Creating Eden in a Despoiled Land

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Abstract

Situated in a worked out china clay quarry in Cornwall, England, the Eden Project – an educational garden and unique post-mining rehabilitation scheme – has transformed the environmental, social and economic landscape of the county.

The project is successfully growing all the world's major crops in artificial soils, in artificial climates in a worked-out quarry. Before planting could begin however, several major engineering and technological challenges had to be met. China clay workings are notoriously unstable and must be continuously pumped to prevent flooding in a predominantly wet climate. There was also no topsoil available to act as a plant growth substrate. Consequently, two years of work was required to stabilise slopes; install a state of the art drainage and pumping system; develop the basic landscape; construct the world's largest conservatories and create 80,000 tonnes of artificial soils from recycled materials – all before planting could begin.

Eden opened in March 2001. Its Mission is one of education about sustainable development, using displays of common plants that people use everyday around the world as the primary drivers for this message. In its first two years of opening, Eden has attracted two million visitors each year (having previously expected a maximum of 750,000 per year) and generated around £150 million for an otherwise economically depressed region in its first year of operation alone.

This paper reviews the nature of the challenges and how they were overcome.

Introduction

Cornwall is a predominantly rural county at the tip of south-west England. Its climate is dominated by the Atlantic Ocean with warm wet summers and mild wet winters. The permanent population stands at almost 500,000, which increases enormously in summer as millions of visitors flock to its stunning coastline. Tourism is the biggest income generator in the county, but it has tended to stay on the coast or in the more scenic inland areas. Little invites tourists to the interior of the county, where large areas are blighted by post-mining dereliction, thus compounding the economic problems of those who live there. For decades the local economy has been contracting, exacerbated by the low population density and geographical isolation. However, in recent years, the economy has become one of the fastest growing in the UK.

One of the centres of the Industrial Revolution of 18th and 19th Century Great Britain, Cornwall, has an impressive history of innovation and invention. Technology and expertise borne here were exported around the globe, contributing immeasurably to today's modern world. The main heavy industries of the past two centuries have been those involving the extraction and processing valuable minerals. 150 years ago, the county produced half the world's copper and tin (Dines, 1956). Today, not a single working metal mine remains, the last – South Crofty mine – closed in 1998, the tin ore extracted from solid granite 900 m underground was no longer economically viable. The legacy of this industry is found around the county where many derelict metal-mine sites add scenic value to the rural landscapes with the ghostly ruins of granite engine houses dotting the agricultural landscape.

However, Cornwall is also home to another great mineral industry – china clay extraction - which remains vitally important to the region's economy. China clay, or kaolin, is produced by the intense alteration of feldspars in the otherwise unyielding granite bedrock – part of an immense granitic batholith 190 km long and approximately 30 km wide underlying south-west England. Together, the extinct metal mining industry and extant china clay extraction has left an enduring legacy of one of the most intensively mined landscapes on the planet. To state a mantra oft-quoted by the mining industry, "Everything we use is either grown or mined". Both aspects are brought together inside a 150-year old quarry outside St. Austell, Cornwall, England. This paper provides an overview of the development of the Eden Project and the impact that this has had on Cornwall, England.

China clay production

The St. Austell area is renowned for the production of large quantities of high quality china clay or kaolin. It is used in a range of products such as fillers for paper, paints, pharmaceuticals and cosmetics, and in ceramics and porcelain. It is the UK's biggest mineral export after hydrocarbons and in 1998 was worth £250 million to the Exchequer (£130 million locally) and currently employs around 2,000 people locally.

Kaolin is hydraulically-mined using high pressure water jets to wash out the clay from the decomposing granite quarry walls. The clay is separated from the resulting slurry by a variety of gravimetric processing techniques. Annual production of kaolin in 2000 from the St. Austell area was 2.4 million tonnes (of which 88% was exported) producing approximately 20 million tonnes of waste sand, mica and overburden.

In 2000 there were 15 active quarries working in the area plus several inactive pits used as waste tips. Associated with this activity are around 25 million tonnes of waste sand produced every year. There is no market that is able to utilise more than a fraction of the vast quantities produced, so it is piled in waste heaps, tens of metres high, covering nearly 1,300 hectares. The china clay industry has re-engineered the topography of over 3,000 ha of this part of the county.

Post-mining landscape regeneration is occurring through large-scale ecological restoration. Heathland and woodland restoration in the Claylands through a partnership led by English Nature – the UK government's agency for nature conservation – will act as the basis for a sustainable landscape-based economy and providing an acceptable exit strategy for the local china clay industry.

Slope-stabilisation and landforming

The Eden Project is located in an old china clay quarry. Immediately prior to the takeover of the quarry, the economic cessation of extraction was a matter of months away. Over a period of 150 years of activity, approximately 7 million m^3 of material had been removed from the quarry leaving an irregularly-shaped, 22 ha hole of 30 – 70 m depth. A wide variety of slope forms resulted differing in composition, structure and gradient.

The site was physically unstable, poorly-drained and sterile and required an enormous amount of effort to convert into one of the world's great plant showcases. Some of the very first work that was required was stabilisation of the quarry sides. Various stabilisation techniques were used according to the competence of the granite bedrock.

The geotechnical complexity of the slopes meant a variety of stabilising techniques were employed. Hard-engineering slope stabilisation methods included: grading, buttressing, rock-bolting (1500 rock bolts varying in length from 1.5 m to 12 m were installed and some 9000 m^2 of sprayed concrete used) and geotextiles (used to re-direct groundwater issuing from pre-existing slopes away from the recent, overlying fill material into the pit's drainage system).

Enhancement of slope stability was also achieved by the use of vegetation or a combination of vegetation and geo-fabric. The softer granites were also revegetated in order to reduce erosion of the kaolin by rainwater and run-off. Deeper-rooted trees and shrubs have also been planted around the site for stabilisation of shallow-seated instabilities (within two metres or so of the surface). These techniques have been included in visitor-orientated exhibits to explain the engineering uses of plants with real *in-situ* examples. Seed mixes were sprayed onto slopes in a suspension of binding agents and fertilisers - a technique known as hydroseeding. The seed mixes contained seeds of European gorse (*Ulex europaeus*) and common broom (*Cytisus scoparius*) which are natural colonisers of the Claylands. These shrubs provide soil stabilisation at deeper levels and also fix atmospheric nitrogen, converting it to forms useful for other plants and enriching the soil.

Before any construction could begin, production of the necessary land-forms was required. For environmental reasons, it was decided that materials should not be introduced to, or exported from, the pit. This meant the wholesale deconstruction and redevelopment of the existing landscape involving the relocation of

1.5 million tonnes of fill material (primarily waste aggregates) to raise the floor of the pit by 20 m and to develop the present terraced landscaped. Rag drains were also installed into the compacted pit floor to facilitate dewatering of the fill material thus reducing the risk of subsidence at a later date.

Cornwall possesses one of the wettest climates in the UK. This coupled with the crater-shaped pit extending below the water table necessitated a requirement for a high performance drainage system. Surface drains known as "swales" were constructed around the perimeter and within the pit. These ditches are of a permeable construction and designed with bunds and act to reduce the speed of water flow and increase infiltration. These soakaways also provide an opportunity for the development of wetland habitats.

During construction of the new landscapes within the pit (see below), geotextile membranes were installed under various depths of fill to form a drainage blanket which acts as a horizontal conduit to direct sub-surface water into six collection shafts, thus mitigating against a build-up of sub-surface water leading to slope instability. These shafts are connected by pipes to a 22 m deep sump at the base of the pit. From here two sets of two pumps remove on average 6L of water per second, with a maximum discharge consent of 40.2L per second, into a neighbouring stream. Some of this "grey water" is treated and used for flushing toilets and irrigating the outdoor landscape. Rain falling on the biomes is collected, treated and used within the biomes for irrigation and humidification.

Biome construction

Construction of the two massive greenhouses, or biomes, began in December 1999. The largest of the two, the Humid Tropics Biome (HTB), is the largest conservatory in the world. However, owing to its revolutionary design, it weighs approximately 500 tonnes which is roughly equivalent to the mass of air contained within. It is 200 m long, 100 m wide and 50 m high and is constructed from tessellated polygons in a geodesic dome design. Consequently, it is self-supporting with no requirement for internal supports. The smaller, Warm Temperate Biome (WTB), is similarly constructed and approximately half the size of its larger neighbour.

These large, lightweight structures appear at first sight, to possess over-engineered foundations. These consist of a perimeter rim of 2 m thick, 1.5 m deep reinforced concrete containing over 100 rock bolts descending to a maximum depth of 20 metres. Such heavyweight structures are designed to act as anchors, especially in high wind, to prevent the domes from being propelled into the air like a tent in a gale!

To construct the giant Meccano framework of these domes, Eden entered the Guinness Book of World Records twice for the scaffolding structures employed: for the tallest and largest free-standing scaffold ever. The bird-cage scaffold employed over 100,000 poles!

The biomes' structures are made possible only by advanced computer-aided design and fabrication as each node in the honeycomb framework has a unique arrangement of facets relating to the angles of the intersecting polygons.

The 'glazing' is a very strong, light weight, self-cleaning plastic called ethyl-tetra-fluoro-ethylene (ETFE) which is similar, chemically, to the PTFE coating of your non-stick frying pan. If conventional glazing materials had been used, the present buildings would have been impossible owing to the immense weight of the glass and the requirement for huge internal supports. The extra support needed would have reduced light levels, thus compromising subsequent plant growth. The windows consist of triple-glazed pillows, with the individual sheets being held apart by compressed air. The HTB has over 500 of these windows alone, the largest of which is 11 metres across and voluminous enough to house a London taxi!

Soils

Approximately 80,000 tonnes of soil were required for the planting schemes. Such an enormous quantity of topsoil would have been prohibitively expensive to source and transport from around the country and other problems such as consistency of quality and weed and disease problems negated this choice. It was decided early on to manufacture our own soils, thus allowing soil mix recipes to be customised to satisfy specific planting requirements in the knowledge that the constituents are of known origin and quality.

Soil recipes were developed and trialed in partnership with the University of Reading. The ingredients were all recycled waste materials including waste sand from the local china clay industry, composted bark (for the biomes) and composted green waste (for the outdoor areas) as the organic components and a small amount of lignitic clay – a by-product of Devon's ball clay industry. The process of producing artificial soils as done at Eden is not rocket science; if the mixing process can be likened to making a cake, then the mixing spoon is a large digger!

The basic rationale was to achieve the appropriate physical properties of porosity and resistance to decomposition, the latter being particularly important in a greenhouse environment. Chemical properties such as fertility and pH can be more easily manipulated according to specific plant requirements, even on a small scale, so the mixes were chosen to be slightly acid and of low fertility; it is easier to augment these parameters than to reduce them.

Beyond botany

The plants themselves were, and are, chosen according to the story that needs to be told. Many of the economically important plants were donated by international research centres and academic institutions. Others have been brought from conventional nurseries in the UK, Holland, Italy and the USA. Seeds have been donated by various organisations and we have also had generous donations by members of the public whose plants have outgrown the confines of their homes.

Eden illustrates mankind's role in the natural world, taking a positive perspective, emphasising the importance of his involvement by showcasing projects making a difference and describing how individuals can become involved. Throughout history people have utilised the plant kingdom for food, shelter, utensils, weapons, clothing, poisons, medicines, fuel, transport and many other things. We all rely on plants every day of our lives and Eden tells some of these stories, and also that if we want our descendents to benefit as much as us, then we all must act responsibly in our use of our planet's environmental resources.

Behind the scenes

Eden is run as a successful business but is owned by a charitable trust. All Eden's surpluses are ploughed back into Eden to develop and deliver its Mission. Developing alongside the visitor attraction is an organisation known as the Eden Foundation. The garden acts as the public interface between the work of the Foundation and the wider public. The Foundation is currently developing strengths in: education, communication and interpretation, including a commitment to the public understanding of science; post-mining rehabilitation; waste management; sustainable design; horticulture, etc.

We already have a very strong educational arm, working with local schools, colleges and universities and this relationship will only get stronger. In our preview opening during the summer of 2000, nearly 20,000 school children passed through our doors on organised visits.

By working with its partner organisations, Eden is striving to make a difference by showcasing the positive work being done in conservation, education, science, agriculture - horticulture and land-use in an attempt to broach some of the very real and very difficult challenges that must be overcome during this new century, in a culture of 'Real Worldism'. By engaging people with positive messaging and showing them how they can become involved, we hope to achieve more than would be possible by overloading visitors with the more conventional 'doom – gloom' approach.

Future

At the beginning of 2000, approximately fifty people were employed at Eden; a year later 130, and by summer 2001, 400. It is hoped that in the ensuing years, Eden, the St. Austell area and the county of Cornwall will become a focus for environmental technology industries and agricultural and horticultural excellence. By then who knows how many jobs will have been created.

Plans are in currently in development for the construction of a third large conservatory featuring stories from the hot, dry places of the world; as well as a state-of-the-art education centre.

So much has been achieved in such a short time that it is difficult to believe that Eden should not be a success locally, nationally and maybe globally. Eden is a dream borne of Cornwall and realised in Cornwall. We hope that it, and Cornwall, become a paradigm for what can be achieved with an abandoned mineral working and a heady mixture of innovation, ingenuity, passion and dedication.

References

Dines, H.G. (1956). *The Metalliferous Mining Region of South-West England*. 2 vols. HMSO, London.