A n enviable characteristic of the gas-turbine-based generation sector of the electric power industry is its ability to consistently improve performance over time. Upgrades to plants a decade or more old allow them to compete with new combined-cycle facilities and, given favorable fuel pricing, to take market share from coal-fired central stations.

Competition among turbine OEMs and after-market solutions providers drives the technology development that makes the upgrades available. But equipment is only part of the equation. “Can-do” plant personnel continually striving for operational excellence are critical to success.

It’s important to recognize that upgrades don’t just happen. It takes years to develop the modernization and upgrade products conducive to boosting efficiency, improving reliability, decreasing emissions, and/or increasing the durability of critical components to extend the time between planned maintenance outages.

The process typically proceeds something like this: Individual gas turbine (GT) owner/operators identify specific wants/needs for a particular machine and discuss them with colleagues at an appropriate forum, such as the 501F Users Group annual meeting. The consensus view is discussed in an open forum with the OEM—Siemens Energy Inc, Orlando, in this case.

The OEM surveys individual owner/operators to understand specific needs and then prioritizes the requested mods and upgrades. Engineering is done, component tests are conducted in-house, and when expectations are achieved, the enhanced component is certified for field validation.

The collaborative association between the OEM and the users group facilitates identification of plants willing to participate in such testing. Installation of the upgraded component is done at a time convenient for the host plant—such as a scheduled outage—and field validation begins. When the results satisfy Siemens’ stringent evaluation criteria, the upgrade is released for commercial sale.

Note that many of the improvements desired by users for machines in service already have been developed for later models because of the OEM’s commitment to continually improve engine performance. In such cases, the engineering effort focuses on adapting the enhanced component for use in the earlier-vintage machine.

Siemens updates owner/operators at every user-group meeting on the company’s progress with mods and upgrades, which are grouped as follows: (1) Performance and operational flexibility; (2) Emissions and fuel alternatives; and (3) Interval/life extension. In the first category, a W501F upgrade that has generated considerable interest among users is “Thermal performance improvement” with new turbine R4 hardware; in the second, “Low-load turndown”; in the third, “Inspection-interval extension upgrade” better known among W501F owner/operators as “SB55004” for the service bulletin that defines the enhancements.

Improving performance. At the 501F Users Group meeting earlier this year, Greg Perona, GT mods and upgrades marketing team manager, discussed the features and status of many GT enhancements during a 100-min special breakout session. He said the scope of the performance-improvement upgrade for Frames W501FC through W501FD2 (package details vary for the individual models) usually incorporated the following:

- Improved compressor sealing.
- Improved compressor R16 blades (only on FD units).
- New turbine R1 blades.
- Improved turbine sealing.
- Turbine R4 upgrade (only on FD2 units).
- GT mass flow and temperature optimization.

Potential benefits based on a 2 × 1 W501FD2-powered combined cycle operating at base load and ISO conditions include these:

- Base-load power increase of up to 6%.
- Base-load heat-rate improvement of up to 2%.
- Better part-load heat rate.

The low-load turndown (LLCO) program, Perona said, is designed to permit operation at from 50% to 100%
of rated capacity without exceeding 10 ppm CO when ambient temperature is between 59F and 95F. Benefits include the fuel saved by operating at lower load during the evening hours. Also, by running through the night, he continued, units cycle less hours. Also, by running through the night, he continued, units cycle less hours. 

Perona flashed slides up on the screen to illustrate engine modifications required to implement the LLCO solution and to share test results that confirmed expectations. Evidence in hand suggested that benefits of the mod also may include the following:

- Potential reduction in total emissions during engine startup.
- Increase in combined-cycle efficiency at part load.
- Improvement in SCR efficiency at low load.

Benefits of implementing the Siemens upgrade package to extend inspection intervals are compelling, based on information presented by Perona, and can include the following:

- A 56% increase in the interval between hours-based combustor inspections (CI) to 12,500 EBH (equivalent base-load hours).
- A 125% increase in the time to a combined CI/HGP (hot gas path) inspection at 900 ES (equivalent starts).
- Reduced trip and fast-start factors. To illustrate: the trip factor for a trip at 75% to 100% of the GT’s rated output is reduced to eight from 20.

The typical scope for an interval-extension work package includes installation of advanced (1) combustor baskets and C-stage (plus support housing mods); (2) transition pieces and seals; and (3) turbine R1 vanes, ring segments, and isolation rings. A combustion dynamics protection system (CDPS) also is necessary and updated turbine components may be required depending on the site.

The term “advanced components” is associated with improved materials/alloys, coatings, cooling, component interfaces, and manufacturing processes.

Regulatory considerations. Keep in mind that before finalizing any upgrade implementation plan, thoroughly investigate what, if any, regulatory hurdles you may face. Questions you’ll want to know the answers to include the following:

- Will a major permitting effort (read New Source Review) be required?
- How will the desired upgrade package influence air emissions?
- Will the upgrade reopen the plant’s air permit and require a public notice and/or public hearing?
- Will regulators have to review and approve the upgrade plan?
- Will a re-evaluation of Best Available Control Technology be required?

Siemens engineers told the editors that the above-mentioned upgrades should not require major permitting efforts for customers.

KLAMATH COGENERATION PROJECT

1. Klamath Cogeneration Plant, which began life as a 506-MW combined-cycle (top), will be rated 536 MW next spring after upgrades are complete. The 100-MW Klamath Peaking Plant is at lower right.

Klamath Cogen

Ray Martens manages both a nominal 506-MW, W501FD2-powered 2 x 1 combined cycle known as the Klamath Cogeneration Project and a 100-MW simple-cycle peaking facility (two Pratt & Whitney FT8 Twin-Pacs) named Klamath Generation Peakers in Klamath Falls, Ore (Fig 1). He has tracked the development of possible upgrades for his combined cycle as a regular participant in 501F Users Group meetings. Martens is a member of the organization’s steering committee and has more than two decades of experience managing, operating, and maintaining GT-based powerplants.

Klamath Cogen is a world-class plant now part of an integrated portfolio of assets owned by Iberdrola Renewables Inc, Portland, Ore, which includes more than 3000 MW of wind capacity. Recall from the last issue that an important attribute of gas turbines is their ability to provide a quick, low-emissions response to discontinuities in renewables generation (2Q/2009, p 50).

The Oregon plant has been an industry leader since commissioning (details in sidebar) and Iberdrola Renewables took “giant” steps last spring to assure that enviable status is maintained. It agreed to a long-term service program with Siemens that included GT parts and service, generator rewinds and modernization upgrades, a compressor-inlet heating system, a CDPS, and a new control system (SPPA-T3000).

The drivers for this extensive upgrade effort only eight years after commissioning included the following: increase base-load capability of the integrated combined cycle by 30 MW to 536 MW (winter rating), reduce heat rate across the operating regime, protect the compressor against icing, and provide better maintenance-cost predictability. The Unit 2 GT was upgraded in the spring and back in service to meet the 2009 summer peak; GT 1 will be upgraded next spring.

What follows is a summary of Klamath Cogen’s experiences during last spring’s outage, which was the plant’s first major and an ideal time for implementing upgrades. GT 2 had accumulated more than 43,000 hours of operation and 1531 equivalent...
Exhaust manifold behind it is next in line for removal.

Critical to performance improvement was replacement of the existing R4 blades and vanes with those designed for the more advanced W501FD3. This was not a simple swap-out. The FD3 R4 blades and vanes are longer than those for the FD2, so a new exhaust cylinder was required. With the turbine open, Klamath replaced all blades and vanes in R1, R2, and R3.

Here again, the performance gain from the new R4 was a “known” because of data streaming from six FD3s in service at the beginning of 2009—the fleet leader at 17,000 hours and counting. Plus, there was 4000 hours of service history from an FD2 that had completed the thermal performance upgrade with new R4 airfoils in Spring 2008.

Decision time. The FD2 came with a two-piece, horizontally split exhaust cylinder. The FD3 is offered with a single-piece cylinder and the split cylinder as an option. Klamath Cogen opted for the single-piece exhaust because Martens and Willard believed it offered a long-term maintenance advantage. Industry experience indicates that the mating halves of split casings tend to spring outward when the upper half is removed, at least occasionally making reassembly challenging.

Another consideration when transitioning to the improved R4 blades and vanes: A spacer piece is required between the exhaust manifold and the round-to-square transition leading to the heat-recovery steam generator because the FD3 exhaust manifold is shorter than the one for the FD2. The line-up of components between the GT and HRSG is shown in Fig 2.

The combination major inspection/upgrade was a huge project, one requiring many specialized contract workers. Martens said the workforce peaked at about 185, 125 of those assigned by Siemens to handle its share. There were two shifts, with the day shift requiring about 120 personnel at peak. Referring back to Fig 1, you have to ask yourself: How could a plant of this physical size accommodate so many workers? It wasn’t easy. Personnel safety, as always, was a concern. Siemens, for example, staffed each shift with a dedicated human performance/safety technician.

Figs 3-6 illustrate some of the extraordinary work involved: Removal of the existing two-piece FD2 exhaust cylinder and exhaust manifold and their replacement with the improved FD3 single-piece cylinder, new manifold, and the spacer noted earlier. In Fig 3, the lower half of the old exhaust cylinder is removed, exposing the back end of the turbine section in the foreground and the old manifold extending to the building wall.

Fig 4 helps readers appreciate the amount of work proceeding simultaneously. Note that the original exhaust manifold is being lowered onto a flatbed for shipment and recycling. Reassembly begins in Fig 5. The spacer piece bolts to the round-to-square transition. Seems like a “ho-hum” job until you learn that the inboard flange of the transition is outside the building’s structural members. This required Siemens to develop a special cantilevered fixture to position the spacer properly.

Next, the single-piece exhaust cylinder is lowered into position behind the turbine (Fig 6). The annulus between the bearing shield and the outer diameter offers a larger flow path than the FD2 cylinder and is important to achieving performance goals.

Other design enhancements include changes in (1) strut material from stainless steel to Inconel, and (2) diffuser and strut shield material from Hastelloy to stainless. Plus, a thermally unconstrained diffuser support system.

The exhaust manifold drops in between the spacer and exhaust cylinder. A design characteristic of the FD2 manifold is its two large radial struts positioned 180 deg apart. The FD3 manifold has three considerably smaller struts 120 deg apart and tangential to the bearing tunnel to better accommodate expansion and contraction during startup and shutdown.

One challenge associated with installation of the exhaust manifold was that its support structure had to be attached to the building foundation. This may not be as simple as it sounds. Reason is rebar; it can’t be cut for structural reasons. Lesson learned #1: Finding rebar to know where you can drill bolt holes for the exhaust manifold’s support feet can be difficult (Fig 7). The first thing you learn is that a $2000 rebar finder purchased off the Internet can’t necessarily handle the job.

For a new FD3 with a single-piece exhaust (SPEX), the engine rotor, aft bearing housing, and exhaust cylin-
der typically are removed as a unit. When retrofitting an FD2 to an FD3 with SPEX, installing the turbine shaft in the bearing while fitting the bearing assembly into the exhaust cylinder is a challenging task requiring special fixtures and jacking tools. Achieving a proper oil seal also is challenging and requires specially developed tooling as well.

Rotor alignment and positioning with SPEX requires that the shaft be supported during the work, because no exhaust bearing is in place. This is accomplished by installing a special support—one that clamps around the shaft in the torque tube area.

Obviously, once the FD3 single-piece exhaust cylinder is installed, the preference would be to pull the rotor, bearing housing, and cylinder as a unit—as is done for a new FD3 unit with SPEX. Lesson learned #2: The bridge crane might not be as robust as it may look. This is why a procedure was developed by Siemens to lift them separately.

**Crane capacity adequate?**

What the Klamath staff learned was that the plant had a 60-ton crane to handle a 59.5-ton lift—that’s just the fully bladed rotor. Adding the bearing housing and exhaust cylinder to the lift would require an 88-ton crane. Even lifting the rotor together with the special support installed in the torque tube area would create an overload condition. Martens and Willard are considering their options, but none are “cheap” or easy to retrofit.

Another lesson learned and one still to be solved concerns lube-oil (LO) mist-eliminator capacity. The lesson, like that of the crane, is this: EPC contractors provide exactly what’s required by the system specifications—no more, no less. If you want a more flexible design approach that has to be agreed to upfront.

**Performance of the mist eliminator** originally supplied with the plant was considered marginal by Martens. Its job was to maintain a slight negative pressure (7 in. H₂O) on the lube oil system and capture any vapor before it was vented to atmosphere. Although the SPEX vacuum requirements are similar to the original FD2 settings, the vacuum suggested for the new single-piece exhaust cylinder/bearing/seal assembly installed at Klamath Cogen was 12 in. H₂O to address site-specific bearing oil leakage which Siemens believed oil-flow related.

Operating the original mist eliminator under these conditions saturated the filters so quickly, weekly...
replacement was required. By dropping back down to 7 in., the filters might last for up to a year, but leakage from the bearing seal’s telltale drain was at a rate of up to 3 gal/hr (Fig 8). Plant personnel are busy enough without having to handle buckets of LO hourly, or to change filters weekly.

Martens told the editors he was concerned about coking of the R4 blades, but was assured by Siemens that at the telltale leakage rate experienced, this was not probable. The area (disc cavity 5) was inspected during the early fall outage completed as the COMBINED CYCLE Journal went to press and no coking was present.

During the mid-August walk-around conducted as part of the interview, Martens showed the editors a new, higher-capacity mist eliminator, provided by Siemens, awaiting installation in the fall. During the fall outage, Siemens increased the size of vent piping from 2 to 4 in. and a large portion of the engine’s air inlet ductwork, as shown in Fig 13; the piping hook-up to the manifold was easy by comparison (Fig 14).

**Fire suppression.** Most power-plant managers are safety-conscious. Martens lives and breathes safety. One of the things that caught his attention during contract negotiations was that there was no fire detection/suppression system in the aft-end bearing tunnel like there was on the FD2 back end.

Siemens responded to his concerns by pointing to its excellent safety record on the V machines which do not offer such protection. However, to provide Martens the level of comfort he needed, the OEM installed a detection and CO2 suppression system consistent with NFPA (National Fire Protection Assn) rules.

The Klamath plant manager suggested that anyone thinking about an FD3 upgrade to his or her FD2 consider doing the same. He also suggested that a dump test be conducted as part of the installation adding that “there are a lot of places for CO2 fire retardant to keep the seals out back there.”

Martens was on a safety roll. Next, he stressed the importance of conducting an enclosure leak-tightness test because of the new penetrations added in support of the FD3 upgrade. His GT enclosure didn’t pass its first leak-tightness test. Seals around piping and the exhaust end leaked. Foam seal actually moved during the test, he said. Solution: Klamath personnel added a bunch of Z clips to keep the seals from blowing out. FM200 is used for enclosure fire suppression.

**Low-load CO control**

At Klamath Cogen, Siemens implemented the LLCO upgrade as part of its validation program. The plant reported that LLCO worked well and maintained emissions within permit requirements down to 60% of normalized load as required. The system is not operating at the present time but can be reactivated quickly if needed.

Martens favors the inlet-bleed-heat alternative for achieving emission compliance at certain ambient and low-load conditions. He told the editors IBH is more efficient (up to 1%, GT only) than LLCO (although without the same turndown capability) and that it also protects the front end of the compressor against icing. The latter is especially important given that Klamath Cogen has replaced several R1 compressor blades because of ice damage.

During the outage, Willard said, the compressor water-wash casing drains were replaced with pipe of larger diameter to reduce the possibility of plugging and freeze-up. In addition, the drains, which previously were ganged together, are now separate. Plus, the individual drain pipes are segmented not continuous, the downstream sections having “catch cones” to allow positive visual indication of water coming from the casing.

Lesson relearned #3: Ganged drains are a bad idea anywhere, especially when the connection points are at different pressures. The only beneficiary is the EPC contractor, which reduces the time and material required to install the drain system. Installation of the IBH looks like a relatively simple project from the sketch presented as Fig 9: Tap the compressor casing and install a hot-air distribution manifold in the inlet air duct, and then connect them with some pipe. Sounds easy, admitted Martens, but there were some “very real” construction challenges with this portion of the overall project. Chief among them: minimum space, safety concerns, and work preparation.

Having to install the manifold from inside the building made rigging and maneuvering especially difficult. Fig 10 gives you an appreciation for the effort required. Access to the manifold location required removal of package cooling ductwork and a large portion of the engine’s air inlet ductwork, as shown in Fig 11. Fig 12 shows how the large manifold was handled indoors. The IBH air tap off the compressor also was space-challenged (Fig 13); the piping hook-up to the manifold was easy by comparison (Fig 14).

Safety aspects of the IBH project were especially demanding. Fall restraints for manifold installers and protection of personnel working on the GT below from falling objects were two major concerns. To illustrate: Referring back to Fig 11, plywood was installed along the front the work platform where the workers are standing (like it is on the sides) after the manifold lift to prevent tools, etc, from dropping below.

**Work preparation** included scaffolding, which was Klamath’s responsibility. Lesson learned #4: Scaffolding is expensive to rent, install, and disassemble, and it’s easy to significantly underestimate
KLAMATH COGENERATION PROJECT

Assign a capable engineer to develop your outage scaffolding plan. Carefully analyze the work required to maximize the potential for a given scaffolding arrangement to accommodate multiple tasks.

The IBH was tested, tuned, and placed in service with a minimum of hiccups. Operational control is integrated into the new T3000, which when enabled by the operator, allows automatic on/off to maintain CO emissions as required. Klamath Cogen has a startup/shutdown exemption for CO, but startup/shutdown emissions are included in the PSEL (plant site emissions limit) totals. The plant must operate at less than 15 ppm CO above 60% normalized load and include startup/shutdown emissions in the PSEL totals.

Generators, controls, etc

One of the first things that comes to mind when considering an upgrade to boost output: Do you have enough generator to produce the extra power that the GT will deliver? This was not a problem at Klamath because of the plant’s altitude. The generators were operating at below their available capability.

Martens continued with the electrical theme. Analysis indicated the transformers would require more cooling on a peak summer day after the upgrades. Following a thorough internal inspection, which required draining of the transformers, additional radiator/cooling-fan capacity was installed. What Willard did was to remove the radiators and fans from the plant’s spare transformer to increase the cooling capability of the operating transformers. No capacity issues were identified with cabling, bus duct, and the switchyard.

Along with the GT major, a generator overhaul was included as part of Siemens’ scope. The Klamath generators are of the Aeropac 1 design. The Unit 2 stator had suffered spark erosion and was rewound (Fig 15). The Unit 1 stator will be rewound next spring. Martens said that doing a proper stator rewind and associated work is a 30-day effort.

You could tell both by his body language and words that the plant manager was particularly pleased with the work processes, craftsmanship, and cleanliness associated with the generator overhaul. He rated both the foreign-materials exclusion program and the overall job “exceptional.”

Controls upgrade. The W501FD2s installed at Klamath Cogen came with WDPF (Westinghouse Digital Processing Family) controls; the ABB steam turbine, which shipped shortly after that company was bought by Alstom, incorporated ABB’s Advant controls. The WDPF controls wouldn’t support the upgrade packages purchased so Klamath opted for the T3000 as a replacement.

For example, the flexibility controller option offered with the performance upgrade allows the plant to operate in either a power optimization or efficiency optimization mode, depending on ambient conditions, fuel prices, dispatch schedule, etc. Considering all the upgrades implemented, it generally is difficult to implement features such as these without a robust up-to-date control system.

Martens believed that it was prudent to standardize on one control system; as a result, the Advant controls were replaced as
A leader from Day One

The Klamath Cogeneration Project was developed jointly by the City of Klamath Falls, Ore, and PacificCorp Power Marketing, an affiliate of Portland-based PacificCorp. Its energy-efficient design and favorable emissions profile gained instant industry recognition—including the 2001 Powerplant Award from McGraw-Hill’s Power the year Klamath began commercial operation. This journal’s editor was the editorial director of Power at that time.

The 2 × 1 W501FD2-powered combined cycle was the model for an Oregon law that created the first CO2 standard in the US. In 1996, the state’s Energy Facility Siting Council ran a “best of batch” contest focused primarily on reducing greenhouse gases. The Klamath Cogen design won that competition and specific limits in pounds of CO2 per kilowatt-hour later were established for energy facilities in the state. The standards could be met through ultra-efficient cycle design, cogeneration offsets, and/or funding of other CO2 offset projects.

Klamath incorporated all of them: Its guaranteed heat rate was an impressive 6795 Btu/kWh, it supplied process steam to an existing wood-products facility about a quarter mile from the plant, and it funded multiple carbon-offset projects—such as reforestation, methane recovery from coal mines, photovoltaics, expansion of the city’s geothermal district-heating system, etc.

Emissions were ultra-low for the time: 4.5 ppm NOx and 15 ppm CO which could be maintained down to 60% of the combined-cycle’s nominal 500-MW rating. The original DLN (dry low-NOx) combustors maintained 25 ppm NOx at the engine outlet and SCR (selective catalytic reduction) system reduced that to the permit limit. Sound attenuation limited noise at the plant fence to 45 dBA.

Plant design was at the leading edge of engineering practice during the GT bubble of the late 1990s. Examples: (1) PS1 piping was specified for the main and reheat steam systems to minimize erosion/corrosion; (2) stack dampers and a sparging-steam system were installed to retain heat during shutdowns and minimize thermal cycling of the HRSGs; (3) treated municipal wastewater was used to meet 100% of the plant’s cooling needs and dramatically reduce the city’s discharges.

Klamath’s staff is a proud group of 22 men and women that does much of its own engineering, in addition to all the regular O&M work. There is no central-office technical support function. The winning of seven of the COMBINED CYCLE Journal’s Best Practices Awards—including three Best of the Best citations—testify to the capabilities of this talented group. Details of awards received in the last three years:

- 2007 Best of the Best (management category) award for the plant’s management-of-change program, which provides guidelines to ensure that environmental, health, and safety sensitivities, budget compliance, and operational effectiveness are considered before upgrades and/or other changes to plant systems and procedures are finalized and implemented.

- 2007 Best of the Best (O&M category) for redesign of HRSG and auxiliary-boiler direct-contact flash tanks and their associated piping systems which significantly reduced the volume of the blowdown stream to the city’s water treatment facility.

- 2008 Best of the Best (O&M category) for a foolproof system to identify and control icing at the inlets to the plant’s W501FD2s. Considerable engineering and testing were required to deliver a viable solution which included modification of control logic to warn of an icing condition and installation of cameras that the compressor inlet for visual confirmation.

- 2008 Best Practices (environmental category) for decreasing the facility’s carbon footprint by installing controls, equipment, and systems to reduce energy consumption.

- 2009 Best Practices (safety category) for ductwork modifications and the installation of removable handrails on top of W501F enclosures to eliminate fall hazards and to increase the speed of duct removal for engine maintenance.

Ownership changes at Klamath reflect the nature of the deregulated generation sector. Iberdrola Renewables, previously known as PPM Energy Inc, and originally as PacificCorp Power Marketing, purchased the plant from the City of Klamath Falls in 2007.

Going back in time to year 2000, Scottish Power Ltd, formed in 1990 during the UK’s deregulation initiative, purchased PacificCorp and five years later sold it to MidAmerican Energy Holdings Co (read Warren Buffett’s Berkshire Hathaway). The deal did not include PPM Energy. Spain’s Iberdrola SA bought ScottishPower in 2007, an acquisition that included PPM Energy. Shortly thereafter, PPM Energy became Iberdrola Renewables Inc—the plant’s owner of record today. The Iberdrola Renewables affiliate responsible for operating the Klamath facility is doing business as Pacific Klamath Energy Inc.

In fact, Klamath technicians spent an extraordinary amount of time fixing control logic. Much of the “factory wiring” had to be done in the field. Martens’ advice to others considering a similar project: Plan on becoming intimately involved with the controls conversion process from cradle to grave—even to the point of actually managing the project.

Since project completion and the plant’s return to service, Siemens has worked with Klamath Cogen and addressed its concerns. The PAC was signed off recently by the power producer.
Siemens engineers told the editors that the “double click” is a safety feature of the SPPA-T3000. They said there are industry white papers that show the “double click” requirement offers additional safety. Also, that the company takes its customer’s preferences into consideration. The “single click” feature has been added to the SPPA-T3000 product development plan. Hope is that “single click” soon will be available as an option.

Insulation. By the time you get to the first major, the original GT insulation system may be pretty well beat up. Keeping the package temperature under control is important. Klamath replaced its insulation system with one from Crossby Dewar Inc, a Canadian-owned firm which exhibited at the 501F User Group’s vendor fair (Fig 16). Only problem experienced, said Martens, was burn-up of igniter cable because of poor fit-up—since corrected.

Main, reheat piping. Plant personnel inspected several CCI-Control Components Inc severe-duty valves this year. HP and reheat bypass valves, and drum-level control valves, continue to perform well. Gas Turbine Materials Associates has surveyed P91 pipe using both hardness testing and replication to identify soft sections (Fig 17). The project is now in its fourth year. Most of the material inspected this year was fine, with issues identified at only a couple of elbows. CCJ