Methods For Delivering the Program Best in Class Technology Investment for the Future

CPB Table B.9 Corrosion Management System

Section B Corrosion Monitoring Activities

Program	Plan/Objectives	Target	Implementation	Evaluation	Corrective Action
1.1 Corrosion Monitoring	Monitor for changes in corrosion rates	System dependant targets Corrosion rate to meet overall objectives Regulatory compliance Compliance with industry standards	Short term corrosion rate determination Medium term corrosion rate determination	ER probes Weight loss coupon rate Pitting Rates	Adjust Mitigating action to achieve corrosion rate target
	Monitor effectiveness of the chemical mitigation programs	Optimize Corrosion Inhibitor Rates and Distribution Optimize chemical mitigation programs e.g. Oxygen scavenger Biocide Drag reducing agent Scale	See above	See above	Provide feedback to Chemical treatment Operations Inspection activities Adjust Mitigation Effort Production Chemistry
	Monitor changes in the process conditions	Field-wide Velocity Management targets	Weekly Review of Operational Controls by CIC Group Operations review of fluid velocities Velocity alarms in Distributive Control System (DCS)	Mixture Velocities, Water Cuts, and Water Rates	Adjust production rates to meet velocity management targets
	Corrosion mechanism changes with time	Mitigation action in place prior to threat to mechanical integrity	Data availability and access Ease of 'data mining' and evaluation Single data storage Comprehensive data management and reporting process	Long-Term Process Change	Develop mitigation program Mechanism management as part of routine business
1.2 Erosion Monitoring	Monitor the effectiveness of the erosion mitigation programs	V/Ve < 2.5 Max mixture Velocity and water cut matrix Well Put-On-Production (POP) process Regulatory compliance Compliance with industry standards	Unified velocity management standard across the North Slope Monthly compilation Of High Risk Wells Inspection of High Risk Wells Mixture velocity calculation in DCS	Mixture Velocity Inspection resul	Additional inspection and monitoring at high risk sites Adjust Process Conditions Well shut-in Production reduction Design/debottleneck facilities

GPB Table B.10 Corrosion Management System Element – Monitoring

Program	Plan/Objectives	Target	Implementation	Evaluation	Corrective Action
1.3 Corrosion Mitigation	Mitigate Corrosion Through Application of Corrosion Inhibitors	Control Corrosion Rates to Acceptable Levels (See Overall Program Goals) Regulatory compliance Compliance with industry standards	Continuous Injection into individual wells as far upstream as possible - currently at Wellhead Protect all equipment between injection point and separator on plant	ER Probes WLC's Inspection	Corrosion Inhibitor Development Adjust Mitigation Effort
		Control Corrosion Rates to Acceptable Levels (See Overall Program Goals)	Batch Treatments on a routine schedule with injection at the Wellhead	WLC's Inspection	Corrosion Inhibitor Development Adjust Mitigation Effort Through Reviews
	Mitigate Corrosion through Operational Controls	Operational Guidelines	Weekly Reviews by CIC Group	Mixture Velocities	Adjust Process Conditions
	Mitigate Corrosion through Maintenance Pigging	Achieve Scheduled Frequency	Maintenance Pigging	Inspection Pigging Returns	Adjust Maintenance Pigging Schedule
1.4 Erosion Mitigation	Mitigate Erosion Through Operational Controls and Design	Control Erosion Rates to Acceptable Levels (See Overall Program Goals) V/Ve < 2.5 Regulatory compliance Compliance with industry standards	Well POP process V/Ve Guidelines	V/Ve Inspection (ERM)	Adjust Process Conditions

GPB Table B.10 (continued) Corrosion Management System Element – Mitigation

Section B Corrosion Monitoring Activities

<b>Program</b>	<b>Plan/Objectives</b>	<b>Target</b>	<b>Implementation</b>	<b>Evaluation</b>	<b>Corrective Action</b>
1.5 Inspection	Integrated inspection program to provide a overall assessment of plant condition and corrosion rates	Inspection activity level Leak/save target Inspection increases Plant condition Regulatory compliance	Corrosion rate monitoring program (CRM) Erosion rate monitoring program (ERM) Comprehensive inspection program (CIP) Frequent inspection program (FIP) Corrosion under Insulation program (CUI)	NDE technique sheets and procedures Standardized assessment of piping condition, degradation rate and mechanism	Provide feedback to chemical mitigation program Erosion management program Fitness for service assessment Equipment life assessment Proactive repair scheduling
	Assessment of Current Damage Mechanisms	Zero Increases	Internal and external programs	See above	Repair/replace/monitor
	Search for New Damage Mechanisms	Mitigation action in place prior to threat to FFS	Baseline new equipment Apply lessons learnt from industry practice else where in the world Apply lessons learned for other BP operations Apply learnings across the field for similar equipment/process conditions Communications with Operations and P reservoir Engineers	See above	Develop mitigation program Mechanism management as part of routine business
1.6 Fitness for Service	Fitness for service assurance	Regulatory compliance Compliance with industry standard	See above inspection programs	Battelle Modified B31G fitness-for-service criteria (note piping only) BP Internal specification for the assessment of damaged pipe	Repair equipment Replace equipment Derate equipment Abandon equipment
	Structural integrity	Regulatory compliance Compliance with industry standard	Walking speed survey every 5 years	Piping design code BP Spec, B31.4 and B31.8 Piping stress analysis Nondestructive testing as required	Repair/replace Correct support defect Monitor for further degradation

GPB Table B.10 (continued) Corrosion Management System Element – Inspection

<b>Program</b>	<b>Plan/Objectives</b>	<b>Target</b>	<b>Implementation</b>	<b>Evaluation</b>	<b>Corrective Action</b>
1.7 Continuous Improvement	Provide Feedback to Monitoring, Mitigation, and Inspection Programs	Continuous Improvement	Integrated Program with Monitoring, Inspection, Operational Controls, and Corrosion Inhibitor Provides Feedback Control Loop for Program Improvements Consolidated data store, MIMIR	Weekly program review Quarterly program review Annual program reviews and strategy assessment Annual equipment life/availability review Key Performance Indicators	Strategic adjustment Budget/funding level changes Mitigation process change and review Technical/R&D requirements and programs

GPB Table B.10 (continued) Corrosion Management System Element – Inspection

Section B Corrosion Monitoring Activities

Program	Plan/Objectives	Target	Implementation	Evaluation	Corrective Action
1.1.1 Monitoring – Electrical Resistance Probes (ER)	Monitor the Effectiveness of the Mitigation Programs	< 2mpy Regulatory compliance Compliance with industry standard	ER Probes - Upstream and/or Downstream Ends of Flow lines	Investigate Cause for Corrosion Rate Increase	Mitigation Adjustments ER Probe Maintenance
1.1.2 Monitoring – Weight Loss Coupons (WLC)	Monitor the Effectiveness of the Mitigation Programs	Gen CR: < 2mpy Pit CR: < 20mpy Regulatory compliance Compliance with industry standard	WLC – Installed Flow lines, Well lines, Headers, and Piping	Investigate Cause for Corrosion Rate Increase	Mitigation Adjustments Inspection Program Adjustments
1.1.3 Monitoring – Process Conditions	Monitor changes in the Process Conditions	(See Mixture Velocity and Erosion Sections Below) Regulatory compliance Compliance with industry standard		Investigate Cause for Process Upset Long-Term Process Change Monitor Impact	Mitigation Adjustments
1.1.4 Monitoring – Mixture Velocity Management Program	Monitor the Effectiveness of the Mitigation Programs	Operational Guidelines Mix Vel Limits Regulatory compliance Compliance with industry standard	Operations Acceptance of Mixture Velocity Guidelines SETCIM	Review Alarm List to Determine True Offenders	Adjust Process Conditions
1.1.5 Monitoring – Erosion Management Program	Monitor the Effectiveness of the Erosion Mitigation Programs	Operational Guidelines Well Put on Production (POP) $V/V_e < 2.5$ Regulatory compliance Compliance with industry standard	Operations Acceptance of Erosion Guidelines High Risk Well Inspection Program (ERM)	Monthly Reviews to Determine High Risk Equipment and Repeat Offenders	Adjust Process Conditions

GPB Table B.11 Monitoring Program Techniques

Section B Corrosion Monitoring Activities

Program	Plan/Objectives	Target	Implementation	Evaluation	Corrective Action
1.2.1 Mitigation – Corrosion Inhibitor	Mitigate Corrosion Through Application of Corrosion Inhibitors	Control Corrosion Rates to Acceptable Levels (See Overall Program Goals) Regulatory compliance Compliance with industry standard Control Corrosion Rates to Acceptable Levels (See Overall Program Goals)	Continuous Injection Into Individual Wells as Far Upstream As Possible – Currently at Wellhead Protect All Equipment Between Injection Point and Separation Plant  Batch Treatments on a Routine Schedule with Injection at the Wellhead	ER Probes WLC's Inspection  WLC's Inspection	Corrosion Inhibitor Development Adjust Mitigation Effort  Corrosion Inhibitor Development Adjust Mitigation Effort through Reviews
1.2.2 Mitigation – Operational Control, Maintenance, and Material Selection	Mitigate Corrosion Through Operational Controls  Mitigate Erosion through Operational Controls  Mitigate Corrosion through Maintenance Pigging Corrosion Resistant Alloys	Operational Guidelines Mixture Velocity Limits Regulatory compliance Compliance with industry standard Operational Guidelines Well POP $V/V_e < 2.5$  Achieve Scheduled Frequency Zero Increases (I's)	Operations Acceptance of Mixture Velocity Guidelines  Operations Acceptance of Erosion Guidelines High Risk Well Inspection Program (ERM) Maintenance Pigging  Selected Facilities & Equipment	Mixture Velocities Review Alarm List to determine true offenders  Monthly Reviews to Determine High Risk Equipment and Repeat Offenders Inspection Pigging Returns Inspection Applicability For Service Requirements	Adjust Process Conditions  Adjust Process Conditions  Adjust Maintenance Pigging Schedule Replace as Necessary
1.2.3 Mitigation – Structural Integrity	Mitigate structural damage caused by subsidence, jacking, vibration, impact, snow loading, etc. through inspections	No failures due to structural damage Regulatory compliance Compliance with industry standard	Operational procedures for visual surveillance of pipelines Piping stress analysis as required NDE inspections as required	Review Pipeline Design Code/BP Specification	Repair, replace and correct deficiencies as required Add Pipeline Vibration Dampeners (PVDs) as required

GPB Table B.11 (continued) Mitigation Program Techniques

<b>Program</b>	<b>Plan/Objectives</b>	<b>Target</b>	<b>Implementation</b>	<b>Evaluation</b>	<b>Corrective Action</b>
1.3.1 Corrosion Rate Monitoring (CRM)	Assessment of current corrosion mechanisms Monitor for new corrosion mechanisms	No measurable active corrosion -Zero increases (I's) Regulatory compliance Compliance with industry standard	CRM Program - Fixed locations on approximately bi-annual frequency	Inspections Condition of Equipment Rate of degradation	Mitigation Adjustments Repair/Replace Preventative Maintenance
1.3.2 Erosion Rate Monitoring (ERM)	Monitor high risk wells Assessment of current erosion locations	Manageable rate of degradation Regulatory compliance Compliance with industry standard	ERM Program - monthly to quarterly	Inspections Condition of Equipment Rate of degradation	Mitigation Adjustments Repair/Replace Preventative Maintenance
1.3.3 Frequent Inspection Program (FIP)	Assessment of High Corrosion Rates Monitor locations near repair	Fitness-for-Service Regulatory compliance Compliance with industry standard	FIP Program - monthly to bi-annual	Inspections Condition of Equipment Rate of degradation	Mitigation Adjustments Repair/Replace Preventative Maintenance
1.3.4 Comprehensive Integrity Program (CIP)	Comprehensive Coverage of equipment Fitness-for-Service review	Fitness-for-Service Regulatory compliance Compliance with industry standard	CIP - Condition and rate based half-life recurring frequency Extend coverage through new locations	Inspections Condition of Equipment Rate of degradation	Mitigation Adjustments Repair/Replace Preventative Maintenance
1.3.5 Corrosion Under Insulation (CUI)	Comprehensive Coverage of equipment	Inspection of Locations susceptible to CUI Fitness For Service Regulatory compliance Compliance with industry standard	CUI - Risk based annual program Management of location inventory through recurring examinations	Detect Damage Areas Analysis of occurrence	Repair/Replace Preventative Maintenance

GPB Table B.11 (continued) Mitigation Program Techniques

Method	Technique	Description	Sensitivity	Accuracy	Freq	Notes/Comments
Corrosion Monitoring	Electrical Resistance (ER) Probes	Measurement of corrosion rate by monitoring changes in electrical resistance of a metal probe due to volume loss	High	Low	H/D	Correlate poorly to actual pipewall corrosion rates
	Weight Loss Coupons Corrosion Rate	Exposure of metal samples to corrosive fluid and calculation of volume loss rates based on weight	Medium	Medium	M	Limited benefit in determining short-term effects, such as flow regime changes on corrosion rates
	Weight Loss Coupons Pitting Rate	Exposure of metal samples and assessment of pitting rate via measurement of pit depths	Medium	Medium	M	Not a very sensitive measure for GPB 3phase but more effective in the PW system
	Galvanic Probe	Detects changes in corrosivity as a function of current flow between two dissimilar metals.	High	Low	C	Not a reliable measurement of mild steel corrosion rate. Very suitable to monitor oxygen and chlorine changes in seawater
	Linear Polarization Resistance (LPR)	Electrochemical technique for assessing corrosion rate by application of controlled voltage and measuring current response	High	Low	H/D	Not used at GPB due to the interference of hydrocarbon films on measurement

GPB Table B.12 Corrosion Monitoring Techniques – Benefits and Limitations

Method	Technique	Description	Sensitivity	Accuracy	Freq	Notes/Comments
Process Monitoring	Mixture velocity	Mixture velocity of fluids in pipe-work	Medium	Medium	D	Accuracy dependent upon production information (T, P, Oil, Water, Gas)
	Water cut	Percent water in liquid fluids	Medium	Medium	D	Accuracy dependent upon production information (Oil, Water)
	Temperature and pressure	Measured temperature and pressure in process equipment	Medium	Medium	D	
	Dissolved Oxygen	Amount of oxygen dissolved in Sea Water	High	Medium	D	In-line accuracy problematic. Chemet method more accurate
	Iron (Fe) counts	Amount of Iron (Fe) dissolved in process water	High	Low	M	
	Microbiological activity	Amount of microbiological life forms in process fluids	Medium	Low	M	

GPB Table B.13 Process Monitoring techniques – Benefits and Limitations

Method	Technique	Description	Sensitivity	Accuracy	Freq	Notes/Comments
Inspection/NDE	Radiographic Testing (RT)	Assessment of pipe wall degradation by passing gamma or x-ray radiation through a specimen and projecting an image on conventional lead screen/film. Irregular density variations of the image can indicate metal loss.	Medium	Medium	M/Q/H/ Y	Utilized for detection, monitoring, and fit for service assessment of pipe metal loss in the form of mechanical, corrosion, and erosion degradation. Currently being phased out in lieu of 'greener' process of DRT - see below
	Digital Radiographic Testing (DRT)	Assessment of pipe wall degradation by passing gamma or x-ray radiation through a specimen and projecting an image on phosphor screen/imaging plate. Irregular density variations of the image can indicate metal loss.	Medium	Medium	M/Q/H/ Y	Utilized for detection, monitoring, and fit for service assessment of pipe metal loss in the form of mechanical, corrosion, and erosion degradation. DRT provides additional benefits in waste reduction associated with conventional film and processing chemicals
	Tangential Radiography Testing (TRT)	Assessment of pipe wall degradation by passing gamma or x-ray radiation through insulation at the tangent of the specimen and projecting an image on screen/film, phosphor screen/imaging plate, or detector array.	High	Low	Y	Utilized for detection of corrosion under insulation (CUI). Deployed where potential moisture ingress is suspected on thermally insulated piping
	Ultrasonic Testing (UT)	Assessment of pipe wall thickness by sending/receiving ultrasound through a specimen. Echoes returning indicate remaining thickness of the specimen.	Medium	High	M/Q/H/ Y	Utilized for detection, monitoring, and fit for service assessment of pipe metal loss in the form of mechanical, corrosion, and erosion degradation
	Guided Wave Ultrasonic Testing (GUT)	Volumetric assessment of pipe wall by sending/receiving ultrasound through a specimen in the form of cylinder Lamb Waves. Monitoring changes in these waves indicate potential changes in pipe thickness. Alternatively, echoes returning to the source transducer may also indicate interruptions or pitting in the pipe segment.	Low	Low	Y	Utilized for cased piping assessment where access does not support use of traditional inspection methods. The method is capable of semi-quantifying metal loss but cannot discriminate between internal and external corrosion
	Electromagnetic Pulse Testing (EMT)	Assessment of pipe wall by propagating broadband electromagnetic waves on the exterior surface of the specimen. When waves traveling down steel pipe encounter corrosion on the pipe surface, the waves are distorted. Distortions in waveform may indicate rust by-product on the surface of the steel and subsequent metal loss.	High	Low	Y	Utilized for cased piping assessment where access does not support use of traditional inspection methods. The method cannot quantify metal loss and has a tendency to report false positive results but seldom overlooks surface atmospheric corrosion

GPB Table B.14 Inspection/Non-Destructive Examination (NDE) Techniques – Benefits and Limitations

Method	Technique	Description	Sensitivity	Accuracy	Freq	Notes/Comments
Inspection/NDE (Cont)	In-line Inspection – Smart Pig Magnetic Flux (MFL) Technique	Assessment of pipelines for the detection and measurement of metal loss. These pigs carry high strength magnets, which apply a strong magnetic field into the pipe wall. The magnetic field saturates the pipe steel with magnetic flux. As a result, areas of metal loss cause the flux to leak out of the pipe wall. The flux leakage data are recorded and used to infer the size and depth of any metal loss defects in the pipe.	High	Medium	N/A	Utilized where design and process operation permit in-line pigging. Metal loss MFL In-line Inspection provides complete evaluation of pipeline integrity within the limitations of the MFL technique.

GPB Table B.14 (continued) Inspection/Non-Destructive Examination (NDE) Techniques – Benefits and Limitations

Section B Corrosion Monitoring Activities

Service	Equipment Type	Monitoring Technique	Inspection Program	Mitigation Program*
Oil	Flow line	ER Probes WLC Process Monitoring	CRM FIP CIP CUI	CI Injection Mixture Velocities Periodic Maintenance Pigging Operational Controls
	Well line	WLC Process Monitoring	CRM ERM FIP CIP CUI	CI Injection Mixture Velocities Mixture Velocities Operational Controls
Produced Water	Flow line	WLC	CRM FIP CIP CUI	CI Injection** CI Carry Over Periodic Maintenance Pigging Mixture Velocities Operational Controls
	Well line	WLC	CRM FIP CIP CUI	CI Injection** CI Carry Over Mixture Velocities Operational Controls
Seawater	Flow line	WLC Galvanic Probes Dissolved O <sub>2</sub> Microbiological Activity	CRM FIP CIP CUI	Biocide Treatment O <sub>2</sub> Scavenger Periodic Maintenance Pigging Operational Controls
	Well line	WLC Microbiological Activity	CRM FIP CIP CUI	Biocide Treatment Periodic Maintenance Pigging Operational Controls
Export oil	Flow line	WLC FR Probes	CRM FIP CIP CUI	CI Carry Over Mixture Velocities Operational Controls Periodic Maintenance Pigging

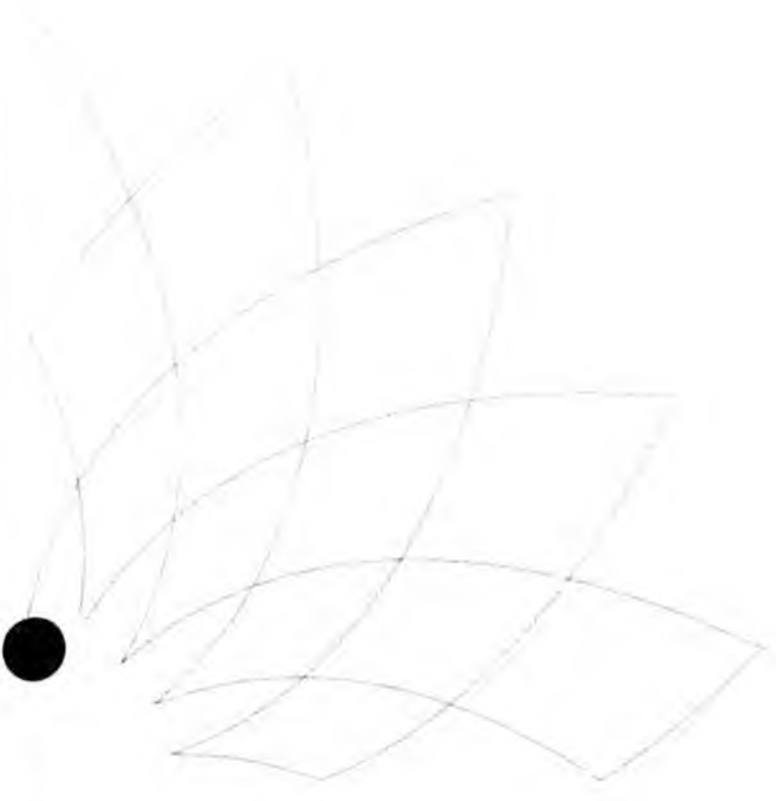
\*Applicable to all inspection programs noted

\*\*No CI Injection for FS-2 PW

**GPB Table B.15 Corrosion Management System Implementation by Equip Type and Service**

**Section C**

**Weight Loss Coupons and Probes**



## **Section C Weight Loss Coupons and ER Probes**

This section summarizes the results of the weight loss coupon corrosion monitoring and ER probe programs. Each of the major service categories are reviewed in turn with the results of the program discussed along with major conclusions and significant recommendations.

Detailed data tables for each configuration of equipment type, flow line and well line, and each service category, 3-phase, produced water and seawater, are provided in Appendix 5.

### **Section C.1 Three Phase Production Systems**

The corrosion mechanism of concern in the 3-phase production system is CO<sub>2</sub> corrosion, in which CO<sub>2</sub> from the produced fluids dissolves and dissociates in the produced water to form an acidic environment that is, if untreated, corrosive to carbon steel<sup>5,6</sup>. The primary corrosion control method is the continuous addition of corrosion inhibitor in the flow lines and a mix of continuous and batch inhibitor additions in the well lines.

For the 3-phase production system the target corrosion rate from weight loss coupons is a general corrosion rate of 2 mpy or less (WLC  $\leq$  2 mpy).

#### **Section C.1.1 Cross Country Flow Line Coupons**

GPB Figure C.1 shows the average corrosion rate and percentage of coupons meeting the performance standard target since 1992. The results show the percentage of conformant flow lines has improved consistently over the last decade. The average corrosion rate for 2003 across GPB is approximately a factor of 10 lower than the corrosion rates from the early 1990's.

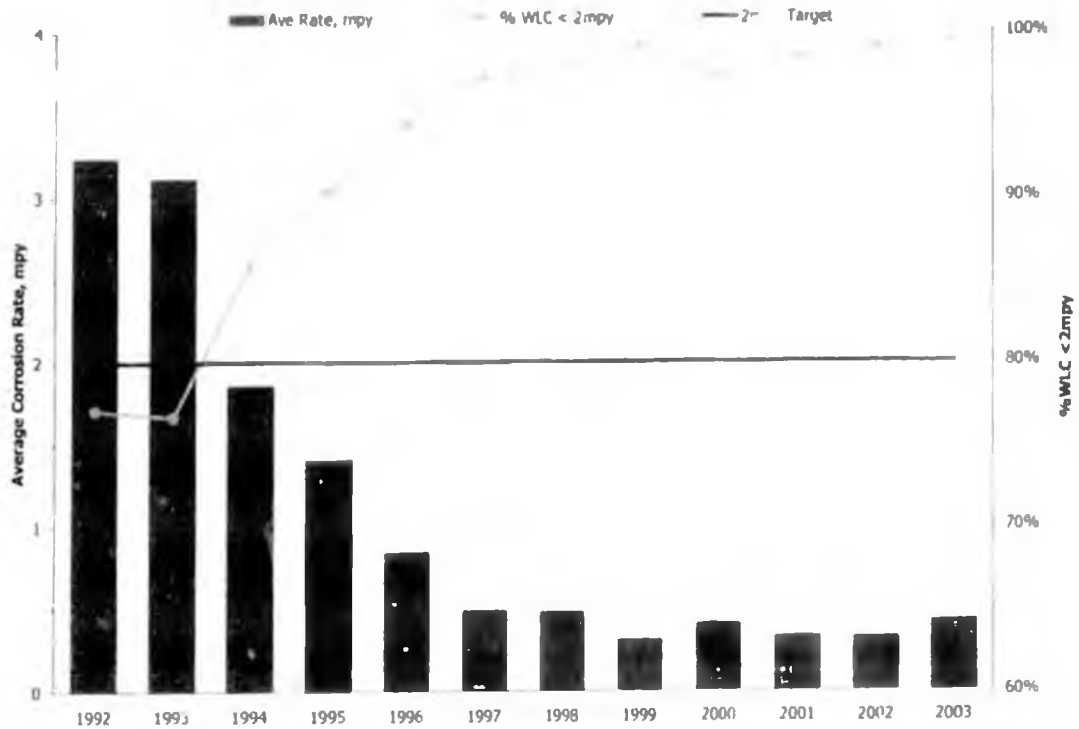
The reduction in corrosion rate is a direct result of the implementation of an aggressive corrosion mitigation program consisting primarily of continuous addition of corrosion inhibitor into the production fluids. The results from 2003 demonstrate the most effective level of corrosion management that has been achieved. This mitigation program has been implemented at considerable capital and operating expense but has resulted in flow lines which are now expected to be fit-for-service (FFS) for approximately 10 times as long as that expected in the early 1990's due to the reduction in corrosion rate.

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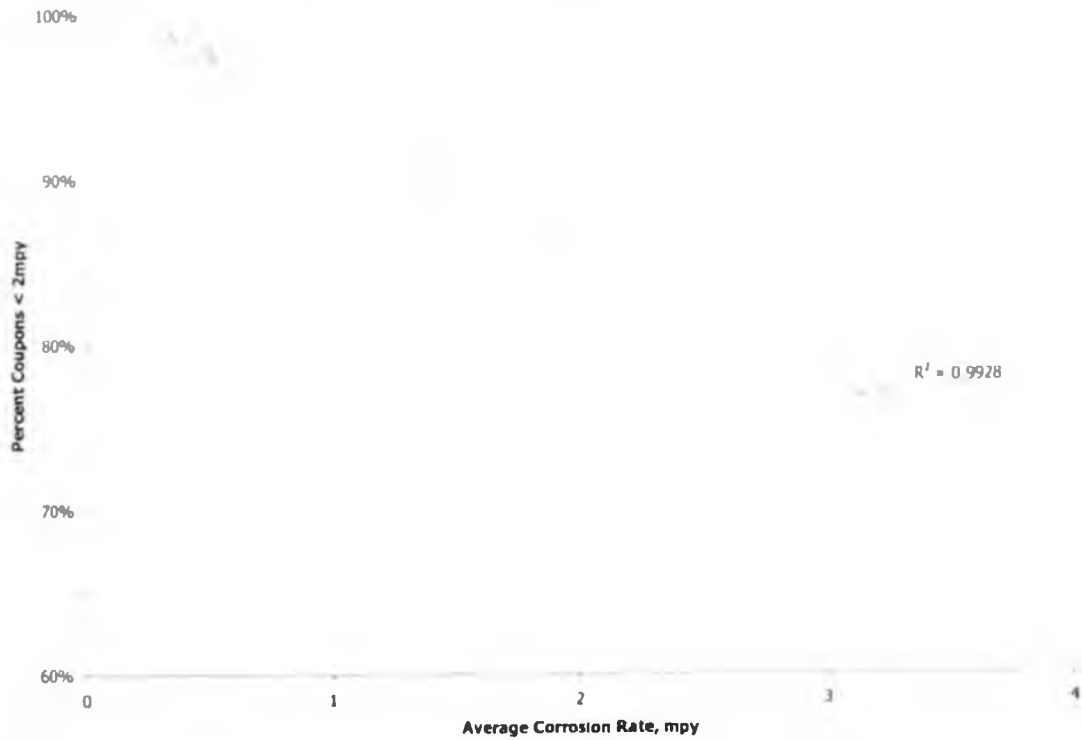
<sup>5</sup> Corrosion Control in Petroleum Production, Harry G Byers, NACE, 1999

<sup>6</sup> Corrosion Control in Oil and Gas Production, Treseder and Tuttle, NACE, 1998

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GPB Figure C.1 Flow Line Oil Service Corrosion Rate Trend



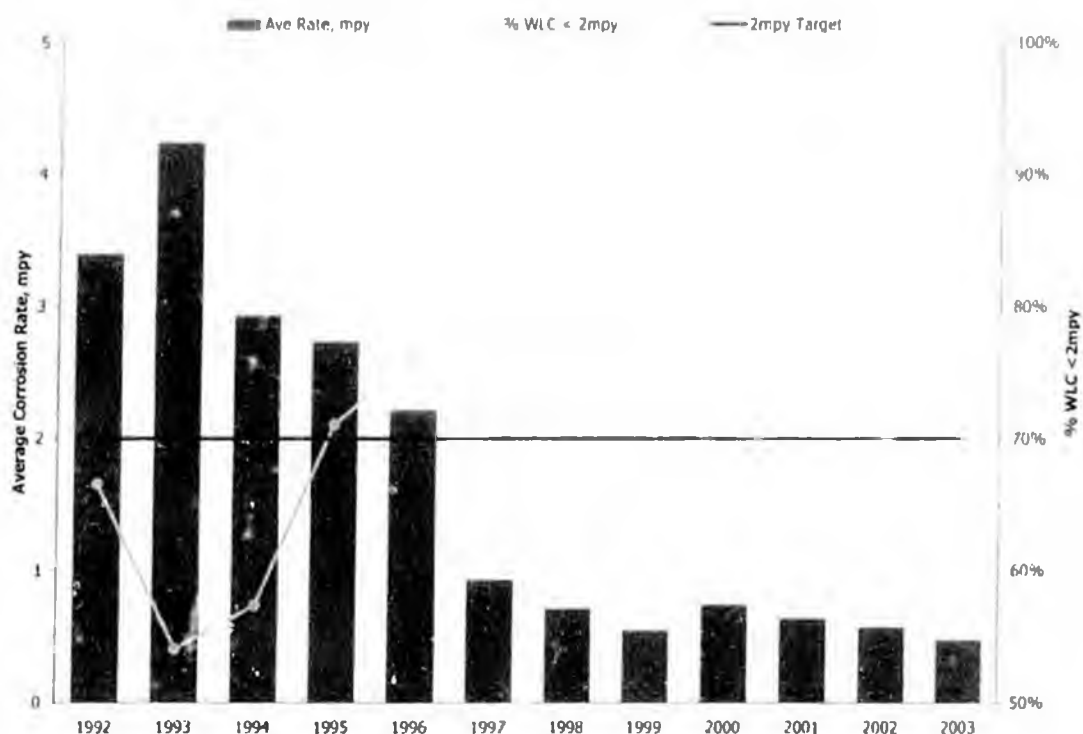
GPB Figure C.2 Correlation Between Flow Line Corrosion Rate and Percentage Conformance

GPB Figure C.2 shows the correlation between average corrosion rate and the percentage of weight loss coupons meeting the 2 mpy target. As might be expected, there is a very strong correlation between these two metrics. However these two metrics should be viewed as being complementary. The percentage less than 2 mpy target has the advantage of highlighting non-conformances that would otherwise be lost in the calculation of the average.

Conversely, the average corrosion rate has the advantage of showing the overall performance trend that would otherwise be lost when only looking at the exceptions >2 mpy. Hence, it is necessary to review both metrics in order to gain an overall understanding of the performance of the program.

### Section C.1.2 Well Line Coupons

GPB Figure C.3 shows the average corrosion rate and percentage of WLC  $\leq$  2 mpy since 1992. The trends are very similar to those seen in the cross-country oil flow lines, showing a long-term improvement in the level of control from early 1990's to the present day. The corrosion rate is at its lowest value and the percentage of coupons  $\leq$  2 mpy is at the highest value since 1992.



GPB Figure C.3 Well Line Oil Service Corrosion Rate Trend

The long term corrosion control improvement in the well lines is of the same magnitude as that seen in the flow lines with corrosion rates being reduced from an average >4 mpy in 1993 down to an average of 0.5 mpy for 2003.

### Section C.1.3 Three Phase Coupon Program Summary

The 3-phase production system has seen a consistently strong improvement in corrosion control since the early 1990's with a near order of magnitude reduction in the cross-country flow line corrosion rates. A similar trend is also seen in the inspection history discussed later in Section E. The decrease in corrosion rates in the 3-phase systems is attributable to the implementation and continuation of the aggressive corrosion inhibition program. The correlation between corrosion inhibitor concentration and corrosion rates in 3-phase flow lines is discussed in detail in Section D.

### Section C.2 Water Injection Systems

The Water Injection System at GPB is comprised of produced water from the primary processing/separation facilities and seawater extracted from the Beaufort Sea and processed through the Seawater Treatment Plant (STP).

As noted in the 2002 Report, the production database has now been linked to the corrosion and inspection database. This dynamic link provides a much more detailed view of service history/changes for the well line equipment, enabling an improved level of data analysis and quality.

As a consequence of the dynamic linking of the weight loss coupon history to the injection and production data, the totals in Section C will not match the activity totals in Section B, which are reported independent of the injection or production service.

The new reporting format, which augments the performance metrics and was agreed with ADEC, can be summarized as follows:

<b>Report Date</b>	Mid point of the WLC's exposure period, $\text{MidDate} = \text{Date In} + \frac{(\text{Date Out} - \text{Date In})}{2}$
<b>Service Type</b>	(a) Average corrosion rate with 100% exposure to service (b) Average corrosion rate with simple service majority

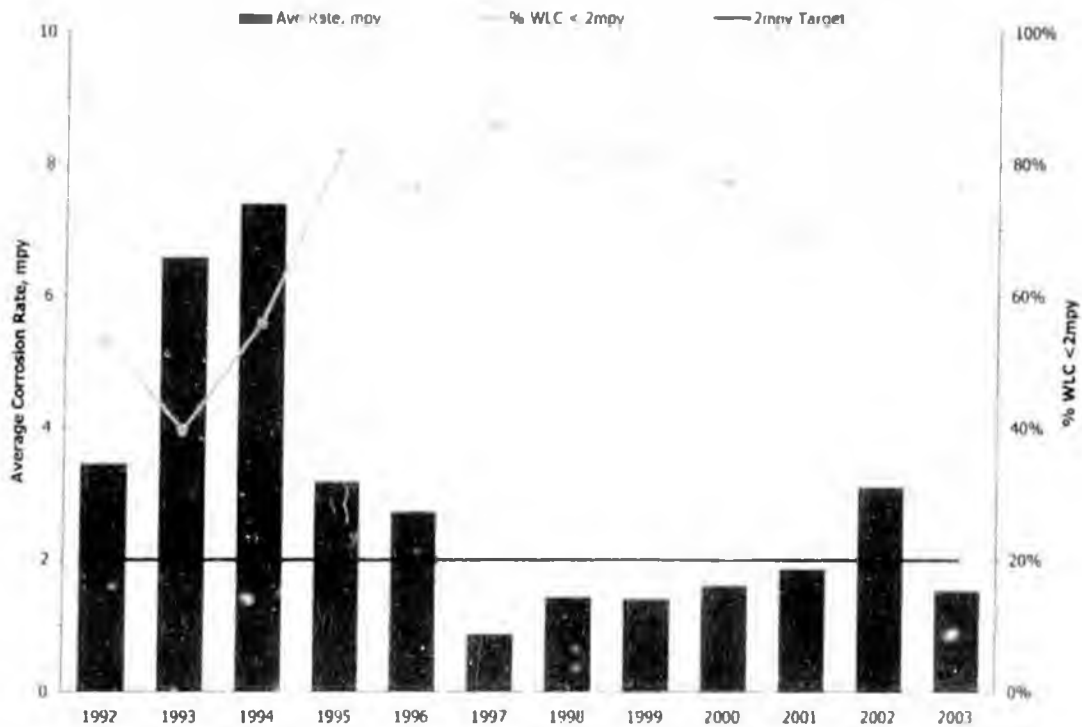
Full data sets are included in the data tables in Appendix 5.

### Section C.2.1 Water Injection System Flow Lines

GPB Figure C.4 is a summary of aggregate data for produced water and seawater flow lines. The data show the 2003 WLC corrosion rates have decreased below the 2 mpy target. The decrease in rate is largely due to corrosion mitigation actions taken in the SW system, which are discussed in detail in Section C.2.3.

The data set for 2003 has been expanded from previous years. Additional monitoring locations, from the facility piping, have been added to the data set to provide increased insight into the performance of the water injection flow lines.

These locations are exposed to mainline flow but are physically located inside the facility module walls.



GPB Figure C.4 Flow Line PW/SW Service Corrosion Rate Trend

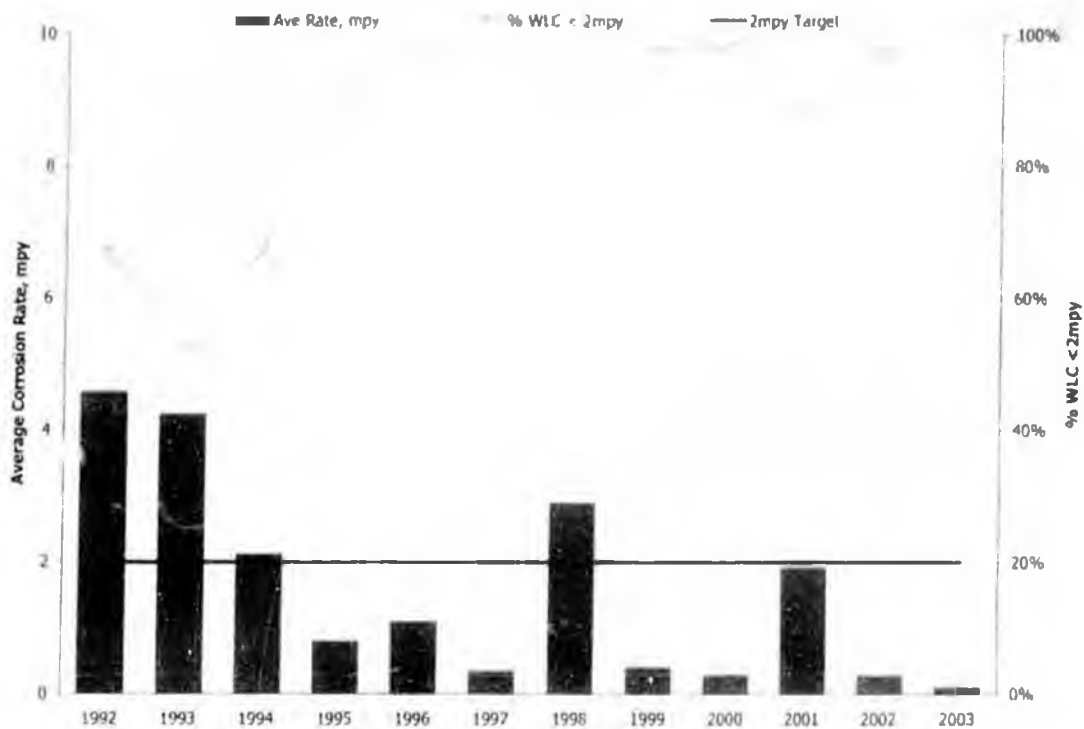
In summary, the average WLC corrosion rates for the aggregate water injection service improved in 2003, reversing a negative 5-year trend. This improvement is attributable to corrosion mitigation actions in the seawater system over the recent years.

### Section C.2.2 Produced Water Injection Well Lines

There are a number of corrosion mechanisms of concern in the produced water (PW) injection system. These mechanisms include CO<sub>2</sub> corrosion and differential concentration effects due to the high particulate content of the system. The particulates consist primarily of residual hydrocarbon remaining after the separation process, entrained production chemicals, and iron sulfides.

GPB Figure C.5 through GPB Figure C.7 summarize the historical corrosion rate data for produced water well lines. The data show the general corrosion rates in the produced water system have fallen as the level of inhibition in the 3-phase system was increased and supplemental produced water corrosion inhibitor injection was initiated.

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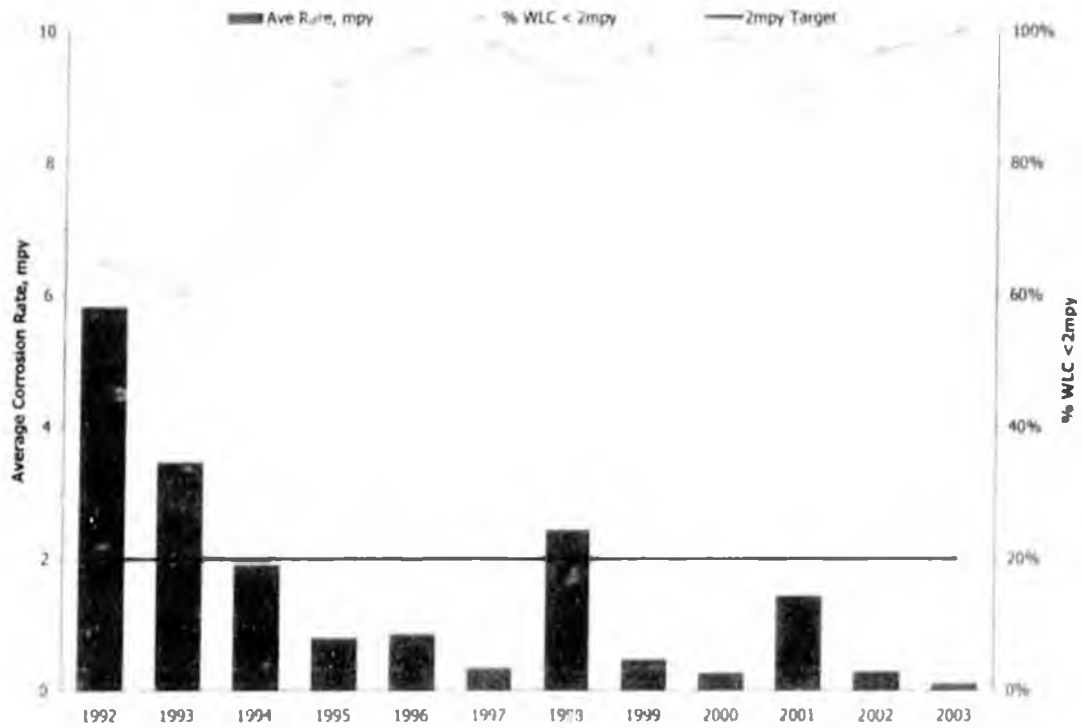
GPB Figure C.5 Corrosion Rates for 100% PW System

GPB Figure C.5 shows the performance for 100% produced water service. The 2003 levels reached a system best with average corrosion rates at ~0.1 mpy and 100% WLC  $\leq$  2 mpy. This initial evaluation of the new treatment is encouraging, but caution is warranted as the data set is limited and long-term trend has not been established.

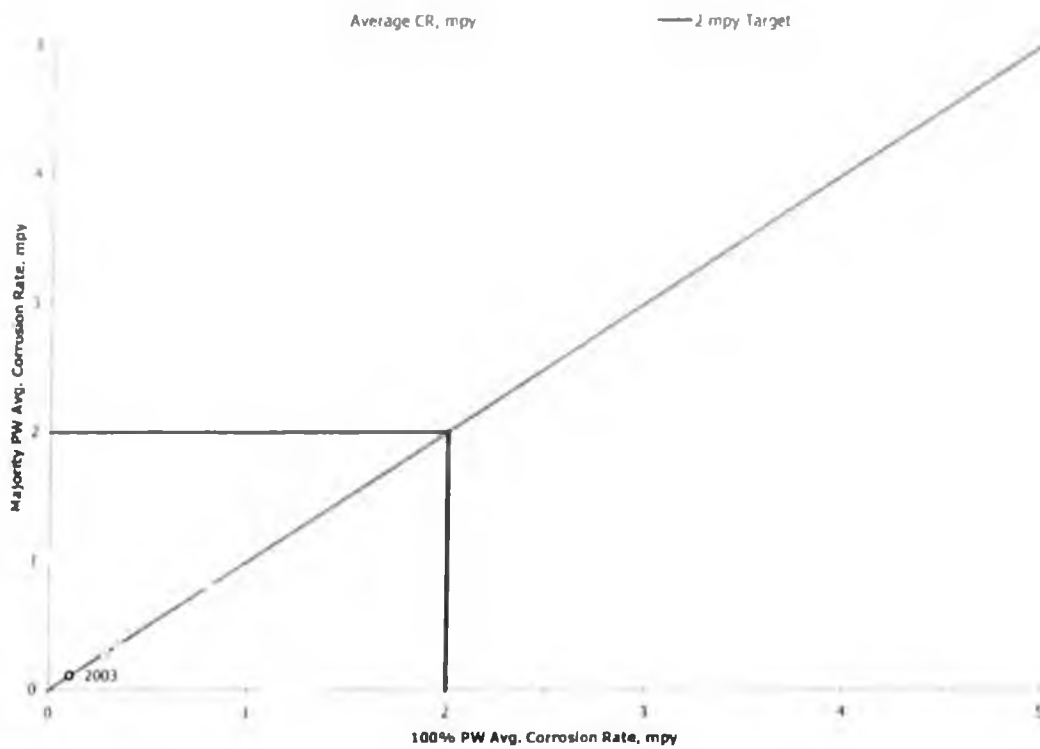
For those coupons where produced water was the majority service, GPB Figure C.6 shows the corrosion rate trends were very similar to those seen for 100% produced water service. Again, the results for 2003 are encouraging, but caution is warranted as the data set is limited, and long-term trend has not been established.

A comparison of the average corrosion rate for produced water between the 100% service and majority service is provided in GPB Figure C.7. The figure shows little difference between the data.

Section C Weight Loss Coupons and ER Probes



GPB Figure C.6 Corrosion Rates for Majority PW System



GPB Figure C.7 Comparison of Corrosion Rates for 100% and Majority PW

The overall improvement in the performance of the PW system from 2001 to date can be attributed primarily to two factors. First, there was a change in the upstream 3-phase continuous corrosion inhibitor in 2002 that gave more favorable partitioning characteristics to the water phase than the prior product. This had the effect of increasing the levels of corrosion inhibitor carried from the upstream system into the produced water distribution network. The second contributor was the expansion of corrosion mitigation programs specific to the PW system started in 2002. The program now includes limited inhibitor injection in the PW system at FS-1, FS-3, GC-1, GC-2 and GC-3.

### **Section C.2.3 Seawater Injection Well Lines**

The main corrosion mechanisms in the seawater (SW) injection systems are,

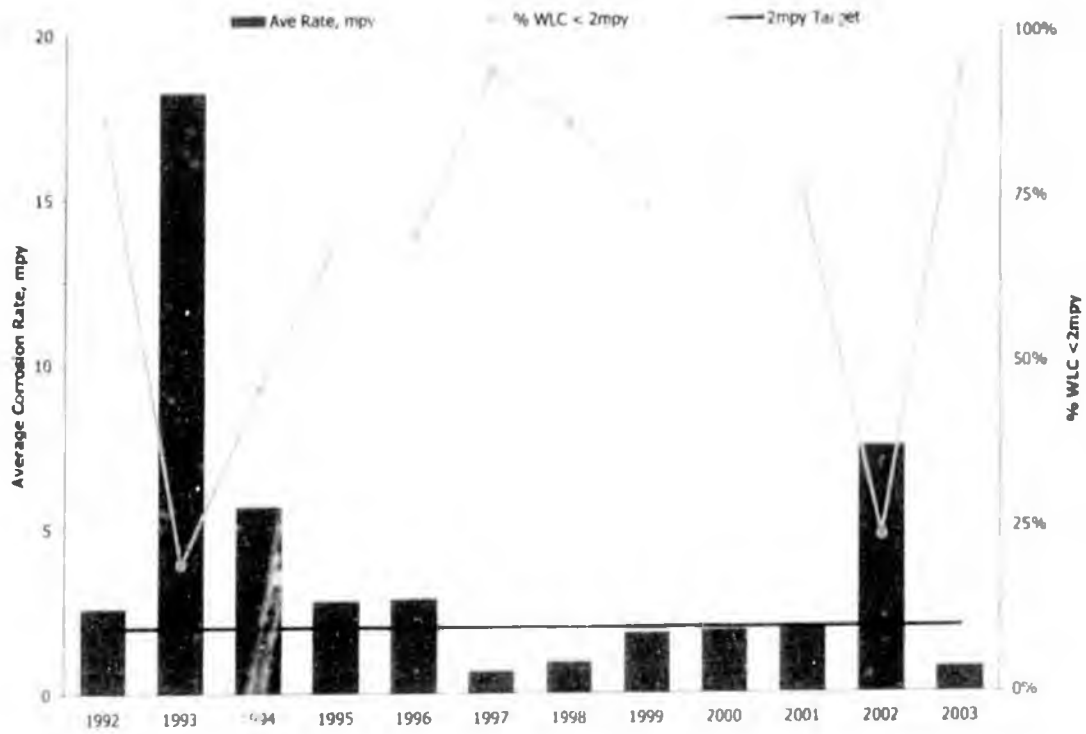
- Dissolved oxygen (DO) corrosion – This mechanism is mitigated by processing the seawater to remove the oxygen. Initial DO removal is achieved mechanically by vacuum stripping, which is then followed by chemical oxygen scavenging.
- Microbiological corrosion (MIC) – MIC is due to the action of anaerobic bacteria, and is mitigated by batch treatment with biocide, after processing to remove DO and prior to seawater transfer to the main cross country flow lines.

As with the PW system, the SW system data are presented as both 100% and majority service for the well line data, along with a comparison of general corrosion rates and pitting corrosion rates.

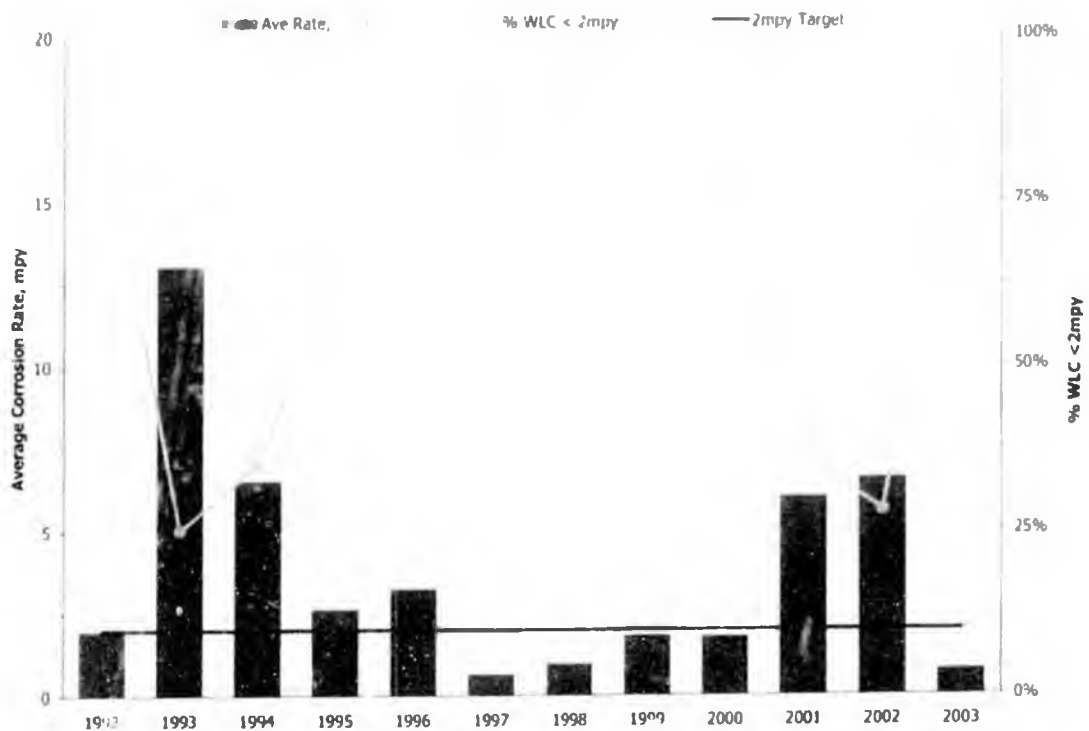
GPB Figure C.8 through GPB Figure C.10 show the corrosion rate trends in the SW system. For both 100% SW service and majority SW service, the general corrosion rates improved in 2003, reversing a 5-year trend.

It is believed the improvement is a result of implementation of the corrective actions outlined in the 2001 and 2002 Meet and Confer sessions with ADEC.

Section C Weight Loss Coupons and ER Probes

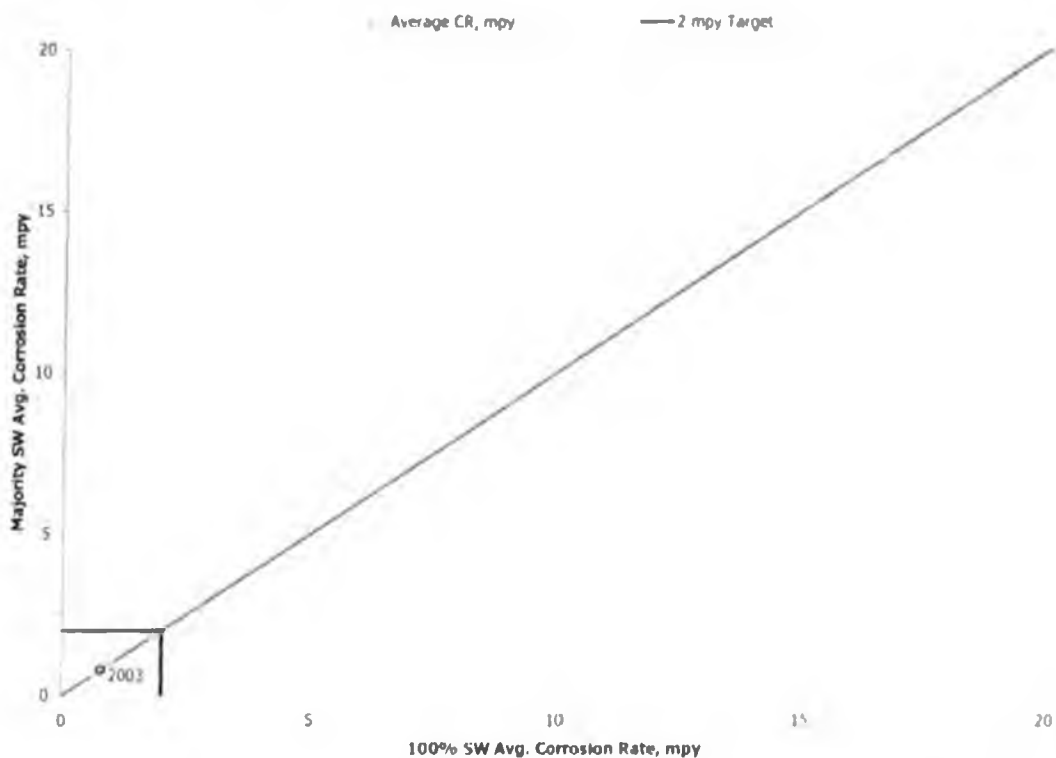


GPB Figure C.8 Corrosion Rate for 100% Seawater System

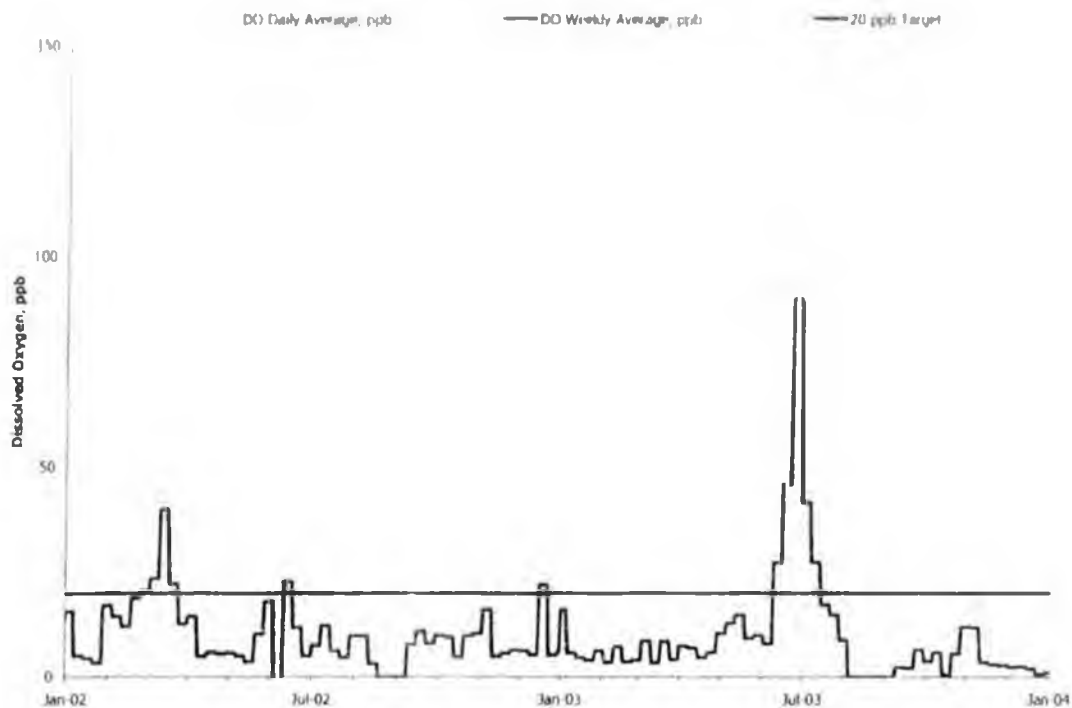


GPB Figure C.9 Corrosion Rates for Majority SW System

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GPB Figure C.10 Comparison of Corrosion Rates for 100% and Majority SW System



GPB Figure C.11 Dissolved Oxygen Control Performance for the Seawater System

GPB Figure C.11 shows the daily and weekly average level of dissolved oxygen control in the seawater system through 2003. The DO excursion in summer 2003 was due to seasonal decreases in rates of the chemical oxygen scavenging reactions during periods of spring runoff and seawater turbidity. This was followed by a ~1 month shutdown to complete system upgrades for increased capacity. DO control improved markedly in the latter part of 2003, and diligent plant operation continues to deliver good DO control.

GPB Table C.1 summarizes the changes in the biocide treatment program for the SW system. Biocide dosage was increased in March 2003 by 50% at STP to increase the effectiveness in downstream parts of the seawater system. This action decreased the downstream coupon corrosion rates faster than expected. In December 2003 the glutaraldehyde/quaternary amine biocide was replaced with glutaraldehyde for operational reasons.

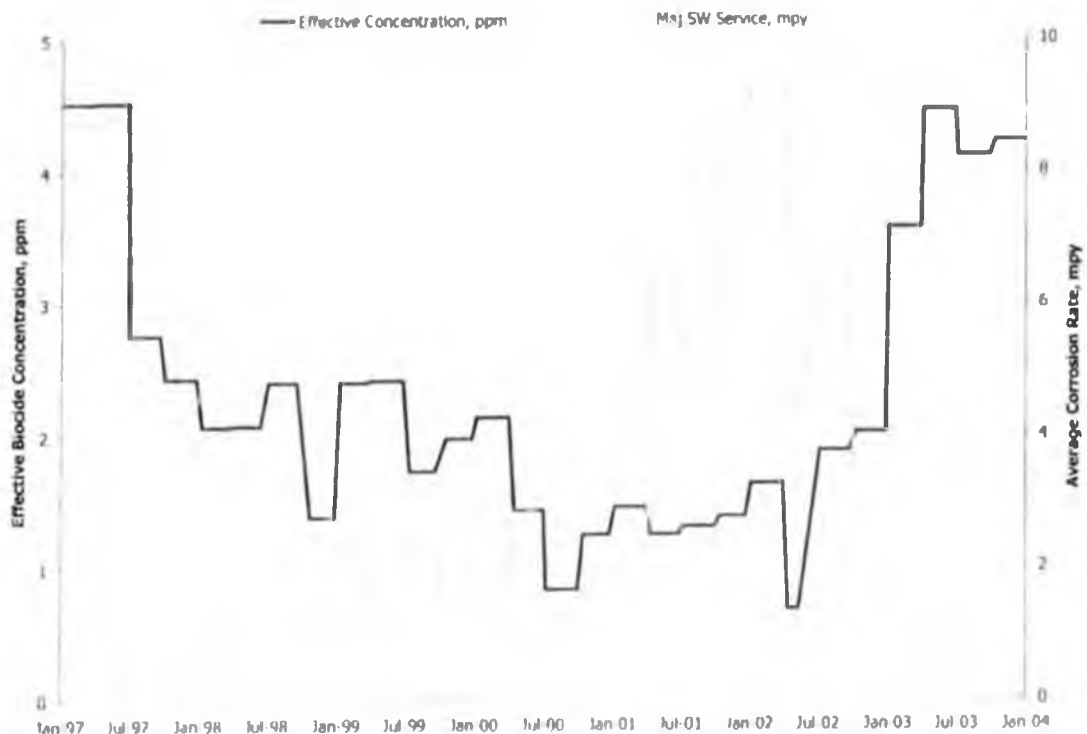
From	To	ppm	Interval days	Product
Jan-97	Jul-97	750	7	Glutaraldehyde
Jul-97	Feb-00	750	14	Glutaraldehyde
Feb-00	Aug-01	450	14	Glutaraldehyde/quaternary amine blend
Aug-01	Jul-02	500	14	Glutaraldehyde/quaternary amine blend
Jul-02	Dec-02	500	7	Glutaraldehyde/quaternary amine blend
Dec-02	Mar-03	500	7	Glutaraldehyde/quaternary amine blend
Mar-03	Dec-03	750	7	Glutaraldehyde/quaternary amine blend
Dec-03	Present	750	7	Glutaraldehyde

**GPB Table C.1 Biocide Treatment Concentration and Interval**

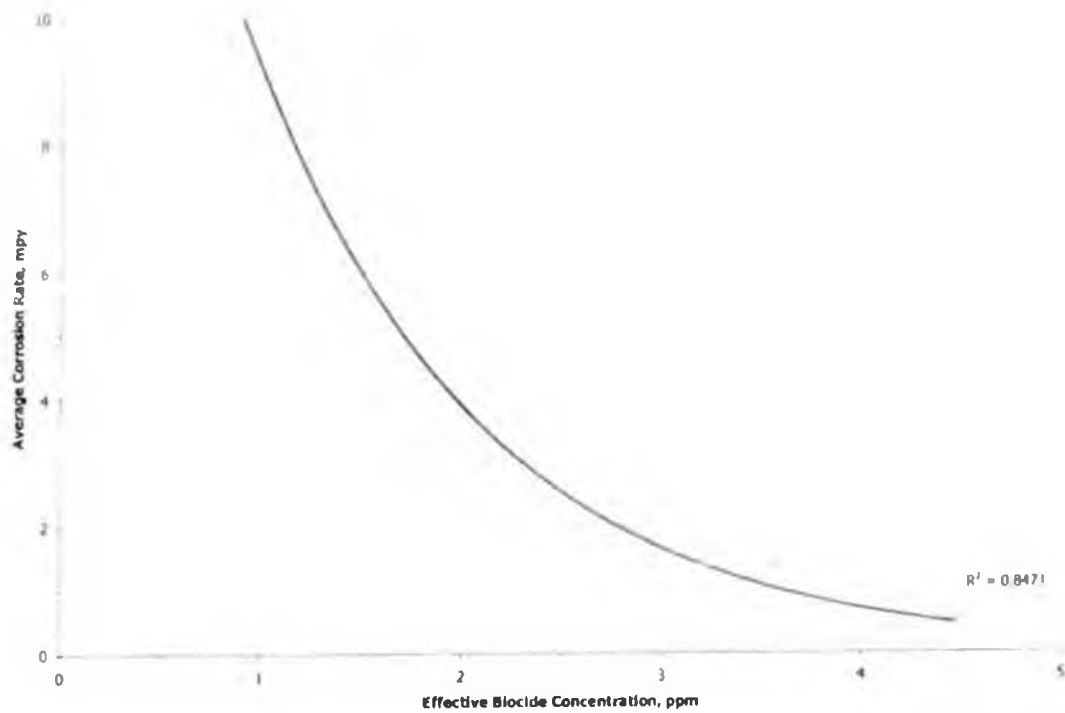
GPB Figure C.12 shows the corresponding effective concentration of biocide and the average corrosion rate for well line coupons in majority SW service. The beneficial effect of increasing the biocide injection concentration at STP is clearly depicted and helped to reduce seawater system corrosion rates below the 2 mpy target.

The effect of increasing biocide on the corrosion rates in the SW system are more clearly shown in GPB Figure C.13, which shows the correlation between the average corrosion rate and effective biocide concentration for 2001 through 2003.

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GPB Figure C.12 Biocide Treatment Concentration and Corrosion Rate



GPB Figure C.13 Average Corrosion Rate vs. Effective Concentration, 2001 - 2003

In summary, improvements made from 2000 to 2003 in DO control and increased biocide injection rate have reduced corrosion rates in the seawater system. The data suggest progress has been made in returning the seawater system to control; however as with the produced water system, caution is warranted. Therefore, there will be an on-going effort in 2004 to assure that this trend is confirmed and continued. Should a long-term trend of reduced corrosion rates not be established then further corrective actions will be implemented.

### Section C.3 Electrical Resistance Probes

ER probes are installed in various locations to monitor corrosion rates in flow lines throughout GPB. ER probes show increases due to material loss from corrosion and the measurements are converted to provide corrosion rates in mils per year. ER probes are equipped with remote data collectors (RDC), which measure and record the metal loss data every 3 hours. This provides an adequate number of data points to assess corrosion rates while maximizing battery life in the units.

The type of ER probe used is a T-10 that has 5 mils (0.005") of usable metal thickness. All flow line ER probes are replaced based on a 1-year service life, or when one half the usable metal thickness has been consumed. This reduces false negative and false positive readings as a result of damaged or unresponsive probes.

ER probes are located on both the upstream (well pad) end and downstream (gathering center) end of flow lines located on the west side of GPB. On the east side, probes are only located on the downstream (flow station) end of flow lines.

ER probe data are collected in the field and uploaded to the corrosion and inspection database once per week. More frequent readings can be made to closely monitor suspect locations/readings. The target for ER probe corrosion rate is  $\leq 2$  mpy. Each ER probe with a corrosion rate greater than 2 mpy is evaluated to determine data validity. After verifying an increase in corrosion rates based on the probe data, a corrosion inhibitor increase may be recommended, refer to Section D.7.

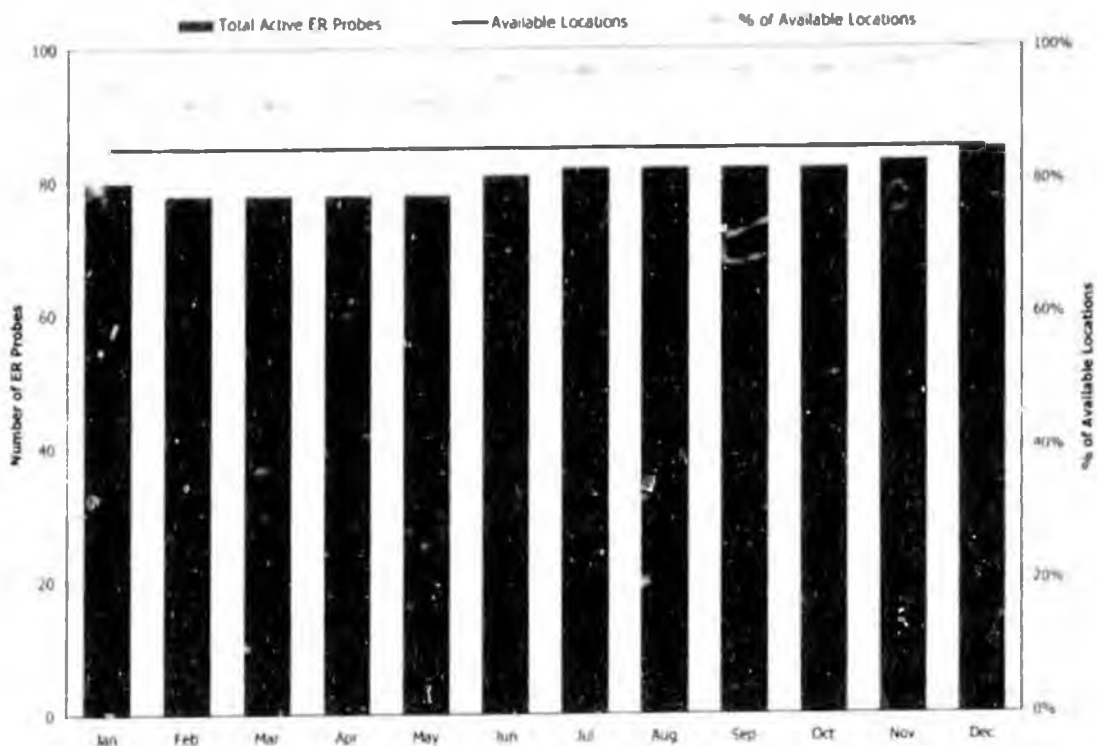
GPB Table C.2 shows the number of probes with corrosion rates greater than target as compared to the number actioned dating back to 2001.

Year	% <2mpy	No. ER Probe > 2	No. ER Probes Actioned
2001	97%	193	6
2002	97%	137	6
2003	93%	138	21

**GPB Table C.2 Number of ER Probes >2mpy and Actioned**

- The 21 occurrences greater than 2 mpy in 2003 were mitigated with corrosion inhibitor rate increases – see Section H.1.5.

GPB Figure C.14 shows the number of ER probes and the percentage of time the ER probes were providing data. The number of flow lines monitored with ER probes has increased due to the addition of new probe locations and an increased emphasis on equipment maintenance.



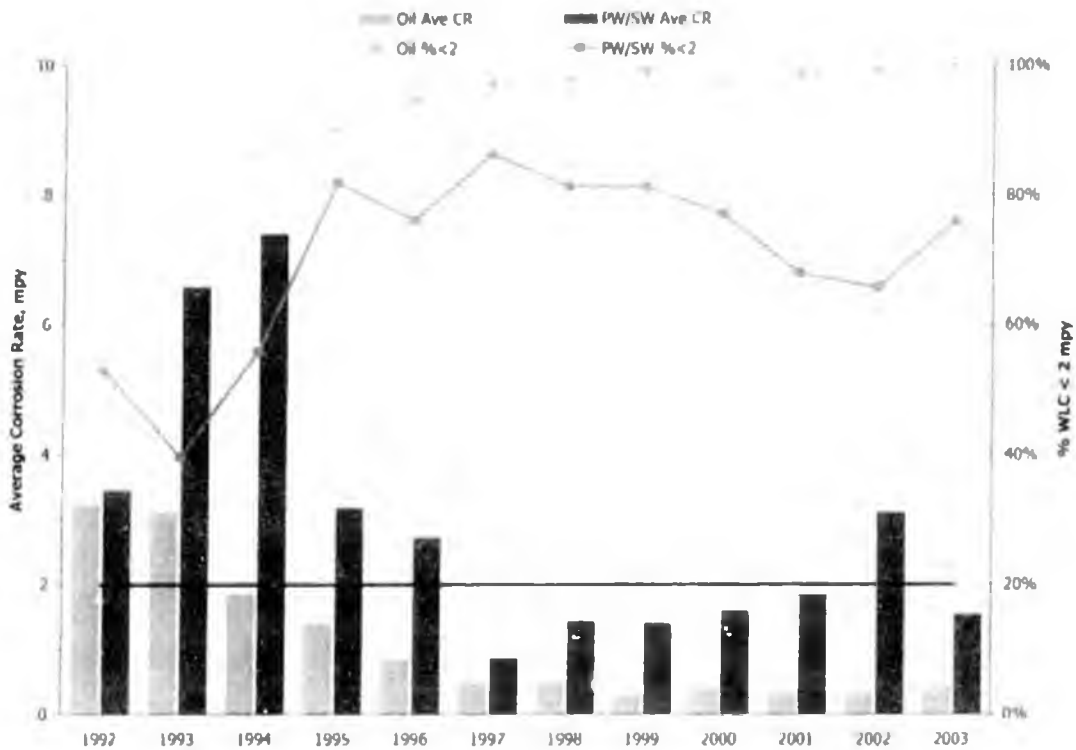
GPB Figure C.14 Equipment Monitored Using ER Probes

^ significant effort was made in 2003 to improve reliability of data provided by the ER probe monitoring equipment. Equipment availability improved during 2003, from 95% at the beginning to 100% at year-end.

## Section C.4 1992 to Date Summary

### Section C.4.1 System by System Summary

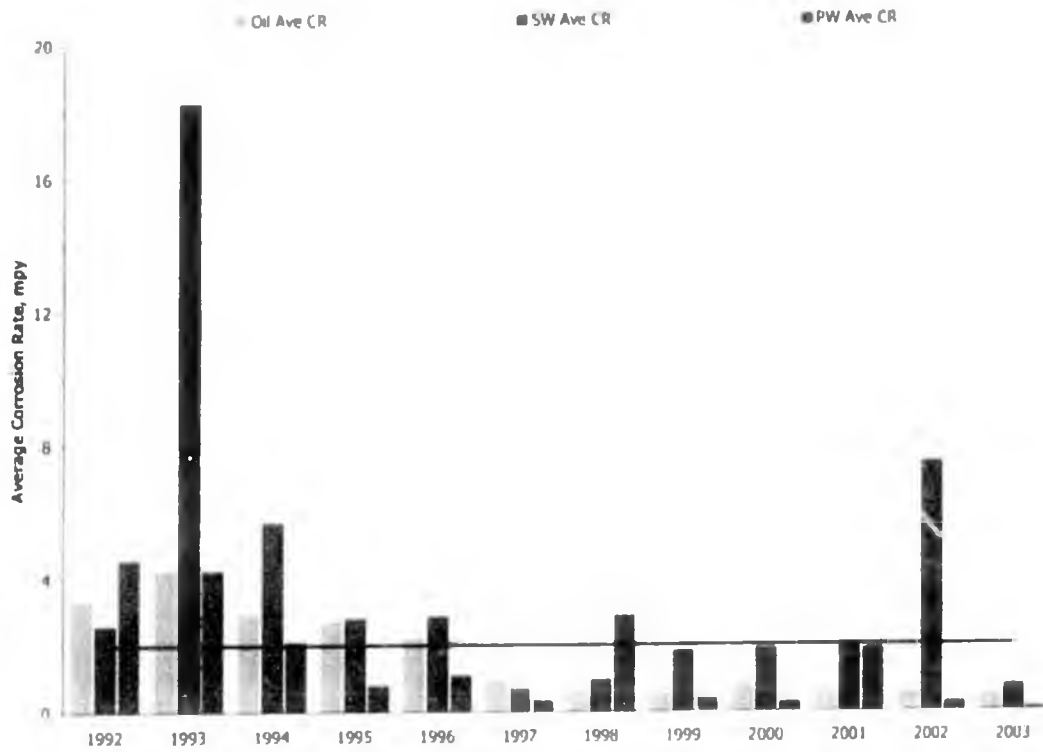
This section provides system-by-system summary since 1992 for the major systems at GPB. GPB Figure C.15 shows the corrosion rate and corrosion target conformance since 1992. The performance in the 3-phase production system has improved slightly from 2002. The data set for water injection flow lines has been updated to include additional monitoring locations. The improvement from 2002 to 2003 is a result of the on-going corrective actions being implemented in the SW injection system.



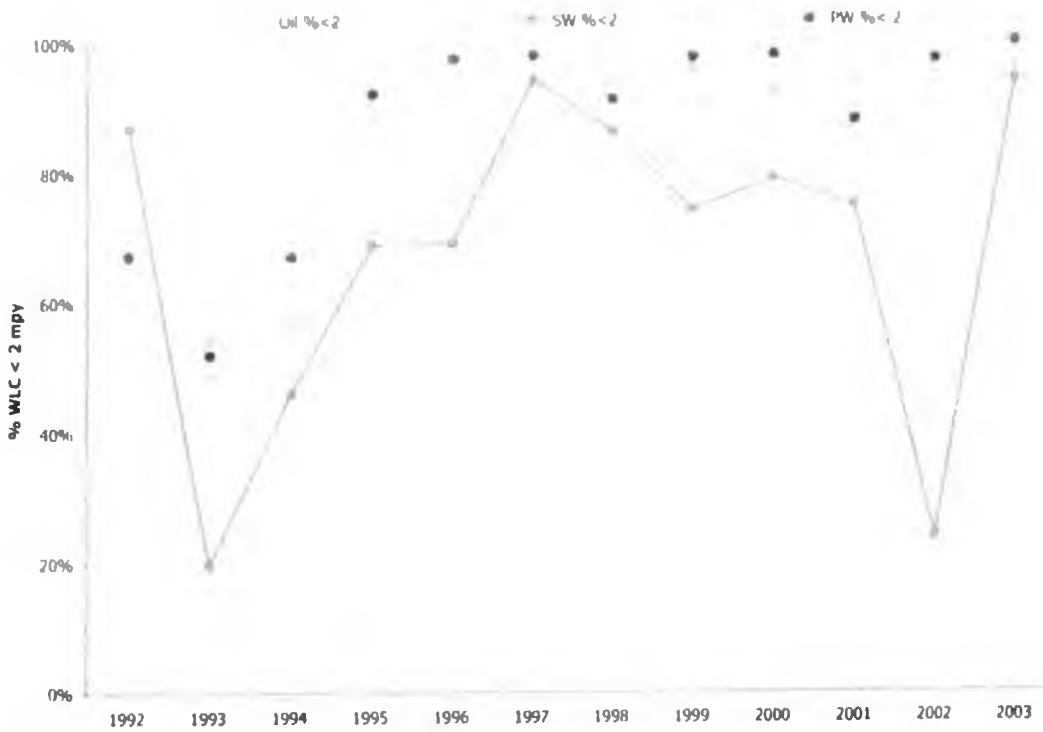
GPB Figure C.15 Flow Line Corrosion Coupon Summary by Equipment and Service

GPB Figure C.16 shows the corrosion rate and GPB Figure C.17 shows corrosion conformance for well lines. The well line 3-phase system has improved between 2002 and 2003. The produced water well lines corrosion performance continues to improve and corrosion rates decreased to their lowest level since 1992. The well lines in seawater service show a marked improvement in performance and in the level of conformance to the 2 mpy target. As previously discussed, there have been a number of changes made to the mitigation programs in the SW system.

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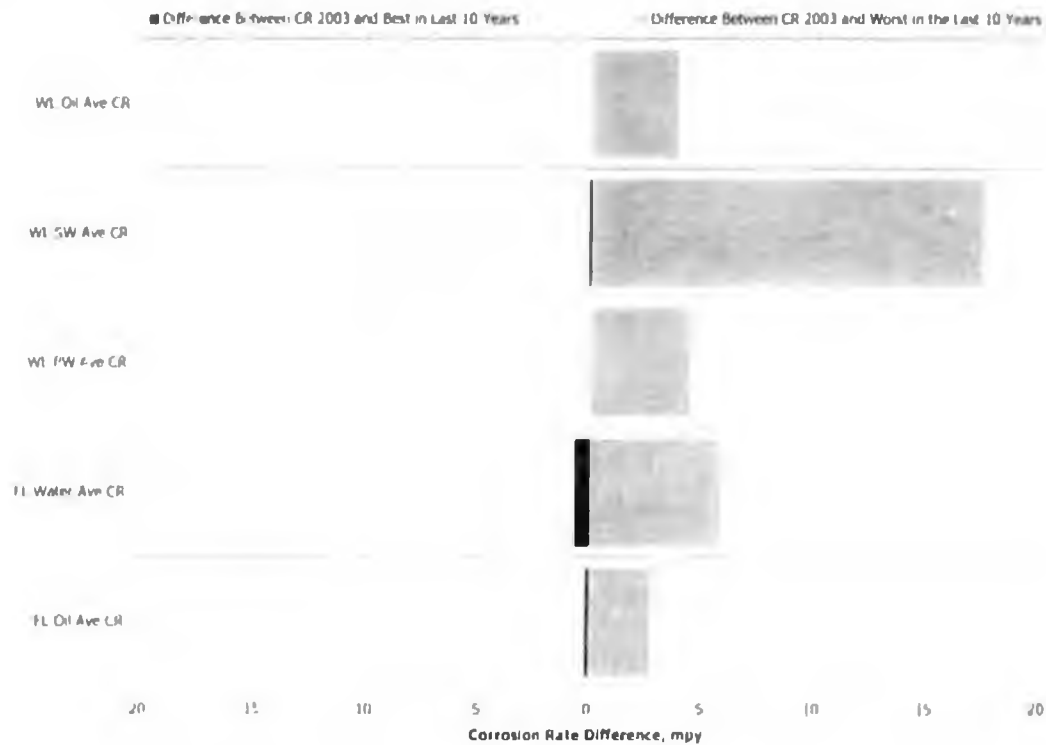


GPB Figure C.16 Well Line Average Corrosion Rate Summary by Equipment and Service



GPB Figure C.17 Well line %<2mpy Summary by Equipment and Service

In order to assess the relative performance of the corrosion management program today versus that of the last 11 years, GPB Table C.3 and GPB Figure C.18 were generated as a summary. The data show the difference between the 2003 WLC corrosion rate for each of the systems and the best, or lowest, WLC corrosion rate and the worst, or highest, WLC corrosion rate observed since 1992. This is an approximate measure of the successes and/or shortcomings of the program today versus the ~11-year history and highlights areas for attention. The results indicate the current level of corrosion control, as determined by weight loss coupons, is at or near the best levels of control in the last 11 years for each system.



GPB Figure C.18 WLC Corrosion Rate Difference by Service and Type

System	2003 CR mpy	Best mpy	(Best - 2003) mpy	Worst mpy	(Worst - 2003) Mpy
FL Oil Ave CR	0.43	0.32	-0.12	3.2	2.80
FL Water Ave CR	1.54	0.87	-0.67	9.34	7.80
WL PW Ave CR	0.11	0.11	0.00	4.61	4.50
WL SW Ave CR	0.78	0.68	-0.10	18	17.22
WL Oil Ave CR	0.47	0.47	0.00	4.3	3.83

GPB Table C.3 WLC Corrosion Rate Difference by Service and Type

In summary,

**Well Line Oil Service** – Significant improvements in performance occurred from 1992 to 1997 when the average corrosion rate (CR) was reduced from 3.6 to 1.0 mpy (~70% improvement) and conformance to the 2 mpy target was increased from 64% to 88% (~40% improvement). Since then, CR and target conformance performance has increased to the 2003 values of 0.5 mpy and 96% respectively. Continued improvements are expected due to corrosion inhibitor distribution optimization (individual target rates and expansion of continuous injection systems).

**Flow Line Oil Service** - Consistent with historical best performance, 99% of coupons pulled in 2003 were less than or equal to the corrosion control target of 2 mpy. Significant improvements in performance occurred from 1992 to 1997 when the average CR was reduced from 3.3 to 0.5 mpy (~85% improvement) and conformance to the 2 mpy target was increased from 77 to 97% (~25% improvement). Since then, CR and target conformance performance has improved to the 2003 values of 0.4 mpy and 99%, respectively.

**Flow Line Processed Oil** – These are the flow lines supplying processed hydrocarbon to Pump Station 1 and as might be expected for a very low water cut production stream, the corrosion rates are consistently very low with 100% of the coupons being reported as less than 2 mpy from 1995 to 2003.

**Well Line PW Service** – Average CR and percent conformance with the 2 mpy target achieved historical best performance at 0.1 mpy and 100%. The two excursions, 1998 and 2001, were likely the result of reduced system velocities and oil system corrosion inhibitor changes. Work continues in the evaluation of new the corrosion control techniques designed specifically for the PW system.

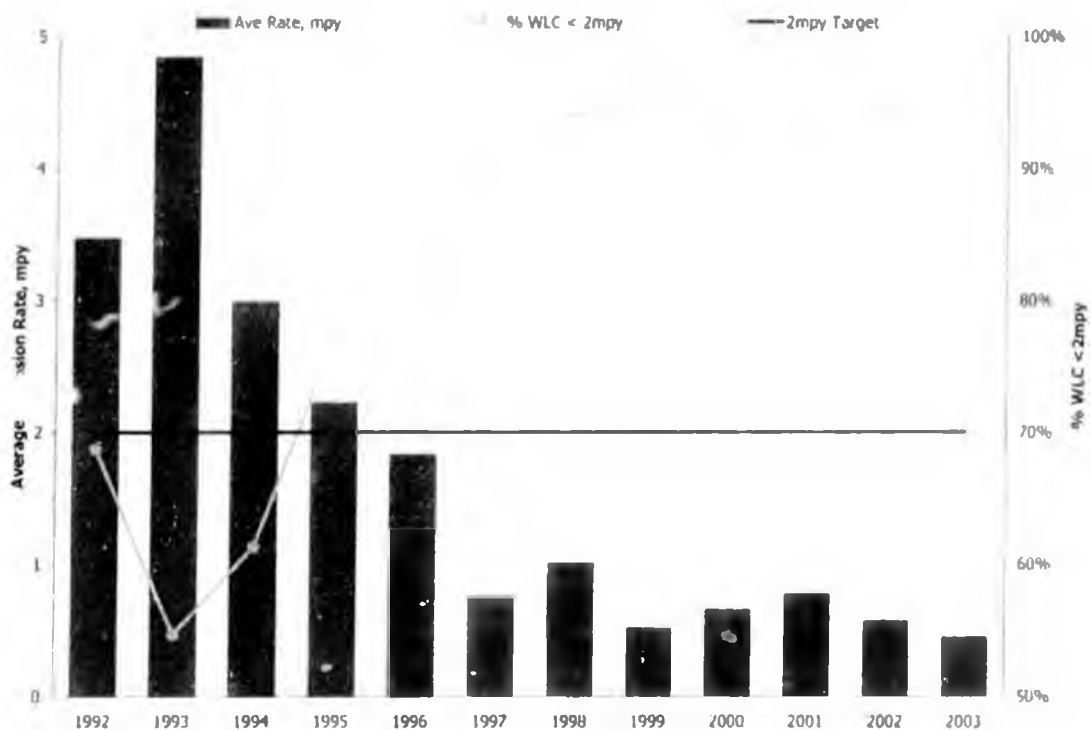
**Well Line SW Service** – Performance deteriorated from 1997 through 2002 with the average CR increased from 0.7 to 7.5 mpy. Average CR and percent conformance with the 2 mpy target rebounded in 2003 to 0.7 mpy and 94% respectively. This is a direct result of specific corrective actions that were implemented in 2001 and 2002. While these initial data are encouraging, it is probably too soon to be assured that the corrosion trend has been reversed. SW system corrosion control will continue to be a focus in 2004.

**Flow Line PW/SW Service** – Performance deteriorated from 1992 to 1994 when average CR increased from 3.5 to 7.4 mpy. However, significant improvements occurred from 1994 to 1997 when the average CR was reduced to 0.8 mpy. Since then, CR and target conformance degraded until 2003 when performance improved to 1.5 mpy and 76% respectively.

### Section C.4.2 Aggregate Summary

As an overall representation of the progress of improving corrosion control, GPB Figure C.19 shows the aggregate performance for all equipment and all services discussed in this report. The average corrosion rates have fallen by 80% from 2.3 mpy in 1995 to 0.5 mpy in 2003 and that the number of coupons meeting or beating the 2 mpy target has increased from 76% in 1995 to 97% in 2003.

It should be noted that the majority of the pipelines are in 3-phase service and hence these aggregate data are dominated by the performance of the 3-phase system.



GPB Figure C.19 GPB Aggregate Performance

For the GPB systems in aggregate, 2003 represents the best ever performance both in terms of average corrosion rates and percentage of WLC  $\leq$  2 mpy target.