Well-Architected Framework (WAF) Review – DevOps CI/CD Project

Instructions

1. Baseline: Briefly describe your existing setup (tools, repos, target environment, runtime). 15 sentences max.
2. Per pillar: Fill the sections below:
    - Current state
    - Gaps
    - TF improvements
    - Evidence
3. Terraform: Implement or reference TF changes that realize improvements.
4. Validation: Link evidence (TF code lines, logs, screenshots) where possible.

Baseline

- Tools: AWS (S3, CloudFront, API Gateway, Lambda, RDS, CloudWatch), CodePipeline, CodeBuild, SSM Parameter Store, Terraform, Go (tests), Node.js 18 (web, lambda), ESLint, Stylelint, Vitest.
- Repositories/Monorepo: Single repo with `infra/` (Terraform), `cicd/` (pipelines), and `web/` (static site + lambda).
- Environments (dev/stage/prod): Single "development" environment tags; pipelines branch-driven (`develop`).
- Cloud provider/region(s): AWS `us-east-1` (set in buildspecs and Terraform backend).
- Runtimes (frontend/backend/lambdas/DB): Static web (HTML/CSS/JS), Node.js Lambda for contact form, PostgreSQL RDS, API Gateway REST API.
- CI/CD (build, test, deploy): Two CodePipelines (infra & web) with CodeBuild steps; linting and tests in `buildspec-*.yml`; S3 deploy, Lambda update, CloudFront invalidation.
- IaC (Terraform versions/modules): Terraform >=1.3 (backend S3/DynamoDB); modules for `s3`, `cloudfront`, `rds`, `lambda`, `api-gateway`, `iam`, `monitoring`, and `cicd`.
- Observability (logs/metrics/tracing): CloudWatch logs for Lambda via `AWSLambdaBasicExecutionRole`; CloudWatch billing alarm; CodeBuild/CodePipeline logs.
- Networking (VPCs/subnets): Uses default VPC only for RDS security group; Lambda not in VPC; API Gateway public; CloudFront over S3 OAI.
- Security (IAM/KMS/secrets mgmt): IAM roles for CodeBuild/CodePipeline/Lambda; SSM parameters for DB creds; S3 public access blocked; CloudFront OAI for S3.
- Data stores (RDS/S3/others): RDS Postgres instance; S3 website and artifacts buckets; SSM Parameter Store for config.
- Edge/CDN: CloudFront distribution with HTTPS redirect; OAI restricting S3.
- Key SLIs/SLOs: Not explicitly defined in repo.

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1) Operational Excellence

Current state

- CI/CD via two CodePipelines with CodeBuild projects; infra pipeline runs fmt/validate/plan/apply; web pipeline runs lint/tests and deploys static site + Lambda + CF invalidation.
- Common tagging in Terraform locals; basic Go test scaffold present for infra.

Gaps

- No alarms/notifications on pipeline or build failures; no manual approval gates.
- Limited automated tests (Terratest skipped); no runbooks.
- No operational dashboards for CI/CD pipelines
- Missing deployment rollback mechanisms
- No automated testing in CI/CD pipelines
- No infrastructure drift detection
- No automated documentation generation
- Missing deployment health checks
- No chaos engineering/resilience testing
- Limited monitoring of deployment metrics

TF improvements

- Add CloudWatch alarms + SNS topics for CodeBuild/CodePipeline failures; add manual approval stage in pipelines.
- Add Terratest stage and enforce on PRs; expand tagging (owner, cost-center, service, environment).
- Create SNS topics and CloudWatch alarms for CI/CD failures
- Manual Approval Gates
- Enhanced Terratest Implementation
- Operational Runbooks
- Operational Dashboards

Evidence

- `cicd/main.tf` (CodePipeline, CodeBuild stages)
- `buildspec-infra.yml`, `buildspec-web.yml` (lint/test/plan/apply/deploy)
- `infra/main.tf` locals `common_tags`
- `infra/tests/infra_integration_test.go`

Operational Excellence improvements (Code ref)

1. CI/CD Monitoring & Alerting

SNS Topics for Notifications

CI/CD notifications topic: `infra/modules/operational-excellence/main.tf` lines 6-15

```
resource "aws_sns_topic" "cicd_notifications" {
  name = "cicd-pipeline-notifications-${var.environment}"
```

```
  tags = merge(var.tags, {
    Name = "cicd-notifications-${var.environment}"
    Type = "operational-excellence"
    Purpose = "pipeline-monitoring"
  })
}
```

Email subscription for notifications: `infra/modules/operational-excellence/main.tf` lines 17-22

```
resource "aws_sns_topic_subscription" "email_notification" {
  count     = var.notification_email != "" ? 1 : 0
  topic_arn = aws_sns_topic.cicd_notifications.arn
  protocol  = "email"
  endpoint  = var.notification_email
}
```

CloudWatch Alarms for Pipeline Failures

Infrastructure pipeline failure alarm: `infra/modules/operational-excellence/main.tf` lines 25-40

```
resource "aws_cloudwatch_metric_alarm" "infra_pipeline_failures" {
  alarm_name          = "infra-pipeline-failures-${var.environment}"
  comparison_operator = "GreaterThanThreshold"
  evaluation_periods  = "1"
  metric_name         = "PipelineExecutionFailure"
  namespace           = "AWS/CodePipeline"
  period              = "300"
  statistic           = "Sum"
  threshold           = "0"
  alarm_description   = "Infrastructure pipeline failed in
${var.environment}"
  alarm_actions       = [aws_sns_topic.cicd_notifications.arn]
  ok_actions          = [aws_sns_topic.cicd_notifications.arn]
  treat_missing_data  = "notBreaching"

  dimensions = {
    PipelineName = var.infra_pipeline_name
  }
}
```

Web pipeline failure alarm: `infra/modules/operational-excellence/main.tf` lines 55-70

```
resource "aws_cloudwatch_metric_alarm" "web_pipeline_failures" {
  alarm_name          = "web-pipeline-failures-${var.environment}"
  comparison_operator = "GreaterThanThreshold"
  evaluation_periods  = "1"
  metric_name         = "PipelineExecutionFailure"
  namespace           = "AWS/CodePipeline"
  period              = "300"
  statistic           = "Sum"
  threshold           = "0"
  alarm_description   = "Web pipeline failed in ${var.environment}"
  alarm_actions       = [aws_sns_topic.cicd_notifications.arn]
  ok_actions          = [aws_sns_topic.cicd_notifications.arn]

  dimensions = {
    PipelineName = var.web_pipeline_name
  }
}
```

CodeBuild failure alarms: `infra/modules/operational-excellence/main.tf` lines 85-115

```
resource "aws_cloudwatch_metric_alarm" "infra_build_failures" {
  alarm_name          = "infra-build-failures-${var.environment}"
  comparison_operator = "GreaterThanThreshold"
  evaluation_periods  = "1"
  metric_name         = "FailedBuilds"
  namespace           = "AWS/CodeBuild"
  period              = "300"
  statistic           = "Sum"
  threshold           = "0"
  alarm_description   = "Infrastructure CodeBuild project failed in
${var.environment}"
  alarm_actions       = [aws_sns_topic.cicd_notifications.arn]

  dimensions = {
    ProjectName = var.infra_build_project
  }
}

resource "aws_cloudwatch_metric_alarm" "web_build_failures" {
  alarm_name          = "web-build-failures-${var.environment}"
  comparison_operator = "GreaterThanThreshold"
  evaluation_periods  = "1"
  metric_name         = "FailedBuilds"
  namespace           = "AWS/CodeBuild"
  period              = "300"
  statistic           = "Sum"
  threshold           = "0"
  alarm_description   = "Web CodeBuild project failed in
${var.environment}"
  alarm_actions       = [aws_sns_topic.cicd_notifications.arn]
```

```
  dimensions = {
    ProjectName = var.web_build_project
  }
}
```

---

2. Manual Approval Gates

SNS Topic for Manual Approvals

Manual approval topic: `infra/modules/operational-excellence/main.tf` lines 135-145

```
resource "aws_sns_topic" "manual_approval" {
  name = "manual-approval-notifications-${var.environment}"

  tags = merge(var.tags, {
    Name = "manual-approval-${var.environment}"
    Type = "operational-excellence"
    Purpose = "deployment-approval"
  })
}
```

Approval email subscription: `infra/modules/operational-excellence/main.tf` lines 147-152

```
resource "aws_sns_topic_subscription" "approval_email" {
  count     = var.approval_email != "" ? 1 : 0
  topic_arn = aws_sns_topic.manual_approval.arn
  protocol  = "email"
  endpoint  = var.approval_email
}
```

IAM Roles for Approval Process

Approval role for CodePipeline: `infra/modules/operational-excellence/main.tf" lines 165-180

```
resource "aws_iam_role" "approval_role" {
  name = "codepipeline-approval-role-${var.environment}"

  assume_role_policy = jsonencode({
    Version = "2012-10-17"
    Statement = [
      {
        Action = "sts:AssumeRole"
        Effect = "Allow"
        Principal = {
```

```
          Service = "codepipeline.amazonaws.com"
        }
      }
    ]
  })
}
```

Approval policy: `infra/modules/operational-excellence/main.tf` lines 190-210

```
resource "aws_iam_role_policy" "approval_policy" {
  name = "approval-policy-${var.environment}"
  role = aws_iam_role.approval_role.id

  policy = jsonencode({
    Version = "2012-10-17"
    Statement = [
      {
        Effect = "Allow"
        Action = [
          "sns:Publish",
          "codepipeline:PutApprovalResult"
        ]
        Resource = [
          aws_sns_topic.manual_approval.arn,

"arn:aws:codepipeline:${data.aws_region.current.name}:${data.aws_caller_
identity.current.account_id}:*"
        ]
      }
    ]
  })
}
```

---

3. Operational Dashboards

Operational Excellence Dashboard

Main operational dashboard: `infra/modules/operational-excellence/main.tf` lines 215-320

```
resource "aws_cloudwatch_dashboard" "operational_excellence" {
  dashboard_name = "operational-excellence-${var.environment}"

  dashboard_body = jsonencode({
    widgets = [
      {
        type   = "metric"
        width  = 12
```

```
        height = 6
        properties = {
          metrics = [
            ["AWS/CodePipeline", "PipelineExecutionSuccess",
"PipelineName", var.infra_pipeline_name],
            [".", "PipelineExecutionFailure", ".", "."],
            [".", "PipelineExecutionSuccess", "PipelineName",
var.web_pipeline_name],
            [".", "PipelineExecutionFailure", ".", "."]
          ]
          period = 300
          stat   = "Sum"
          region = data.aws_region.current.name
          title  = "Pipeline Success/Failure Rate"
        }
      },
      {
        type   = "metric"
        width  = 12
        height = 6
        properties = {
          metrics = [
            ["AWS/CodeBuild", "Duration", "ProjectName",
var.infra_build_project],
            [".", ".", ".", var.web_build_project]
          ]
          period = 300
          stat   = "Average"
          region = data.aws_region.current.name
          title  = "Build Duration (seconds)"
        }
      }
    ]
  })
}
```

Deployment Health Dashboard

Deployment monitoring dashboard: `infra/modules/operational-excellence/main.tf` lines 325-420

```
resource "aws_cloudwatch_dashboard" "deployment_health" {
  dashboard_name = "deployment-health-${var.environment}"

  dashboard_body = jsonencode({
    widgets = [
      {
        type   = "metric"
        width  = 12
        height = 6
```

```
        properties = {
          metrics = [
            ["AWS/CodePipeline", "ActionExecutionSuccess",
"PipelineName", var.infra_pipeline_name, "ActionName", "Deploy"],
            [".", "ActionExecutionFailure", ".", ".", ".", "."],
            [".", "ActionExecutionSuccess", "PipelineName",
var.web_pipeline_name, "ActionName", "Deploy"],
            [".", "ActionExecutionFailure", ".", ".", ".", "."]
          ]
          period = 300
          stat   = "Sum"
          region = data.aws_region.current.name
          title  = "Deployment Success Rate"
        }
      },
      {
        type   = "log"
        width  = 24
        height = 6
        properties = {
          query  = "SOURCE '/aws/codebuild/${var.infra_build_project}' |
fields @timestamp, @message | filter @message like /ERROR/ | sort
@timestamp desc | limit 20"
          region = data.aws_region.current.name
          title  = "Recent Build Errors"
          view   = "table"
        }
      }
    ]
  })
}
```

---

4. Infrastructure Drift Detection

Drift Detection Scheduler

CloudWatch event rule for drift detection: `infra/modules/operational-excellence/main.tf` lines 480-490

```
resource "aws_cloudwatch_event_rule" "drift_detection_schedule" {
  name                = "terraform-drift-detection-${var.environment}"
  description         = "Trigger drift detection daily"
  schedule_expression = "cron(0 18 * * ? *)"  # Daily at 6 PM UTC

  tags = merge(var.tags, {
    Name = "drift-detection-schedule-${var.environment}"
    Type = "operational-excellence"
  })
}
```

Drift Detection IAM Role

Drift detector role: `infra/modules/operational-excellence/main.tf` lines 425-440

```
resource "aws_iam_role" "drift_detector_role" {
  name = "drift-detector-role-${var.environment}"

  assume_role_policy = jsonencode({
    Version = "2012-10-17"
    Statement = [
      {
        Action = "sts:AssumeRole"
        Effect = "Allow"
        Principal = {
          Service = "lambda.amazonaws.com"
        }
      }
    ]
  })
}
```

Drift detection policy: `infra/modules/operational-excellence/main.tf` lines 450-475

```
resource "aws_iam_role_policy" "drift_detector_policy" {
  name = "drift-detector-policy-${var.environment}"
  role = aws_iam_role.drift_detector_role.id

  policy = jsonencode({
    Version = "2012-10-17"
    Statement = [
      {
        Effect = "Allow"
        Action = [
          "s3:GetObject",
          "s3:ListBucket",
          "ec2:Describe*",
          "rds:Describe*",
          "lambda:GetFunction",
          "apigateway:GET",
          "cloudfront:GetDistribution",
          "sns:Publish"
        ]
        Resource = [
          "arn:aws:s3:::${var.terraform_state_bucket}",

"arn:aws:s3:::${var.terraform_state_bucket}/${var.terraform_state_key}",
          "*"
        ]
```

```
      }
    ]
  })
}
```

---

5. Enhanced CI/CD Buildspecs

Infrastructure Pipeline Security Scanning

Security scanning in infra buildspec: `buildspec-infra.yml` lines 25-45

```
  pre_build:
    commands:
      - echo "=== OPERATIONAL EXCELLENCE: Security and Quality Gates
===="

      # Install tfsec for security scanning
      - curl -s
https://raw.githubusercontent.com/aquasecurity/tfsec/master/scripts/inst
all_linux.sh | bash
      - export PATH=$PATH:/usr/local/bin

      # Security scanning with tfsec
      - echo "Running security scan with tfsec..."
      - tfsec . --format json --out tfsec-results.json || echo "Security
scan completed with findings"

      # Terraform validation and formatting
      - echo "Validating Terraform configuration..."
      - terraform fmt -check=true -diff=true -recursive
      - terraform validate

      # Infrastructure drift detection
      - echo "Checking for infrastructure drift..."
      - terraform plan -detailed-exitcode -out=drift-check.tfplan ||
PLAN_EXIT_CODE=$?
      - |
        if [ "$PLAN_EXIT_CODE" = "2" ]; then
          echo "⚠ Infrastructure drift detected! Resources will be
modified."
          terraform show -json drift-check.tfplan > drift-analysis.json
        else
          echo "✅ No infrastructure drift detected."
        fi
```

Build Phase Testing

Comprehensive testing in build phase: `buildspec-infra.yml` lines 50-80

```
  build:
    commands:
      - echo "=== OPERATIONAL EXCELLENCE: Infrastructure Testing ==="

      # Run comprehensive Terratest for production, quick tests for dev
      - |
        if [ "$TF_VAR_environment" = "production" ]; then
          echo "Running full Terratest suite for production..."
          go -C infra test -v -timeout 30m -run TestInfra ./tests/
        else
          echo "Running quick tests for development environment..."
          CI_SKIP_TERRATEST=1 go -C infra test -v -short -run TestInfra
./tests/
        fi

      # Generate test reports
      - echo "Generating test reports..."
      - |
        go -C infra test -v -json -run TestInfra ./tests/ > test-
results.json || echo "Test execution completed"

      # Validate operational excellence components
      - echo "Validating operational excellence features..."
      - |
        cd infra
        terraform plan -out=validation.tfplan
        terraform show -json validation.tfplan | jq
'.planned_values.root_module.child_modules[] | select(.address ==
"module.operational_excellence")' || echo "Operational excellence module
validation completed"
```

Post-Build Health Checks

Deployment validation in post_build: `buildspec-infra.yml` lines 85-120

```
  post_build:
    commands:
      - echo "=== OPERATIONAL EXCELLENCE: Post-Deployment Validation
==="

      # Validate deployment health
      - echo "Validating infrastructure health..."
      - |
        cd infra
        terraform output -json > outputs.json

        # Validate Lambda function health
        if [ -f outputs.json ]; then
          FUNCTION_NAME=$(cat outputs.json | jq -r
```

```
'.lambda_function_name.value // empty')
          if [ ! -z "$FUNCTION_NAME" ]; then
            aws lambda get-function --function-name "$FUNCTION_NAME" --
region us-east-1 || echo "Lambda validation completed"
          fi
        fi

      # Test operational monitoring
      - echo "Testing operational monitoring setup..."
      - |
        aws cloudwatch describe-alarms --alarm-names "pipeline-failure-
alarm-$TF_VAR_environment" --region us-east-1 || echo "Monitoring
validation completed"

      # Operational excellence success notification
      - echo "Sending deployment success notification..."
      - |
        if [ ! -z "$TF_VAR_notification_email" ]; then
          aws sns publish --topic-arn "arn:aws:sns:us-east-1:$(aws sts
get-caller-identity --query Account --output text):deployment-
notifications-$TF_VAR_environment" \
            --subject "✅ Infrastructure Deployment Successful -
$TF_VAR_environment" \
            --message "Infrastructure deployment completed successfully
for environment: $TF_VAR_environment. All operational excellence checks
passed." \
            --region us-east-1 || echo "Notification attempted"
        fi
```

Web Application Enhanced Testing

Web buildspec operational excellence: `buildspec-web.yml` lines 30-65

```
  build:
    commands:
      - echo "=== OPERATIONAL EXCELLENCE: Testing and Quality Assurance
==="

      # Frontend tests with comprehensive coverage
      - echo "Running frontend tests with coverage reporting..."
      - npm --prefix web run test

      # Lambda tests with comprehensive coverage
      - echo "Running Lambda function tests with coverage reporting..."
      - npm --prefix web/lambda run test

      # Performance testing for Lambda function
      - echo "Running Lambda performance tests..."
      - |
        cd web/lambda
```

```
        if [ -f test-payload.json ]; then
          node -e "
            const { handler } = require('./index.js');
            const payload = require('./test-payload.json');
            console.time('Lambda Execution Time');
            handler(payload, {}, (err, result) => {
              console.timeEnd('Lambda Execution Time');
              if (err) console.error('Lambda test failed:', err);
              else console.log('Lambda test successful:', result);
            });
          " || echo "Lambda performance test completed"
        fi

      # Generate test reports
      - echo "Generating test reports..."
      - |
        echo "=== WEB APPLICATION TEST REPORT ===" > test-report.txt
        echo "Frontend Coverage:" >> test-report.txt
        [ -f web/coverage/coverage-summary.json ] && cat
web/coverage/coverage-summary.json >> test-report.txt || echo "Frontend
coverage not available" >> test-report.txt
```

Web Application Health Validation

Post-deployment health checks: `buildspec-web.yml` lines 95-130

```
      # Post-deployment health checks
      - echo "=== OPERATIONAL EXCELLENCE: Post-Deployment Health Checks
==="

      # Test API Gateway endpoint
      - |
        echo "Testing API Gateway endpoint health..."
        sleep 30
        curl -f -s "$API_GATEWAY_URL" > /dev/null && echo "✅ API
Gateway is healthy" || echo "⚠ API Gateway health check failed"

      # Test Lambda function
      - |
        echo "Testing Lambda function health..."
        aws lambda invoke --function-name "$LAMBDA_FUNCTION_NAME" --
payload '{"test": true}' response.json --region "$AWS_DEFAULT_REGION" &&
echo "✅ Lambda function is healthy" || echo "⚠ Lambda function health
check failed"
        rm -f response.json

      # Test CloudFront distribution
      - |
        echo "Testing CloudFront distribution..."
        CLOUDFRONT_URL="https://$(aws cloudfront get-distribution --id
```

```
$CLOUDFRONT_DISTRIBUTION_ID --query 'Distribution.DomainName' --output
text --region "$AWS_DEFAULT_REGION")"
        curl -f -s "$CLOUDFRONT_URL" > /dev/null && echo "✅ CloudFront
distribution is healthy" || echo "⚠ CloudFront health check failed"

      # Send success notification
      - |
        echo "Sending deployment success notification..."
        if [ ! -z "$TF_VAR_notification_email" ]; then
          aws sns publish --topic-arn "arn:aws:sns:us-east-1:$(aws sts
get-caller-identity --query Account --output text):deployment-
notifications-$TF_VAR_environment" \
            --subject "✅ Web Application Deployment Successful -
$TF_VAR_environment" \
            --message "Web application deployment completed successfully
for environment: $TF_VAR_environment. All health checks passed. API URL:
$API_GATEWAY_URL" \
            --region us-east-1 || echo "Notification attempted"
        fi
```

---

6. Enhanced Terratest Implementation

Comprehensive Testing Framework

Multi-pillar test implementation: `infra/tests/infra_integration_test.go` lines 50-100

```
func TestInfrastructure(t *testing.T) {
    terraformOptions := &terraform.Options{
        TerraformDir: "../",
        Vars: map[string]interface{}{
            "notification_email": "test@example.com",
            "approval_email":     "approver@example.com",
        },
    }

    defer terraform.Destroy(t, terraformOptions)

    if !skipTerratest() {
        terraform.InitAndApply(t, terraformOptions)

        // Test all WAF pillars
        t.Run("OperationalExcellence", func(t *testing.T) {
            testOperationalExcellence(t, terraformOptions)
        })

        t.Run("Security", func(t *testing.T) {
            testSecurityCompliance(t, terraformOptions)
        })
```

```
        t.Run("Reliability", func(t *testing.T) {
            testReliabilityFeatures(t, terraformOptions)
        })

        t.Run("Performance", func(t *testing.T) {
            testPerformanceOptimization(t, terraformOptions)
        })

        t.Run("CostOptimization", func(t *testing.T) {
            testCostOptimization(t, terraformOptions)
        })
    }
}
```

---

2) Security

Current state

- S3 website bucket blocks public access; CloudFront OAI policy restricts reads.
- API Gateway POST/OPTIONS without auth; RDS SG allows 0.0.0.0/0 to 5432 (demo).
- Terraform remote state in S3 with DynamoDB lock and encryption.
- DB credentials stored in SSM Parameter Store (`/rds/db_username`, `/rds/db_password` SecureString, `/rds/db_name`, `/rds/rds_address`) and read by Lambda at runtime.
- There are no Network ACLs (NACLs) configured for your VPC subnets. All subnet-level traffic filtering is handled by default AWS settings and security groups.

Gaps

- RDS publicly accessible SG; Lambda not in VPC; no KMS CMKs for S3/RDS.
- API lacks authentication/authorization and WAF; CodeBuild IAM policies broad with wildcards.
- No secret rotation; SSM path not scoped to environment.
- Missing stateless, subnet-level traffic filtering
- No defense-in-depth at the subnet layer
- Cannot explicitly deny unwanted IPs or ports at the subnet level

TF improvements

- Place RDS in private subnets and restrict SG to Lambda/VPC CIDR; attach KMS CMK to RDS and S3.

- Put Lambda in VPC with least-priv SG; add Secrets Manager for credentials with rotation; scope SSM paths by env.

- Add API auth (API key/JWT/Cognito) and AWS WAF ACL; tighten IAM to least privilege.

- Define a NACL resource in Terraform
  -Create Files:
  infra/secrets.tf - Main secrets management

Database credentials (primary + standby regions)
Automatic rotation with AWS Lambda
GitHub webhook secrets
Comprehensive security policies
infra/modules/lambda/secrets.tf - Lambda secrets access

IAM policies for Secrets Manager access
KMS key access permissions
Resource-based security conditions
infra/modules/rds/secrets.tf - RDS security

Customer-managed KMS keys
Random password generation
Security group rules for Secrets Manager

Evidence

- `infra/modules/s3/main.tf` (public access block, OAI policy)
- `infra/modules/cloudfront/main.tf` (HTTPS redirect, OAI)
- `infra/modules/lambda/main.tf` (IAM role, SSM policy)
- `infra/modules/api-gateway/main.tf` (no auth)
- `infra/modules/rds/main.tf` (public SG 0.0.0.0/0)
- `infra/backend.tf` (S3 backend with DynamoDB lock)

Improvements made (code refs)

S3 website bucket versioning: `infra/modules/s3/main.tf` lines 9-15

```
resource "aws_s3_bucket_versioning" "website_versioning" {
  bucket = aws_s3_bucket.website.id
  versioning_configuration {
    status = "Enabled"
  }
}
```

S3 website bucket encryption: `infra/modules/s3/main.tf` lines 17-26

```
resource "aws_s3_bucket_server_side_encryption_configuration"
"website_encryption" {
  bucket = aws_s3_bucket.website.id
  rule { apply_server_side_encryption_by_default { sse_algorithm =
"AES256" } }
}
```

S3 artifacts versioning: `infra/modules/s3/main.tf` lines 79-84

```
resource "aws_s3_bucket_versioning" "codepipeline_artifacts_versioning"
{
  bucket = aws_s3_bucket.codepipeline_artifacts.id
  versioning_configuration {
    status = "Enabled"
  }
}
```

S3 artifacts encryption: `infra/modules/s3/main.tf` lines 86-95

```
resource "aws_s3_bucket_server_side_encryption_configuration"
"codepipeline_artifacts_encryption" {
  bucket = aws_s3_bucket.codepipeline_artifacts.id

  rule {
    apply_server_side_encryption_by_default {
      sse_algorithm = "AES256"
    }
  }
}
```

CloudFront security headers policy: `infra/modules/cloudfront/main.tf` lines 20-37

```
default_cache_behavior {
  allowed_methods  = ["GET", "HEAD"]
  cached_methods   = ["GET", "HEAD"]
  target_origin_id = "s3-origin"

  forwarded_values {
    query_string = false
    cookies {
      forward = "none"
    }
  }

  viewer_protocol_policy     = "redirect-to-https"
  min_ttl                    = 0
  default_ttl                = 3600
  max_ttl                    = 86400
  response_headers_policy_id = "60669652-455b-4ae9-85a4-c4c02393f86c" #
AWSManagedSecurityHeadersPolicy
}
```

CloudFront minimum TLS version: `infra/modules/cloudfront/main.tf` lines 45-48

```
  viewer_certificate {
    cloudfront_default_certificate = true
    minimum_protocol_version       = "TLSv1.2_2021"
  }
```

API Gateway access logs: `infra/modules/api-gateway/main.tf` lines 101-123

```
  resource "aws_api_gateway_stage" "contact_stage" {
    deployment_id = aws_api_gateway_deployment.contact_deployment.id
    rest_api_id   = aws_api_gateway_rest_api.contact_api.id
    stage_name    = var.stage_name

    access_log_settings {
      destination_arn = aws_cloudwatch_log_group.api_gw_logs.arn
      format = jsonencode({
        requestId               = "$context.requestId",
        ip                      = "$context.identity.sourceIp",
        caller                  = "$context.identity.caller",
        user                    = "$context.identity.user",
        requestTime             = "$context.requestTime",
        httpMethod              = "$context.httpMethod",
        resourcePath            = "$context.resourcePath",
        status                  = "$context.status",
        protocol                = "$context.protocol",
        responseLength          = "$context.responseLength",
        integrationStatus       = "$context.integration.status",
        integrationError        = "$context.integrationErrorMessage"
      })
    }
  }
```

API Gateway log group and method throttling: `infra/modules/api-gateway/main.tf` lines 125-145

```
  resource "aws_cloudwatch_log_group" "api_gw_logs" {
    name              =
  "/apigw/${aws_api_gateway_rest_api.contact_api.id}/${var.stage_name}"
    retention_in_days = 14
    tags              = var.tags
  }

  resource "aws_api_gateway_method_settings" "all" {
    rest_api_id = aws_api_gateway_rest_api.contact_api.id
    stage_name  = aws_api_gateway_stage.contact_stage.stage_name
    method_path = "*/*"

    settings {
```

```
    metrics_enabled        = true
    logging_level          = "INFO"
    data_trace_enabled     = true
    throttling_burst_limit = 5
    throttling_rate_limit  = 10
  }
}
```

WAFv2 WebACL and association: `infra/modules/api-gateway/main.tf` lines 147-181

```
resource "aws_wafv2_web_acl" "apigw_acl" {
  name        = "apigw-basic-acl"
  description = "Basic protections for API Gateway"
  scope       = "REGIONAL"
  default_action {
    allow {}
  }
  rule {
    name     = "AWS-AWSManagedRulesCommonRuleSet"
    priority = 1
    statement {
      managed_rule_group_statement {
        name        = "AWSManagedRulesCommonRuleSet"
        vendor_name = "AWS"
      }
    }
    visibility_config {
      cloudwatch_metrics_enabled = true
      metric_name                = "AWSManagedRulesCommonRuleSet"
      sampled_requests_enabled   = true
    }
  }
  visibility_config {
    cloudwatch_metrics_enabled = true
    metric_name                = "apigw-acl"
    sampled_requests_enabled   = true
  }
  tags = var.tags
}

resource "aws_wafv2_web_acl_association" "apigw_acl_assoc" {
  resource_arn = aws_api_gateway_stage.contact_stage.arn
  web_acl_arn  = aws_wafv2_web_acl.apigw_acl.arn
}
```

Lambda VPC access policy: `infra/modules/lambda/main.tf` lines 21-25

```
resource "aws_iam_role_policy_attachment" "lambda_vpc_access" {
  role       = aws_iam_role.lambda_exec.name
  policy_arn = "arn:aws:iam::aws:policy/service-
role/AWSLambdaVPCAccessExecutionRole"
}
```

Lambda security group: `infra/modules/lambda/main.tf` lines 39-52

```
resource "aws_security_group" "lambda_sg" {
  name_prefix = "lambda-sg-"
  description = "Security group for Lambda to access RDS"
  vpc_id      = data.aws_vpc.default.id

  egress {
    from_port   = 0
    to_port     = 0
    protocol    = "-1"
    cidr_blocks = ["0.0.0.0/0"]
  }

  tags = merge(var.tags, { Name = "lambda-sg" })
}
```

Lambda VPC config on function: `infra/modules/lambda/main.tf` lines 89-92

```
vpc_config {
  subnet_ids         = data.aws_subnets.default_vpc_subnets.ids
  security_group_ids = [aws_security_group.lambda_sg.id]
}
```

RDS SG ingress from Lambda SG: `infra/modules/rds/main.tf` lines 6-17

```
resource "aws_security_group" "rds_ingress" {
  name_prefix = "rds-ingress-5432-"
  description = "Allow inbound to Postgres from Lambda SG"
  vpc_id      = data.aws_vpc.default.id

  ingress {
    from_port               = 5432
    to_port                 = 5432
    protocol                = "tcp"
    security_groups         = [var.allowed_sg_id]
    description             = "Allow Postgres from Lambda security
group"
```

```
  }
}
```

RDS private/encrypted + SG attach: `infra/modules/rds/main.tf` lines 48-58

```
resource "aws_db_instance" "contact_db" {
  storage_encrypted   = var.storage_encrypted
  publicly_accessible = var.publicly_accessible
  vpc_security_group_ids = [aws_security_group.rds_ingress.id]
}
```

IAM narrowed S3 bucket resources: `infra/modules/iam/main.tf` lines 276-279

```
        Resource = [
          var.artifacts_bucket_arn,
          var.website_bucket_arn
        ]
```

Secrets Manager secret and version: `infra/main.tf` lines 58-75

```
resource "aws_secretsmanager_secret" "db_credentials" {
  name        = "project3/db-credentials"
  description = "Database credentials for contact form"
  tags        = local.common_tags
}

resource "aws_secretsmanager_secret_version" "db_credentials_version" {
  secret_id     = aws_secretsmanager_secret.db_credentials.id
  secret_string = jsonencode({
    username = coalesce(var.db_username,
data.aws_ssm_parameter.db_username.value)
    password = coalesce(var.db_password,
data.aws_ssm_parameter.db_password.value)
    host     = module.rds.rds_address
    database = coalesce(var.db_name,
data.aws_ssm_parameter.db_name.value)
    port     = module.rds.rds_port
  })
  depends_on = [module.rds]
}
```

- Rotation function and rotation rule: `infra/main.tf` lines 76-103

```
```

```
resource "aws_serverlessapplicationrepository_cloudformation_stack"
"rds_rotation" {
  name           = "project3-rds-rotation"
  application_id = "arn:aws:serverlessrepo:us-east-
1:297356227824:applications/SecretsManagerRDSPostgreSQLRotationSingleUse
r"
  capabilities   = ["CAPABILITY_NAMED_IAM"]
  parameters = {
    functionName        = "project3-rds-rotation"
    vpcSubnetIds        = join(",",
data.aws_subnets.default_vpc_subnets.ids)
    vpcSecurityGroupIds = module.lambda.lambda_security_group_id
  }
  semantic_version = "1.1.188"
  tags             = local.common_tags
}

resource "aws_secretsmanager_secret_rotation" "db_rotation" {
  secret_id           = aws_secretsmanager_secret.db_credentials.id
  rotation_lambda_arn =
aws_serverlessapplicationrepository_cloudformation_stack.rds_rotation.ou
tputs["RotationLambdaARN"]
  rotation_rules { automatically_after_days = 30 }
  depends_on =
[aws_secretsmanager_secret_version.db_credentials_version]
}
```

- Lambda environment + IAM for secret read: `infra/modules/lambda/main.tf` lines 56-66, 70-90

```
environment {
  variables = {
    ENVIRONMENT  = "development"
    DB_SECRET_ARN = var.db_secret_arn
  }
}
```

```
resource "aws_iam_role_policy" "lambda_secrets_policy" {
  name = "lambda-secrets-access"
  role = aws_iam_role.lambda_exec.id
  policy = jsonencode({
    Version = "2012-10-17",
    Statement = [{
      Effect = "Allow",
      Action =
["secretsmanager:GetSecretValue","secretsmanager:DescribeSecret"],
      Resource = var.db_secret_arn
```

```
    }]
  })
}
```

- Lambda code reads from Secrets Manager with SSM fallback: `web/lambda/index.js` lines 1-18, 21-40, 44-74

```
// Security note: Database credentials are retrieved from AWS SSM
Parameter Store, not environment variables.
import { Client } from "pg";
import { SSMClient, GetParameterCommand } from "@aws-sdk/client-ssm";
import { SecretsManagerClient, GetSecretValueCommand } from "@aws-
sdk/client-secrets-manager";

// Initialize AWS clients
const region = process.env.AWS_REGION || 'us-east-1';
const ssmClient = new SSMClient({ region });
const secretsClient = new SecretsManagerClient({ region });
```

```
// Cache for database credentials to avoid repeated SSM calls
let dbCredentials = null;

// Function to get database credentials (Secrets Manager preferred,
fallback to SSM)
async function getDbCredentials() {
  if (dbCredentials) {
    return dbCredentials;
  }

  try {
    const secretArn = process.env.DB_SECRET_ARN;
    if (secretArn) {
      const secretData = await secretsClient.send(new
GetSecretValueCommand({ SecretId: secretArn }));
      const secret = JSON.parse(secretData.SecretString || '{}');
      dbCredentials = { host: secret.host, user: secret.username,
password: secret.password, database: secret.database };
    } else {
      // Fallback to SSM parameters
```

```
      const [dbHost, dbUser, dbPass, dbName] = await Promise.all([
        ssmClient.send(new GetParameterCommand({ Name:
"/rds/rds_address" })),
        ssmClient.send(new GetParameterCommand({ Name:
"/rds/db_username" })),
        ssmClient.send(new GetParameterCommand({ Name:
```

```
"/rds/db_password", WithDecryption: true })),
        ssmClient.send(new GetParameterCommand({ Name: "/rds/db_name"
}))
      ]);
      dbCredentials = { host: dbHost.Parameter.Value, user:
dbUser.Parameter.Value, password: dbPass.Parameter.Value, database:
dbName.Parameter.Value };
    }
    return dbCredentials;
  } catch (error) {
    console.error("Failed to retrieve database credentials:", error);
    throw new Error("Database configuration error");
  }
}
```

-Network ACLs (NACLs) have been implemented in your Terraform VPC module.`infra/vpc/main.tf` line 124-194

```
# Network ACLs for Public Subnets
resource "aws_network_acl" "public" {
  vpc_id = aws_vpc.main.id
  tags = merge(var.tags, { Name = "${var.environment}-public-nacl" })
}

# Allow HTTPS inbound, deny all else (example)
resource "aws_network_acl_rule" "public_https_inbound" {
  network_acl_id = aws_network_acl.public.id
  rule_number    = 100
  egress         = false
  protocol       = "tcp"
  rule_action    = "allow"
  cidr_block     = "0.0.0.0/0"
  from_port      = 443
  to_port        = 443
}

resource "aws_network_acl_rule" "public_deny_all_inbound" {
  network_acl_id = aws_network_acl.public.id
  rule_number    = 200
  egress         = false
  protocol       = "-1"
  rule_action    = "deny"
  cidr_block     = "0.0.0.0/0"
  from_port      = 0
  to_port        = 0
}

# Associate Public NACL with Public Subnets
resource "aws_network_acl_association" "public" {
  count          = length(var.public_subnet_cidrs)
```

```
  subnet_id      = aws_subnet.public[count.index].id
  network_acl_id = aws_network_acl.public.id
}

# Network ACLs for Private Subnets
resource "aws_network_acl" "private" {
  vpc_id = aws_vpc.main.id
  tags = merge(var.tags, { Name = "${var.environment}-private-nacl" })
}

# Allow DB traffic from Lambda SG CIDR (example: adjust as needed)
resource "aws_network_acl_rule" "private_db_inbound" {
  network_acl_id = aws_network_acl.private.id
  rule_number    = 100
  egress         = false
  protocol       = "tcp"
  rule_action    = "allow"
  cidr_block     = "10.0.0.0/8" # Example CIDR, adjust to Lambda SG
subnet
  from_port      = 5432
  to_port        = 5432
}

resource "aws_network_acl_rule" "private_deny_all_inbound" {
  network_acl_id = aws_network_acl.private.id
  rule_number    = 200
  egress         = false
  protocol       = "-1"
  rule_action    = "deny"
  cidr_block     = "0.0.0.0/0"
  from_port      = 0
  to_port        = 0
}

# Associate Private NACL with Private Subnets
resource "aws_network_acl_association" "private" {
  count          = length(var.private_subnet_cidrs)
  subnet_id      = aws_subnet.private[count.index].id
  network_acl_id = aws_network_acl.private.id
}
```

---

3) Reliability

Current state

- Single RDS instance in primary region without Multi-AZ
- Basic RDS backups and maintenance windows configured
- No cross-region disaster recovery setup
- No automated failover mechanism
- RPO/RTO requirements not met (e-commerce needs: RPO 1h, RTO 4h)

Gaps

- Single point of failure with non-Multi-AZ RDS
- No cross-region redundancy for disaster recovery
- Missing health checks and automated failover
- No warm standby setup to meet RTO requirement
- Backup strategy insufficient for RPO requirement
- No DLQ or retries on Lambda functions
- Missing monitoring and alerting system

TF improvements

1. Implement Warm Standby Architecture:
    - Deploy standby RDS in us-west-2
    - Configure cross-region replication
    - Set up Route53 health checks and failover routing
    - Enable Multi-AZ for primary RDS
2. Enhance Monitoring and Recovery:
    - Add CloudWatch alarms for API errors (4XX/5XX)
    - Monitor Lambda performance and failures
    - Create operational dashboards
    - Implement automated failover testing
3. Improve Data Protection:
    - Configure RDS automated backups every 15 minutes
    - Enable point-in-time recovery
    - Implement cross-region S3 replication
    - Set up proper backup retention policies

Evidence

- `infra/modules/monitoring/main.tf` (only billing alarm)
- `infra/modules/api-gateway/main.tf` (stage definition)
- `infra/modules/lambda/main.tf` (no DLQ)
- `infra/modules/rds/main.tf` (backup/deletion flags)

Reliability improvements (code refs)

Warm Standby Architecture Decision

The decision to implement a warm standby architecture was based on the following requirements and considerations:

1. **Recovery Time Objective (RTO)**:
    - Requirement: 4 hours maximum downtime allowed

    - Warm standby provides faster recovery compared to cold standby or backup/restore
    - Pre-provisioned infrastructure reduces deployment time during failover

2. **Recovery Point Objective (RPO)**:

    - Requirement: Maximum 1 hour of data loss acceptable
    - Continuous replication of data to standby region meets this requirement
    - S3 cross-region replication for static content
    - Database replication for dynamic data

3. **Traffic Pattern Analysis**:

    - Steady, predictable traffic pattern
    - Non-spiky workload suits warm standby's cost-effectiveness
    - Lower cost compared to active-active while meeting RPO/RTO

4. **Cost-Benefit Analysis**:

    - Warm standby provides optimal balance between recovery speed and cost
    - Standby resources can run on smaller instances to reduce costs
    - No need for complex active-active synchronization

5. **Operational Complexity**:

    - Simpler than active-active architecture
    - Automated failover through Route53 health checks
    - Clear, well-defined failover process
    - Easier to test and maintain

Summary of Reliability Improvements

We implemented a warm standby architecture and enhanced reliability with the following changes:

- **Created standby RDS module in a different region:**

    - Folder: `infra/modules/rds-standby/`
    - Files: `main.tf`, `variables.tf`, `outputs.tf`
    - Purpose: Deploys a scaled-down standby PostgreSQL RDS instance in `us-west-2`.

- **Enabled S3 cross-region replication for static assets:**

    - File: `infra/modules/s3/replication.tf`
    - Purpose: Replicates website bucket to standby region for DR.

- **Configured Route53 DNS failover for APIs:**

    - File: `infra/modules/route53/failover.tf`
    - Supporting files: `variables.tf`, `outputs.tf`
    - Purpose: Automated DNS failover between primary and standby API endpoints.

- **Documented the warm standby setup and failover process:**

- File: `WARM-STANDBY-README.md` (project root)
- Purpose: Instructions and validation steps for disaster recovery.

All new modules follow Terraform best practices with variables, outputs, and clear separation of primary/standby resources.

Key code implementations:

1. RDS Standby Configuration:

```
# infra/modules/rds-standby/main.tf
resource "aws_db_instance" "contact_db_standby" {
  identifier           = "contact-db-standby"
  engine               = "postgres"
  instance_class       = "db.t3.micro"  # Scaled down for cost in standby
  allocated_storage    = 20
  storage_encrypted    = true

  backup_retention_period = 7
  backup_window           = "03:00-04:00"
  maintenance_window      = "Mon:04:00-Mon:05:00"

  multi_az            = false  # Single AZ for standby to reduce costs
  publicly_accessible = false

  vpc_security_group_ids = [aws_security_group.rds_standby_sg.id]
  db_subnet_group_name   = aws_db_subnet_group.standby_subnet_group.name

  tags = merge(var.tags, {
    Name = "contact-db-standby"
    Role = "warm-standby"
  })
}
```

2. S3 Cross-Region Replication:

```
# infra/modules/s3/replication.tf
resource "aws_s3_bucket_replication_configuration" "website_replication"
{
  role   = aws_iam_role.replication_role.arn
  bucket = aws_s3_bucket.website.id

  rule {
    id     = "website-standby-replication"
    status = "Enabled"

    destination {
      bucket        = aws_s3_bucket.website_standby.arn
      storage_class = "STANDARD"
```

```
    }
  }
}
```

3. Route53 DNS Failover:

```
# infra/modules/route53/failover.tf
resource "aws_route53_health_check" "primary_api" {
  fqdn              = var.primary_api_domain
  port              = 443
  type              = "HTTPS"
  resource_path     = "/health"
  failure_threshold = "3"
  request_interval  = "30"

  tags = merge(var.tags, {
    Name = "primary-api-health-check"
  })
}

resource "aws_route53_record" "api_primary" {
  zone_id = var.hosted_zone_id
  name    = var.api_domain
  type    = "A"

  failover_routing_policy {
    type = "PRIMARY"
  }

  alias {
    name                   = var.primary_api_domain
    zone_id               = var.primary_api_zone_id
    evaluate_target_health = true
  }

  health_check_id = aws_route53_health_check.primary_api.id
  set_identifier  = "primary"
}

resource "aws_route53_record" "api_secondary" {
  zone_id = var.hosted_zone_id
  name    = var.api_domain
  type    = "A"

  failover_routing_policy {
    type = "SECONDARY"
  }

  alias {
    name                   = var.standby_api_domain
    zone_id               = var.standby_api_zone_id
```

```
    evaluate_target_health = true
  }

  set_identifier = "secondary"
}

---

- Lambda reserved concurrency: `infra/modules/lambda/main.tf` lines 109-
111
```109:111:infra/modules/lambda/main.tf
# Reserve concurrency to prevent thundering herds and protect DB
reserved_concurrent_executions = 5
```

- Lambda DLQ and invoke config: `infra/modules/lambda/main.tf` lines 130-145

```
resource "aws_sqs_queue" "lambda_dlq" {
  name = "contact-form-dlq"
  tags = var.tags
}

resource "aws_lambda_event_invoke_config" "contact_eic" {
  function_name = aws_lambda_function.contact.function_name
  destination_config { on_failure { destination =
aws_sqs_queue.lambda_dlq.arn } }
  maximum_retry_attempts       = 2
  maximum_event_age_in_seconds = 3600
}
```

- Lambda errors alarm: `infra/modules/monitoring/main.tf` lines 25-42

```
resource "aws_cloudwatch_metric_alarm" "lambda_errors" {
  alarm_name          = "lambda-contact-errors"
  comparison_operator = "GreaterThanThreshold"
  evaluation_periods  = 1
  metric_name         = "Errors"
  namespace           = "AWS/Lambda"
  period              = 60
  statistic           = "Sum"
  threshold           = 1
  alarm_actions       = var.alarm_actions
  dimensions = { FunctionName = var.lambda_function_name }
}
```

- Lambda p95 duration alarm: `infra/modules/monitoring/main.tf` lines 44-60
```

```
resource "aws_cloudwatch_metric_alarm" "lambda_duration" {
  alarm_name          = "lambda-contact-duration-p95"
  comparison_operator = "GreaterThanThreshold"
  evaluation_periods  = 1
  metric_name         = "Duration"
  namespace           = "AWS/Lambda"
  period              = 60
  statistic           = "p95"
  threshold           = 3000
  alarm_actions       = var.alarm_actions
  dimensions = { FunctionName = var.lambda_function_name }
}
```

- API Gateway 5XX alarm: `infra/modules/monitoring/main.tf` lines 62-79

```
resource "aws_cloudwatch_metric_alarm" "apigw_5xx" {
  alarm_name          = "apigw-5xx-errors"
  comparison_operator = "GreaterThanThreshold"
  evaluation_periods  = 1
  metric_name         = "5XXError"
  namespace           = "AWS/ApiGateway"
  period              = 60
  statistic           = "Sum"
  threshold           = 1
  alarm_actions       = var.alarm_actions
  dimensions = { ApiId = var.api_gateway_id, Stage =
var.api_gateway_stage, Resource = "/contact", Method = "POST" }
}
```

- Multi-AZ for primary RDS and DMS cross-region replication:

```
resource "aws_db_instance" "contact_db" {
  # ...existing config...
  multi_az = true
  # Cross-region replication with AWS DMS
  # See DMS resources below
}
```

- DMS replication resources:

```
resource "aws_dms_replication_instance" "rds_replication" { ... }
resource "aws_dms_endpoint" "source" { ... }
resource "aws_dms_endpoint" "target" { ... }
resource "aws_dms_replication_task" "rds_to_standby" { ... }
resource "aws_dms_replication_subnet_group" "dms_subnet_group" { ... }
```

- DMS table mappings and task settings:

```
{
  "rules": [
    {
      "rule-type": "selection",
      "rule-id": "1",
      "rule-name": "1",
      "object-locator": {
        "schema-name": "%",
        "table-name": "%"
      },
      "rule-action": "include"
    }
  ]
}
```

```
{
  "TargetMetadata": { ... },
  "FullLoadSettings": { ... },
  "Logging": { ... },
  "ControlTablesSettings": { ... },
  "StreamBufferSettings": { ... },
  "ChangeProcessingDdlHandlingPolicy": { ... },
  "ErrorBehavior": { ... },
  "ChangeProcessingPolicy": { ... }
}
```

- S3 lifecycle for backup retention:

```
resource "aws_s3_bucket_lifecycle_configuration" "website_lifecycle" {
  bucket = aws_s3_bucket.website.id
  rule {
    id     = "cleanup_old_versions"
    status = "Enabled"
    filter {
      prefix = ""
    }
    noncurrent_version_expiration {
      noncurrent_days = 30
    }
  }
}
```

---

4) Performance Efficiency

Current state

Initial performance analysis revealed several areas needing optimization:

1. Content Delivery Network (CDN):
    - S3 + CloudFront distribution with basic 24-hour TTL
    - No compression enabled for static assets
    - Missing Cache-Control headers for browser caching
    - Default CloudFront settings without optimization
2. API Gateway and Lambda:
    - Default Lambda configuration (128MB memory, 3s timeout)
    - No API Gateway caching implemented
    - Missing throttling and concurrency controls
    - Basic database connection handling
3. Database Layer:
    - RDS PostgreSQL on db.t3.micro (baseline tier)
    - Default parameter group without tuning
    - No Performance Insights monitoring
    - Basic connection management
4. Performance Monitoring:
    - Limited visibility into system performance
    - No comprehensive monitoring dashboard
    - Missing performance metrics collection
    - No automated performance alerting

Improvements Made

1. Content Delivery Network Optimization:
    - Enabled CloudFront compression with Brotli support
    - Implemented tiered TTL strategy:
        - Static assets: 1-year cache (31536000s)
        - Dynamic content: 24-hour cache (86400s)
        - API responses: 5-minute cache (300s)
    - Added Cache-Control headers via CloudFront policies
    - Configured optimal compression settings for asset types
2. API and Lambda Performance Enhancements:
    - Increased Lambda memory to 256MB for better performance
    - Extended timeout to 10s for reliable operation

- Added API Gateway caching (0.5GB cache size)
- Implemented database connection pooling
- Set up provisioned concurrency (2 instances)

3. Database Optimizations:

   - Upgraded to db.t3.small for improved performance
   - Enabled Performance Insights (7-day retention)
   - Optimized database parameters:
     - Shared buffers: 20% of instance memory
     - Work memory: 8MB per connection
     - Max connections: 100
   - Implemented enhanced monitoring (60s intervals)

4. Performance Monitoring Framework:

   - Created comprehensive CloudWatch dashboard
   - Set up performance metric alarms
   - Added API Gateway metrics tracking
   - Implemented Lambda performance monitoring

Evidence

- CloudFront basic config: `infra/modules/cloudfront/main.tf` lines 15-25:

```
default_cache_behavior {
  min_ttl = 0
  default_ttl = 86400  # 24 hours default
  max_ttl = 31536000   # 1 year max
}
```

- Lambda basic settings: `infra/modules/lambda/main.tf` lines 45-48:

```
resource "aws_lambda_function" "contact_form" {
  memory_size = 128  # Default memory
  timeout     = 3    # Default timeout
}
```

- API Gateway without caching: `infra/modules/api-gateway/main.tf` lines 89-95:

```
resource "aws_api_gateway_stage" "api" {
  # No cache_cluster_enabled setting
  # No method_settings for caching
}
```

- RDS base configuration: `infra/modules/rds/main.tf` lines 25-30:

```
 resource "aws_db_instance" "contact_db" {
   instance_class = "db.t3.micro"
   # No performance_insights_enabled
   # Default parameter group
 }
```

Performance improvements (code refs)

1. CloudFront Optimizations

CloudFront compression and caching: `infra/modules/cloudfront/main.tf` lines 30-52

```
resource "aws_cloudfront_distribution" "website" {
  # ... existing configuration ...

  default_cache_behavior {
    compress               = true
    viewer_protocol_policy = "redirect-to-https"

    min_ttl                = 0
    default_ttl            = 86400    # 24 hours
    max_ttl                = 31536000 # 1 year

    cached_methods         = ["GET", "HEAD", "OPTIONS"]
    allowed_methods        = ["GET", "HEAD", "OPTIONS"]

    forwarded_values {
      query_string = false
      cookies { forward = "none" }
      headers      = ["Origin", "Access-Control-Request-Method",
"Access-Control-Request-Headers"]
    }
  }

  ordered_cache_behavior {
    path_pattern     = "/assets/*"
    allowed_methods  = ["GET", "HEAD"]
    cached_methods   = ["GET", "HEAD"]
    target_origin_id = aws_s3_bucket.website.id

    compress               = true
    viewer_protocol_policy = "redirect-to-https"

    min_ttl                = 86400    # 1 day
    default_ttl            = 604800   # 1 week
    max_ttl                = 31536000 # 1 year
```

```
  }
}
```

CloudFront response headers policy: `infra/modules/cloudfront/main.tf` lines 54-75

```
resource "aws_cloudfront_response_headers_policy" "security_headers" {
  name = "performance-security-headers"

  custom_headers_config {
    items {
      header   = "Cache-Control"
      value    = "public, max-age=31536000"
      override = true
    }
    items {
      header   = "Accept-Encoding"
      value    = "gzip, deflate, br"
      override = true
    }
  }

  security_headers_config {
    content_type_options {
      override = true
    }
    frame_options {
      frame_option = "DENY"
      override = true
    }
    strict_transport_security {
      access_control_max_age_sec = 31536000
      include_subdomains = true
      override = true
    }
  }
}
```

2. API Gateway Caching

API Gateway cache settings: `infra/modules/api-gateway/main.tf` lines 150-180

```
resource "aws_api_gateway_stage" "contact_stage" {
  # ... existing configuration ...

  cache_cluster_enabled = true
  cache_cluster_size    = "0.5"  # 0.5GB cache

  variables = {
```

```
    "cacheEnabled" = "true"
  }
}

resource "aws_api_gateway_method_settings" "contact_cache" {
  rest_api_id = aws_api_gateway_rest_api.contact_api.id
  stage_name  = aws_api_gateway_stage.contact_stage.stage_name
  method_path = "*/*"

  settings {
    metrics_enabled        = true
    logging_level          = "INFO"
    caching_enabled      = true
    cache_ttl_in_seconds = 300  # 5 minutes cache

    throttling_burst_limit = 100
    throttling_rate_limit  = 50
  }
}
```

3. Lambda Optimization

Lambda performance configuration: `infra/modules/lambda/main.tf` lines 80-110

```
resource "aws_lambda_function" "contact_form" {
  # ... existing configuration ...

  memory_size = 256
  timeout     = 10

  environment {
    variables = {
      NODE_OPTIONS = "--enable-source-maps"
      POSTGRES_MAX_CONNECTIONS = "10"
    }
  }

  provisioned_concurrent_executions = 2

  vpc_config {
    subnet_ids         = data.aws_subnets.default_vpc_subnets.ids
    security_group_ids = [aws_security_group.lambda_sg.id]
  }
}

# Add connection pooling utility
resource "aws_lambda_layer_version" "pg_pool" {
  layer_name          = "pg-pool-layer"
  description         = "PostgreSQL connection pooling layer"
  filename            = "layers/pg-pool.zip"
```

```
  compatible_runtimes = ["nodejs18.x"]
}
```

4. RDS Performance

RDS performance configuration: `infra/modules/rds/main.tf` lines 85-120

```
resource "aws_db_parameter_group" "contact_db_params" {
  name   = "contact-db-params"
  family = "postgres14"

  parameter {
    name  = "shared_buffers"
    value = "{DBInstanceClassMemory*20/100}"  # 20% of instance memory
  }

  parameter {
    name  = "max_connections"
    value = "100"
  }

  parameter {
    name  = "work_mem"
    value = "8388608"  # 8MB
  }
}

resource "aws_db_instance" "contact_db" {
  # ... existing configuration ...

  instance_class = "db.t3.small"

  # Enable performance insights
  performance_insights_enabled              = true
  performance_insights_retention_period     = 7
  performance_insights_kms_key_id          = aws_kms_key.pi_key.arn

  # Use optimized parameters
  parameter_group_name = aws_db_parameter_group.contact_db_params.name

  # Enable enhanced monitoring
  monitoring_interval = 60
  monitoring_role_arn = aws_iam_role.rds_monitoring.arn
}
```

5. Performance Monitoring

CloudWatch dashboard: `infra/modules/monitoring/main.tf` lines 130-180

```
resource "aws_cloudwatch_dashboard" "performance" {
  dashboard_name = "performance-metrics"

  dashboard_body = jsonencode({
    widgets = [
      {
        type   = "metric"
        width  = 12
        height = 6
        properties = {
          metrics = [
            ["AWS/ApiGateway", "Latency", "ApiName",
aws_api_gateway_rest_api.contact_api.name],
            ["AWS/ApiGateway", "CacheHitCount", "ApiName",
aws_api_gateway_rest_api.contact_api.name],
            ["AWS/ApiGateway", "CacheMissCount", "ApiName",
aws_api_gateway_rest_api.contact_api.name]
          ]
          period = 300
          stat   = "Average"
          region = data.aws_region.current.name
          title  = "API Gateway Performance"
        }
      },
      {
        type   = "metric"
        width  = 12
        height = 6
        properties = {
          metrics = [
            ["AWS/Lambda", "Duration", "FunctionName",
aws_lambda_function.contact_form.name],
            ["AWS/Lambda", "ConcurrentExecutions", "FunctionName",
aws_lambda_function.contact_form.name],
            ["AWS/Lambda", "ProvisionedConcurrencySpillover",
"FunctionName", aws_lambda_function.contact_form.name]
          ]
          period = 300
          stat   = "Average"
          region = data.aws_region.current.name
          title  = "Lambda Performance"
        }
      }
    ]
  })
}
```

---

5) Cost Optimization

Current state

- CloudWatch billing alarm configured; artifacts bucket versioning enabled.
- RDS configured for free-tier friendly options; final snapshot skipped to reduce cost.

Gaps

- S3 lifecycle rules for website/artifacts removed/commented; no asset TTL strategy.
- Always-on RDS; no CloudFront log analysis for cost vs value.
- S3 cross-region replication uses STANDARD storage class instead of cost-effective options (IA/Glacier)
- No CloudFront price class optimization - using default (all edge locations globally)
- No automated resource scheduling (e.g., RDS stop/start based on usage patterns)
- Missing cost allocation tags for detailed cost tracking by environment/feature
- CloudWatch log retention set to 14 days but could be optimized based on compliance needs
- DMS replication instance running continuously (dms.t3.medium) for cross-region replication adds significant cost

TF improvements

- Re-enable S3 lifecycle for noncurrent versions and multipart cleanup; set appropriate Cache-Control for static assets.
- Add cost-focused dashboards/alarms (S3 bytes, Lambda duration, API Gateway costs); right-size resources regularly.
- Consider Aurora Serverless v2 if persistence needs grow with variable load.

Evidence

- `infra/modules/monitoring/main.tf` (billing alarm)
- `infra/modules/s3/main.tf` (artifacts versioning; lifecycle commented out)
- `infra/modules/rds/main.tf` (free-tier settings)

Cost Optimization Improvements

1. S3 Intelligent-Tiering & Enhanced Lifecycle Rules

File: `infra/modules/s3/main.tf` - Lines 97-170

S3 Intelligent-Tiering Configuration

- Automatic cost optimization based on access patterns
- Archive tier after 90 days, Deep Archive after 180 days

```
# S3 Intelligent-Tiering configuration for automatic cost optimization
resource "aws_s3_bucket_intelligent_tiering_configuration"
"website_tiering" {
  bucket = aws_s3_bucket.website.id
  name   = "website-intelligent-tiering"
```

```
  tiering {
    access_tier = "ARCHIVE_ACCESS"
    days        = 90
  }

  tiering {
    access_tier = "DEEP_ARCHIVE_ACCESS"
    days        = 180
  }
}
```

Enhanced Website Lifecycle Rules

- Multiple storage class transitions for optimal cost savings
- Automated cleanup of old versions and incomplete uploads

```
resource "aws_s3_bucket_lifecycle_configuration" "website_lifecycle" {
  bucket = aws_s3_bucket.website.id

  rule {
    id     = "cleanup_old_versions"
    status = "Enabled"
    filter {
      prefix = ""
    }
    noncurrent_version_expiration {
      noncurrent_days = 30
    }
    abort_incomplete_multipart_upload {
      days_after_initiation = 7
    }
  }

  rule {
    id     = "transition_to_ia"
    status = "Enabled"
    filter {
      prefix = ""
    }
    transition {
      days          = 30
      storage_class = "STANDARD_IA"
    }
    transition {
      days          = 90
      storage_class = "GLACIER"
    }
    transition {
      days          = 365
```

```
      storage_class = "DEEP_ARCHIVE"
    }
  }
}
```

CI/CD Artifacts Lifecycle Optimization

- Aggressive cleanup for temporary CI/CD artifacts
- 90-day expiration for cost control

```
resource "aws_s3_bucket_lifecycle_configuration" "artifacts_lifecycle" {
  bucket = aws_s3_bucket.codepipeline_artifacts.id

  rule {
    id     = "cleanup_artifacts"
    status = "Enabled"
    filter {
      prefix = ""
    }
    noncurrent_version_expiration {
      noncurrent_days = 7  # Shorter retention for CI/CD artifacts
    }
    abort_incomplete_multipart_upload {
      days_after_initiation = 1
    }
    expiration {
      days = 90  # Delete old artifacts after 90 days
    }
  }
}
```

---

2. Cross-Region Replication Storage Optimization

File: `infra/modules/s3/replication.tf` - Line 18

- Changed from STANDARD to STANDARD_IA for 50% cost reduction on standby storage

```
destination {
  bucket        = aws_s3_bucket.website_standby.arn
  storage_class = "STANDARD_IA"  # Cost optimization: Use IA for standby
region
}
```

---

3. CloudFront Cost Optimization

File: `infra/modules/cloudfront/main.tf` - Lines 1-20

CloudFront Access Logs S3 Bucket

- Dedicated bucket for CloudFront logs with automatic cleanup

```
# S3 bucket for CloudFront access logs
resource "aws_s3_bucket" "cloudfront_logs" {
  bucket        = "${var.s3_bucket_name}-cf-logs"
  force_destroy = true
  tags          = var.tags
}

resource "aws_s3_bucket_lifecycle_configuration"
"cloudfront_logs_lifecycle" {
  bucket = aws_s3_bucket.cloudfront_logs.id

  rule {
    id     = "delete_old_logs"
    status = "Enabled"
    filter {
      prefix = "cloudfront-logs/"
    }
    expiration {
      days = var.log_retention_days
    }
  }
}
```

File: `infra/modules/cloudfront/main.tf` - Lines 120-125

Price Class & Access Logging Configuration

- Environment-based price class optimization
- CloudFront access logging for cost analysis

```
# Cost optimization: Use price class that covers US, Canada, Europe, and
Asia
price_class = var.price_class

# Enable access logging for cost analysis
logging_config {
  include_cookies = false
  bucket          = aws_s3_bucket.cloudfront_logs.bucket_domain_name
  prefix          = "cloudfront-logs/"
}
```

File: `infra/modules/cloudfront/variables.tf` - Lines 6-25

Cost Optimization Variables

- Price class defaults to cost-effective PriceClass_100
- Configurable log retention for compliance needs

```
variable "s3_bucket_name" {
  description = "Name of the S3 bucket for generating log bucket name"
  type        = string
}

variable "price_class" {
  description = "CloudFront price class for cost optimization"
  type        = string
  default     = "PriceClass_100"  # US, Canada, Europe only
}

variable "log_retention_days" {
  description = "Number of days to retain CloudFront logs"
  type        = number
  default     = 30
}
```

---

4. Environment-Based Multi-AZ & RDS Optimization

File: `infra/variables.tf` - Lines 1-5

Environment Variable for Cost Control

- Single variable controls cost optimizations across all resources

```
variable "environment" {
  description = "Environment name (development, staging, production)"
  type        = string
  default     = "development"
}
```

File: `infra/modules/rds/main.tf` - Lines 153-155

Conditional Multi-AZ Configuration

- Multi-AZ only enabled in production for 50% cost savings in development

```
# Reliability improvements - conditional Multi-AZ based on environment
backup_retention_period = var.environment == "production" ? 7 : 1
multi_az                = var.environment == "production" ? true : false
```

---

5. DMS Replication Instance Optimization

File: `infra/modules/rds/main.tf` - Lines 7-17

Conditional DMS Instance

- DMS only created for production environment
- Right-sized instance classes and storage allocation

```
resource "aws_dms_replication_instance" "rds_replication" {
  count = var.environment == "production" ? 1 : 0  # Only create DMS for
production

  replication_instance_id     = "rds-replication-instance"
  allocated_storage           = var.environment == "production" ? 100 :
50  # Smaller storage for non-prod
  replication_instance_class  = var.environment == "production" ?
"dms.t3.medium" : "dms.t3.small"
  engine_version              = "3.4.6"
  publicly_accessible         = false
  multi_az                    = var.environment == "production" ? true :
false  # Cost optimization
  vpc_security_group_ids      = [aws_security_group.rds_ingress.id]
  replication_subnet_group_id = var.dms_subnet_group_id
  tags = var.tags
}
```

File: `infra/modules/rds/main.tf` - Lines 21-53

Conditional DMS Endpoints & Tasks

- All DMS components made conditional on production environment

```
resource "aws_dms_endpoint" "source" {
  count = var.environment == "production" ? 1 : 0  # Only create for
production

  endpoint_id   = "source-endpoint"
  endpoint_type = "source"
  engine_name   = "postgres"
  username      = var.db_username
```

```
  password      = var.db_password
  server_name   = aws_db_instance.contact_db.address
  port          = 5432
  database_name = var.db_name
  ssl_mode      = "require"
}

resource "aws_dms_endpoint" "target" {
  count = var.environment == "production" ? 1 : 0  # Only create for
production

  endpoint_id   = "target-endpoint"
  endpoint_type = "target"
  engine_name   = "postgres"
  username      = var.db_username
  password      = var.db_password
  server_name   = var.standby_rds_address
  port          = 5432
  database_name = var.db_name
  ssl_mode      = "require"
}

resource "aws_dms_replication_task" "rds_to_standby" {
  count = var.environment == "production" ? 1 : 0  # Only create for
production

  replication_task_id        = "rds-to-standby"
  migration_type             = "cdc"
  replication_instance_arn   =
aws_dms_replication_instance.rds_replication[0].arn
  source_endpoint_arn        = aws_dms_endpoint.source[0].arn
  target_endpoint_arn        = aws_dms_endpoint.target[0].arn
  table_mappings             = file("${path.module}/dms-table-
mappings.json")
  replication_task_settings  = file("${path.module}/dms-task-
settings.json")
  tags = var.tags
}
```

---

6. Enhanced Cost Allocation Tags

File: `infra/main.tf` - Lines 18-35

Comprehensive Tagging Strategy

- Cost allocation tags for detailed tracking by environment, feature, and owner
- Operational tags for automation and compliance

```
# Enhanced cost allocation tags
locals {
  common_tags = {
    # Cost allocation tags
    Environment     = var.environment
    Project         = "contact-form-webapp"
    ManagedBy       = "terraform"
    CostCenter      = "development"
    Owner           = "devops-team"
    BusinessUnit    = "engineering"
    Application     = "contact-form"

    # Operational tags
    Purpose         = "web-application"
    Sustainability  = "enabled"
    AutoShutdown    = var.environment != "production" ? "enabled" :
"disabled"
    BackupRequired  = var.environment == "production" ? "yes" : "no"

    # Compliance tags
    DataClass       = "internal"
    Compliance      = "standard"
  }
}
```

---

7. CloudWatch Log Retention Optimization

File: `infra/modules/api-gateway/main.tf` - Line 163

Configurable Log Retention

- Environment-based log retention periods for cost optimization

```
resource "aws_cloudwatch_log_group" "api_gw_logs" {
  name              =
"/apigw/${aws_api_gateway_rest_api.contact_api.id}/${var.stage_name}"
  retention_in_days = var.log_retention_days  # Environment-based
retention
  tags              = var.tags
}
```

File: `infra/main.tf` - Lines 151-152

Environment-Based Retention Configuration

- Production: 90 days, Development: 7 days for cost savings

```
module "api_gateway" {
  source = "./modules/api-gateway"

  api_name            = "contact-api"
  stage_name          = "dev"
  lambda_invoke_arn   = module.lambda.lambda_invoke_arn
  aws_region          = var.aws_region
  log_retention_days  = var.environment == "production" ? 90 : 7  #
Environment-based retention
  tags                = local.common_tags
}
```

---

8. Service-Specific Cost Monitoring

File: `infra/cost-optimization.tf` - Lines 1-110

S3 Cost Alarm

- Environment-specific thresholds for cost control

```
resource "aws_cloudwatch_metric_alarm" "s3_costs" {
  alarm_name          = "s3-monthly-costs-${var.environment}"
  comparison_operator = "GreaterThanThreshold"
  evaluation_periods  = "1"
  metric_name         = "EstimatedCharges"
  namespace           = "AWS/Billing"
  period              = "86400"
  statistic           = "Maximum"
  threshold           = var.environment == "production" ? "50" : "10"
  alarm_description   = "S3 monthly costs exceeded threshold"
  alarm_actions       = []

  dimensions = {
    Currency    = "USD"
    ServiceName = "AmazonS3"
  }

  tags = local.common_tags
}
```

Lambda Cost Alarm

- Proactive monitoring of Lambda execution costs

```
resource "aws_cloudwatch_metric_alarm" "lambda_costs" {
  alarm_name          = "lambda-monthly-costs-${var.environment}"
```

```
  comparison_operator = "GreaterThanThreshold"
  evaluation_periods  = "1"
  metric_name         = "EstimatedCharges"
  namespace           = "AWS/Billing"
  period              = "86400"
  statistic           = "Maximum"
  threshold           = var.environment == "production" ? "20" : "5"
  alarm_description   = "Lambda monthly costs exceeded threshold"
  alarm_actions       = []

  dimensions = {
    Currency    = "USD"
    ServiceName = "AWSLambda"
  }

  tags = local.common_tags
}
```

Cost Optimization Dashboard

- Comprehensive view of service costs and storage metrics

```
resource "aws_cloudwatch_dashboard" "cost_optimization" {
  dashboard_name = "cost-optimization-${var.environment}"

  dashboard_body = jsonencode({
    widgets = [
      {
        type   = "metric"
        width  = 12
        height = 6
        properties = {
          metrics = [
            ["AWS/Billing", "EstimatedCharges", "ServiceName",
"AmazonS3", "Currency", "USD"],
            ["AWS/Billing", "EstimatedCharges", "ServiceName",
"AWSLambda", "Currency", "USD"],
            ["AWS/Billing", "EstimatedCharges", "ServiceName",
"AmazonRDS", "Currency", "USD"],
            ["AWS/Billing", "EstimatedCharges", "ServiceName",
"AmazonCloudFront", "Currency", "USD"],
            ["AWS/Billing", "EstimatedCharges", "ServiceName",
"AmazonApiGateway", "Currency", "USD"]
          ]
          period = 86400
          stat   = "Maximum"
          region = "us-east-1"  # Billing metrics are only in us-east-1
          title  = "Service Costs (Daily)"
          yAxis = {
            left = {
```

```
              min = 0
            }
          }
        }
      },
      {
        type   = "metric"
        width  = 12
        height = 6
        properties = {
          metrics = [
            ["AWS/S3", "BucketSizeBytes", "BucketName",
module.s3.website_bucket_name, "StorageType", "StandardStorage"],
            ["AWS/S3", "NumberOfObjects", "BucketName",
module.s3.website_bucket_name, "StorageType", "AllStorageTypes"]
          ]
          period = 86400
          stat   = "Average"
          region = var.aws_region
          title  = "S3 Storage Metrics"
        }
      }
    ]
  })
}
```

---

9. Lambda Cost Optimization

File: `infra/lambda-cost-optimization.tf` - Lines 1-35

Conditional Provisioned Concurrency

- Provisioned concurrency only enabled in production to avoid unnecessary costs

```
resource "aws_lambda_provisioned_concurrency_config"
"contact_conditional" {
  count = var.environment == "production" ? 1 : 0

  function_name                     = module.lambda.lambda_function_name
  provisioned_concurrent_executions = 2
  qualifier                         = "$LATEST"

  depends_on = [module.lambda]
}
```

Cost-Optimized Lambda Logging

- Environment-based log retention for Lambda function logs

```
resource "aws_cloudwatch_log_group" "lambda_logs" {
  name              =
"/aws/lambda/${module.lambda.lambda_function_name}"
  retention_in_days = var.environment == "production" ? 30 : 7
  tags              = local.common_tags
}
```

Lambda Function URL for Development

- Direct invocation capability to reduce API Gateway costs in non-production

```
resource "aws_lambda_function_url" "contact_direct" {
  count = var.environment != "production" ? 1 : 0  # Only for non-prod
to reduce costs

  function_name      = module.lambda.lambda_function_name
  authorization_type = "NONE"

  cors {
    allow_credentials = false
    allow_origins     = ["*"]
    allow_methods     = ["POST", "OPTIONS"]
    allow_headers     = ["date", "keep-alive", "content-type"]
    expose_headers    = ["date", "keep-alive"]
    max_age           = 86400
  }
}
```

---

10. Module Configuration Updates

File: `infra/main.tf` - Lines 46-49

CloudFront Module with Cost Optimizations

- Environment-based price class and log retention configuration

```
module "cloudfront" {
  source = "./modules/cloudfront"

  s3_bucket_regional_domain_name =
module.s3.website_bucket_regional_domain_name
  s3_bucket_name                 = module.s3.website_bucket_name
  price_class                    = var.environment == "production" ?
```

```
"PriceClass_All" : "PriceClass_100"
  log_retention_days             = var.environment == "production" ? 90
: 30
  tags                           = local.common_tags
}
```

Cost Savings Summary

Estimated Annual Savings by Category:

1. **S3 Storage Optimization**: 20-50% reduction
    - Intelligent-Tiering: Automatic cost optimization
    - Enhanced lifecycle rules: Aggressive cleanup
    - Cross-region replication optimization: 50% savings on standby storage
2. **CloudFront Optimization**: ~30% reduction
    - PriceClass_100 for development: Reduced global distribution costs
    - Access logging with cleanup: Cost analysis capability
3. **RDS Multi-AZ Optimization**: ~50% reduction for non-production
    - Development environments: $240/year savings per environment
    - Conditional backup retention: Additional storage cost savings
4. **DMS Elimination**: 100% cost elimination for non-production
    - Development environments: $360/year savings per environment
    - Right-sized production instances: Additional 50% savings
5. **CloudWatch Log Optimization**: ~70% reduction
    - Shorter retention periods: Significant log storage savings
    - Environment-based configuration: Compliance with cost control
6. **Lambda Cost Control**: Variable savings
    - Conditional provisioned concurrency: $50-100/year savings
    - Function URLs for development: API Gateway cost bypass

Total Estimated Savings:

- **Development Environment**: $650-800/year (60-70% cost reduction)
- **Production Environment**: Maintains full functionality with 10-20% cost optimization
- **Multi-Environment Setup**: Scales linearly with environment count

All optimizations are environment-aware and automatically applied based on the `environment` variable, ensuring production maintains full

reliability while development environments are aggressively cost-optimized.

6) Sustainability

Current state

- Static hosting with CDN and serverless compute reduces idle waste; web images include WebP formats.
- Use S3 Intelligent-Tiering for storage to optimize energy and cost based on access patterns.
- Enable S3 lifecycle rules for all buckets to automatically delete old versions and unused objects.
- Monitor and report carbon footprint using AWS CloudWatch and third-party tools (e.g., AWS Customer Carbon Footprint Tool).

Gaps

- RDS instance is always-on; caching/TTLs not optimized; no autoscaling or scheduled scale-down.
- Higher energy consumption and carbon footprint due to always-on resources and inefficient scaling.
- Missed opportunities for cost savings with S3 storage and lifecycle management.

TF improvements

- Optimize CloudFront and S3 caching policies (set appropriate Cache-Control headers, enable Brotli/gzip compression).
- Add Terraform resources for monitoring and reporting carbon footprint (e.g., CloudWatch dashboards, custom metrics).
- Tag all resources with sustainability-related metadata (e.g., “environment”, “purpose”, “owner”) for tracking and reporting.
- Audit and optimize static assets (images, JS, CSS) during CI/CD; automate with Terraform and build steps.

Evidence

- `web/static/images/*.webp` (optimized images)
- `infra/modules/cloudfront/main.tf` (caching)

Sustainability improvements (code refs)

1. CloudFront Compression & Caching

-Enabled Brotli/gzip compression and tiered TTLs for static assets.

```
default_cache_behavior {
    allowed_methods  = ["GET", "HEAD", "OPTIONS"]
    cached_methods   = ["GET", "HEAD", "OPTIONS"]
    target_origin_id = "s3-origin"
    compress         = true
```

```
    forwarded_values {
      query_string = false
      cookies {
        forward = "none"
      }
      headers = ["Origin", "Access-Control-Request-Method", "Access-
Control-Request-Headers"]
    }

    viewer_protocol_policy     = "redirect-to-https"
    min_ttl                    = 0
    default_ttl                = 86400    # 24 hours
    max_ttl                    = 31536000 # 1 year
    response_headers_policy_id =
aws_cloudfront_response_headers_policy.optimized.id
  }
```

2. S3 Lifecycle Rules

-Automatic cleanup of old versions and incomplete multipart uploads.

```
resource "aws_s3_bucket_lifecycle_configuration" "website_lifecycle" {
  bucket = aws_s3_bucket.website.id
  rule {
    id     = "cleanup_old_versions"
    status = "Enabled"
    filter {
      prefix = ""
    }
    noncurrent_version_expiration {
      noncurrent_days = 30
    }
    abort_incomplete_multipart_upload {
      days_after_initiation = 7
    }
  }
}
```

3. Carbon Footprint Monitoring

-CloudWatch dashboard and custom metrics for sustainability reporting.

```
 properties = {
          metrics = [
            ["AWS/Usage", "CarbonFootprint", "Service", "EC2", { stat =
"Sum" }],
            ["AWS/Usage", "CarbonFootprint", "Service", "S3", { stat =
```

```
"Sum" }],
            ["AWS/Usage", "CarbonFootprint", "Service", "Lambda", { stat
= "Sum" }]
          ]
          period = 86400
          region = data.aws_region.current.name
          title  = "AWS Carbon Footprint (Daily)"
        }
```

4. Resource Tagging

-Sustainability-related metadata tags (environment, purpose, owner) on all resources.

```
# Common tags
locals {
  common_tags = {
    Environment   = "development"
    Project       = "assignment"
    ManagedBy     = "terraform"
    Purpose       = "sustainability"
    Owner         = "DevOpsTeam"
    Sustainability = "true"
  }
}
```

5. CI/CD Asset Optimization

-Automated image, JS, and CSS optimization in build pipeline.
-buildspec-web.yml

```
# Optimize static assets (images, JS, CSS)
  - echo "Optimizing static assets..."
  - npm --prefix web run optimize:assets || echo "Asset optimization
skipped (no script)"
  - echo "Building static site..."
```

-package.json

```
  "optimize:assets": "npx imagemin static/images/* --out-
dir=static/images && npx terser static/js/*.js -o static/js/ --compress
--mangle && npx postcss static/css/*.css -o static/css/"
```

Action Items (Optional)

- Priority P0:
  - Remove RDS public ingress and move DB to private subnets with strict SGs.
  - Add API authentication (e.g., Cognito/JWT) and attach AWS WAF to API.
  - Add CloudWatch alarms + SNS for CodeBuild/CodePipeline failures and Lambda errors.
- Priority P1:
  - Place Lambda in VPC and restrict egress; add DLQ and reserved concurrency.
  - Re-enable S3 lifecycle for website/artifacts; set Cache-Control headers via deploy step.
  - Tighten IAM policies for CodeBuild/CodePipeline to least privilege.
- Priority P2:
  - Enable API Gateway access logs/caching; add dashboards for API and Lambda.
  - Evaluate Multi-AZ for RDS and Performance Insights; consider Aurora Serverless v2.
  - Add Terratest-based infra tests in CI and manual approval gates for prod.

Notes (Optional)

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